Research in Technology Education

Editors

Philip A. Reed
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59th Yearbook, 2010
Council on Technology Teacher Education

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FOREWORD

Due to the laboratory-based nature of technology and engineering education programs, professionals in our field have often focused on the resources in our classrooms and laboratories and the instructional methodologies used to address specific concepts. Formal research into content and practice has often given way to "what seems right". New curriculum is constantly being introduced (based on what is occurring in business and industry), yet the inclusion for those evolving concepts in courses and programs is typically not verified.

Hence, the importance of the 2010 CTTE yearbook and its focus on the dire need for an aggressive research agenda in your field. This publication is designed to help direct the professional efforts of researchers, classroom educators, administrators, and curriculum specialists. Each chapter draws attention to a different aspect of investigative thought and action.

The 14 chapters in this volume include the observations and insights of a wide variety of authors. While they are traditional teacher educators, each shares their recommendations based on varying experiences. We are fortunate to have so many interested professionals who were willing to help all of us grow in the area of scholarship.

The Council on Technology Teacher Education applauds the efforts of co-editors James LaPorte and Philip Reed, and the entire author team, for highlighting research within our field as well as research that informs our field. This is a most timely topic for our membership, as technology and engineering educators have much to learn about research . . . methodology, implementation strategies, research skills, and the applications of formal studies.

In conclusion, thanks to the efforts of the CTTE Yearbook Planning Committee and to the co-editors and 17 chapter authors featured in this publication. The Council is proud of this latest yearbook and hopes it finds more time opened on your desktop (and less time with other CTTE materials on a shelf).

Richard D. Seymour
President, CTTE
March 2010

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YEARBOOK PROPOSALS

Each year at the ITEEA International Conference, the CTTE Yearbook Committee reviews the progress of yearbooks in preparation and evaluates proposals for additional yearbooks. Any member is welcome to submit a yearbook proposal, which should be written in sufficient detail for the committee to be able to understand the proposed substance and format. Fifteen copies of the proposal should be sent to the committee chairperson by February 1 of the year in which the conference is held. Below are the criteria employed by the committee in making yearbook selections.

CTTE Yearbook Committee

CTTE Yearbook Guidelines

A. Purpose

The CTTE Yearbook Series is intended as a vehicle for communicating major topics or issues related to technology teacher education in a structured, formal series that does not duplicate commercial textbook publishing activities.

B. Yearbook topic selection criteria

An appropriate yearbook topic should:

1. Make a direct contribution to the understanding and improvement of technology teacher education;
2. Add to the accumulated body of knowledge of technology teacher education and to the field of technology education;
3. Not duplicate publishing activities of other professional groups;
4. Provide a balanced view of the theme and not promote a single individual's or institution's philosophy or practices;
5. Actively seek to upgrade and modernize professional practice in technology teacher education; and,
6. Lend itself to team authorship as opposed to single authorship.

Proper yearbook themes related to technology teacher education may also be structured to:

1. Discuss and critique points of view that have gained a degree of acceptance by the profession;
2. Raise controversial questions in an effort to obtain a national hearing; and,
3. Consider and evaluate a variety of seemingly conflicting trends and statements emanating from several sources.

C. The Yearbook Proposal

1. The yearbook proposal should provide adequate detail for the Yearbook Committee to evaluate its merits.

2. The yearbook proposal includes the following elements:
   a) Defines and describes the topic of the yearbook;
   b) Identifies the theme and describes the rationale for the theme;
   c) Identifies the need for the yearbook and the potential audience or audiences;
   d) Explains how the yearbook will advance the technology teacher education profession and technology education in general;
   e) Diagram symbolically the intent of the yearbook;
   f) Provides an outline of the yearbook which includes:
      i) A table of contents;
      ii) A brief description of the content or purpose of each chapter;
      iii) At least a three level outline for each chapter;
      iv) Identification of chapter authors (s) and backup authors;
      v) An estimated number of pages for each yearbook chapter; and,
      vi) An estimated number of pages for the yearbook (not to exceed 250 pages).
   g) Provides a timeline for completing the yearbook.

It is understood that each author of a yearbook chapter will sign a CTTE Editor/ Author Agreement and comply with the Agreement. Additional information on yearbook proposals is found on the CTTE web site at [ur] http://www.ctteonline.org/

PREVIOUSLY PUBLISHED YEARBOOKS

*1. *Inventory Analysis of Industrial Arts Teacher Education Facilities, Personnel and Programs*, 1952.
*2. *Who's Who in Industrial Arts Teacher Education*, 1953.
*3. *Some Components of Current Leadership: Techniques of Selection and Guidance of Graduate Students; An Analysis of Textbook Emphases*; 1954, three studies.
*4. *Superior Practices in Industrial Arts Teacher Education*, 1955.
*5. *Problems and Issues in Industrial Arts Teacher Education*, 1956.
*6. *A Sourcebook of Reading in Education for Use in Industrial Arts and Industrial Arts Teacher Education*, 1957.
*7. *The Accreditation of Industrial Arts Teacher Education*, 1958.
*8. *Planning Industrial Arts Facilities,* 1959. Ralph K. Nair, ed.
*9. *Research in Industrial Arts Education*, 1960. Raymond Van Tassel, ed.
*10. *Graduate Study in Industrial Arts*, 1961. R.P. Norman and R.C. Bohn, eds.
*11. *Essentials of Preservice Preparation*, 1962. Donald G. Lux, ed.
*12. *Action and Thought in Industrial Arts Education*, 1963. E.A.T.Svendsen, ed.
*13. *Classroom Research in Industrial Arts*, 1964. Charles B. Porter, ed.

*14. *Approaches and Procedures in Industrial Arts*, 1965. G.S. Wall, ed.

*15. *Status of Research in Industrial Arts*, 1966. John D. Rowlett, ed.

*16. *Evaluation Guidelines for Contemporary Industrial Arts Programs*, 1967. Lloyd P. Nelson and William T. Sargent, eds.

*17. *A Historical Perspective of Industry*, 1968, Joseph F. Luetkemeyer Jr., ed.

*18. *Industrial Technology Education*, 1969. C. Thomas Dean and N.A. Hauer, eds.; *Who's Who in Industrial Arts Teacher Education*, 1969. John M. Pollock and Charles A. Bunten, eds.

*19. *Industrial Arts for Disadvataged Youth*, 1970. Ralph O. Gallington, ed.

*20. *Components of Teacher Education*, 1971. W.E. Ray and J. Streichler, eds.

*21. *Industrial Arts for the Early Adolescent*, 1972. Daniel J. Householder, ed.

*22. *Industrial Arts in Senior High Schools*, 1973. Rutherford E. Lockette, ed.

*23. *Industrial Arts for the Elementary School*, 1974. Robert G. Thrower and Robert D. Weber, eds.

*24. *A Guide to the Planning of Industrial Arts Facilities*, 1975. D.E. Moon, ed.

*25. *Future Alternatives for Industrial Arts*, 1976. Lee H. Smalley, ed.

*26. *Competency-Based Industrial Arts Teacher Education*, 1977. Jack C. Brueckman and Stanley E. Brooks, eds.

*27. *Industrial Arts in the Open Access Curriculum,* 1978. L.D. Anderson, ed.

*28. *Industrial Arts Education: Retrospect, Prospect*, 1979. G. Eugene Martin, ed.

*29. *Technology and Society: Interfaces with Industrial Arts*, 1980. Herbert A. Anderson and M. James Benson, eds.

*30. *An Interpretive History of Industrial Arts*, 1981. Richard Barella and Thomas Wright, eds.

*31. *The Contributions of Industrial Arts to Selected Areas of Education*, 1982. Donald Maley and Kendall N. Starkweather, eds.

*32. *The Dynamics of Creative Leadership for Industrial Arts Education*, 1983. Robert E. Wenig and John I. Mathews, eds.

*33. *Affective Learning in Industrial Arts*, 1984. Gerald L. Jennings, ed.

*34. *Perceptual and Psychomotor Learning in Industrial Arts Education*, 1985. John M. Shemick, ed.

*35. *Implementing Technology Education*, 1986. Ronald E. Jones and John R. Wright, eds.

*36. *Conducting Technical Research*, 1987. Everett N. Israel and R. Thomas Wright, eds.

*37. *Instructional Strategies for Technology Education*, 1988. William H. Kemp and Anthony E. Schwaller, eds.

*38. *Technology Student Organizations*, 1989. M. Roger Betts and Arvid W. Van Dyke, eds.

*39. *Communication in Technology Education*, 1990. Jane A. Liedtke, ed.

*40. *Technological Literacy*, 1991. Michael J. Dyrenfurth and Michael R. Kozak, eds.

*Out-of-print yearbooks can be obtained in microfilm and in Xerox copies. For information on price and delivery, write to UMI, 300 North Zeeb Road, Dept. P.R., Ann Arbor, Michigan 48106.

PREFACE

Technology education and the programs from which it evolved have a unique history. The emphasis on practical learning that formed the foundation for the field in the 1800s did not fit well with the concurrent liberal education movement and its focus on classical languages, philosophy, rhetoric, literature, and mathematics – applied learning simply did not connect with liberating the mind from the toil and drudgery of the workplace that existed once the industrial revolution had occurred. With the huge influx of immigrants seeking a better life, albeit survival, in the New World, the United States found that skilled workers were essential if the momentum of an increasingly healthier economy was to be maintained. Once again the field had to wrestle with how to increase its vitality, this time while trying to keep its general education values in light of increasing support for vocational education. The vision was to become a required subject in the education of all, encouraged by how science had successfully done so using political influence and backing in the early 1900s. Though admirable progress was made, the field simply did not have any analogy to the clout that scientists had nor the influence of politicians and the dollars they could garner – and, as is still true today, the field simply does not have the numbers. Perhaps the biggest impediment, though, was the lack of regard among those in power for the hands-on, practical experiences that represented the hallmark of the field.

It could be argued that the emphasis on practical learning was carried too far. Master's and doctoral programs in the field became allied with graduate programs in education that emphasized practice rather than research, thereby forfeiting the requisite research competencies and exposure to the culture of research. Even at this higher level of education, some degree programs allowed, or even encouraged, the completion of courses and independent studies that involved the development and honing of technical skills over theory. A culture developed whereby even professors did not value research and consequently passed this thinking on to their students. This attitude is still promulgated today to some extent as evidenced by those entering higher education aspiring to be exclusively teachers, hoping to "leave the research to others," whoever those others might be. In many cases the doctoral dissertation becomes the best, and only, research the terminal degreed person will do.

The climate of higher education has changed dramatically over the past few years. Even those institutions that thought of themselves as "teaching universities" have shifted their focus in light of the need to garner external funds through research grants to replace lost resources at the state level. Moreover, the rankings that are bestowed upon universities by a growing number of organizations have become more important in the competition for students and those rankings, in turn, are becoming increasingly linked to research activity and the scholarship that comes with it. As expectations for accountability rose, technology educators were increasingly being asked to support the value of programs based on research

rather than testimonials and logic.

It was within the foregoing context that this yearbook came about and influenced its organization. First, we realized that our field will not, at least in the foreseeable future, have enough qualified and motivated professionals to conduct the research that is needed, the lack of which scholars and leaders have reprimanded the field for decades. Short of doing the research in isolation, technology educators at least need to be able to extrapolate and generalize from the research of other disciplines that have a link to our own. Moreover, becoming aware of the research in other disciplines will enable technology educators to set priorities for our own research agenda, constrained by our limited human resources. Second, we believed that an investigation into research must necessarily be international in scope. The advantages of electronic technology facilitate international collaboration and enable technology educators to realize accomplishments never before possible. Globally, our numbers are sufficient and our challenges similar enough that we should move a collaborative research agenda forward. Third, we were committed to involving chapter authors who were scholars of high repute as well as those who were just embarking on a career in higher education and might be mentored into research and scholarship through the experience. With guidance from the Yearbook Committee of the Council for Technology Teacher Education, we identified experts in the topics addressed. However, the bottom line is that the authors demonstrated a passion for what we were asking them to do. The passion, commitment, and effort of the authors represented by the pages within are deeply appreciated.

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59th Yearbook Editors
Philip A. Reed
James E. LaPorte

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ACKNOWLEDGMENTS

We would like to thank the Council on Technology Teacher Education for their ongoing commitment to technology education through the CTTE Yearbook series. The yearbooks serve to document the key issues in our profession today and provide a valuable resource for the profession's direction.

We also want to thank each member of the Yearbook Planning Committee for their guidance and support in bringing this volume to life. A special thank you goes to Dr. Michael De Miranda and Ms. Sophie Nelson for their help in assembling and coding this entire volume. The expertise and commitment of all these individuals sustains a long tradition of professionalism that dates back to the inception of the series.

Finally, we particularly want to thank the authors assembled in this Yearbook for their scholarly contribution. We strived to honor the integrity of the author's original manuscripts. We sincerely respect and thank all contributors for their insights and professionalism.

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INTRODUCTION

I am not an education researcher, though I have met a fair number and have done some reading of the literature over the years, particularly related to learning and teaching in the STEM subjects. What impresses me most—I might better say depresses me—is how hard it is to do research in education that produces results which then make a positive difference in students' lives. Too often, in my opinion, the wrong questions are studied or the right questions approached with the wrong methodology. Even when important findings are made, their translation to practice may be slow or simply absent. Some of these missteps are explained by well-meaning but untrained investigators, but even experienced researchers sometimes have difficulty getting traction on the truly important problems.

The education system in the United States is complex, and doing even quasi-scientific research on a phenomenon as squishy as education is difficult. The gold standard in clinical medicine, the randomized, controlled trial, cannot easily be made to fit the messiness of student lives, of the classroom, and of political realities. Identifying and accounting for all of the potentially confounding variables in an "intervention" is simply not possible. Education research is thus an imperfect pursuit—part art, part science. But it is crucial that it be done as rigorously as possible, in a strategic manner, and with sufficient resources over timescales that matter in education—not months or years but decades. In no other way will we learn what works and why.

The timing of this volume is propitious. Not only does it come on the heels of ITEA's name change, to the International Technology and Engineering Educators Association, but it arrives during a time of greatly increased national interest in STEM education. The challenge and opportunity for CTTE and ITEEA are two sides of the same coin: can education research be leveraged to demonstrate the importance and power of the "T" and "E" in STEM? This may be a transformational moment for ITEEA, but only if there is a serious and sustained effort by the profession to mount a quality research campaign. Within these pages, thought leaders in the field have offered recommendations for structuring just such an agenda. The next steps are up to you, your colleagues, and the profession.

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Greg Pearson, Senior
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The Status of Research in Technology Education

Chapter
1

Philip A. Reed
Old Dominion University

INTRODUCTION

Standards and accountability have been a central focus for all levels of education over the past two decades. The intent has been to increase academic rigor, raise student achievement levels, and insure that highly qualified teachers are in all classrooms. However, questions are now being raised whether we have gone too far. There is evidence that students are memorizing material but they are having difficulty with higher levels of cognition. Additionally, there are reports of cheating by students, teachers, and administrators due to the pressures of attaining performance measures. Such evidence is now swaying some initial proponents of high stakes standards and accountability to re-think educational policy and practice (Ravitch, 2010).

It would be naïve and dangerous, however, to relegate the importance of standards and accountability in education to a lower level of importance. If ever there was a profession that must be based on standards and accountability, it is the education of our children, teachers, and other school personnel. Research, not politicians, philosophers, or other influences, should be the primary force behind all aspects of the educational process (see Figure 1). Research on teaching and learning is a multi-faceted enterprise that draws upon the physical sciences as well as the social sciences. Discipline-specific research is necessary to highlight both the synergistic contributions and unique qualities that a field contributes to the educational endeavor.
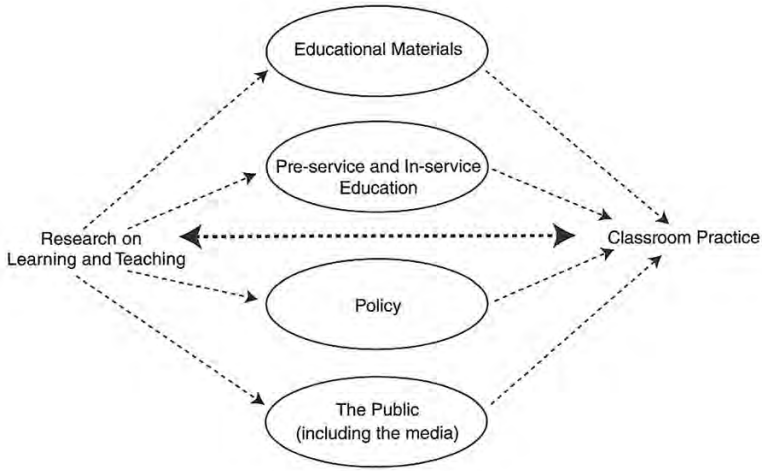
Figure 1: Paths through which research influences practice (National Research Council, 2000).

Technology education has a detailed history grounded in general education as well as discipline- specific philosophies, research, and practice (Barella & Wright, 1981; Martin, 1979, 1995; Rowlett, 1966; Van Tassel, 1960). Despite this record, there have been considerable calls to strengthen technology education research (Cajas, 2000; Foster, 1992a; Garmire & Pearson, 2006; Johnson, 1993; Lewis, 1999; Pearson & Young, 2002; Passmore, 1987; Petrina, 1998; Reed, 2002; Sanders, 1987). This chapter is designed to provide an overview of the historical trends and the contemporary status of technology education research. The chapters that follow focus on specific areas of teaching and learning in order to provide recommendations for technology education scholars.

RESEARCH REVIEWS

The technology education profession has a long history of reviewing and synthesizing its research. The initial published review was the American Council on Industrial Arts Teacher Education (ACIATE, now the CTTE) Yearbook Nine (Van Tassel, 1960). This volume outlined significant research in industrial arts, procedures for scientific research, a theoretical framework, and research needs for both teacher educators and supervisors. The dearth of research recognized in the ninth Yearbook, however, prompted the ACIATE to dedicate the fifteenth Yearbook to the status of research (Rowlett, 1966). This second volume included chapters on the achievement of industrial arts objectives, evaluation, research and experimentation, teacher education, staff studies/non-degree research, and

securing funding. Like all of the reviews and syntheses that would follow, the fifteenth Yearbook included areas of needed research.

During the same timeframe, the Center for Vocational and Technical Education (CVTE) at Ohio State University received funding from the U. S. Office of Education to develop a review and synthesis of research in industrial arts education. This review encompassed the period 1960-1966 and was conducted to set a baseline of research (Streichler, 1966) but, similar to ACIATE Yearbook fifteen (Rowlett, 1966), the report was critical regarding the lack of research and the rigor of the research being conducted. A second review and synthesis conducted by the CVTE just two years later, however, claimed:

> Industrial arts appears to have come of age academically and intellectually. The profession has matured to the point where it is willing to undergo a careful self-appraisal of its basic beliefs, fundamental practices, and educational procedures. As a result, critical yet objective investigations have been conducted on a wide variety of important topics in industrial arts (Householder and Suess, 1969, p. 51).

Clearly these early reports identified weaknesses but they also set a solid research foundation for the field by providing comprehensive bibliographies, reviewing the current state-of-the-art, and setting priorities. Additionally, the classifications established in the initial study were, for the most part, used throughout all five studies: philosophy and objectives, curriculum development, instructional materials and devices, learning processes and teaching methods, student personnel services, facilities and equipment, teacher education, administration and supervision, evaluation, and research (Streichler, 1966).

The third and fourth studies (Dyrenfurth and Householder; 1979; McCrory, 1987) spanned longer periods than the preceding reports but they were also supported by the National Center for Research in Vocational Education (formerly the CVTE) so there were many similarities including format and overall classification schemes. The scope for these studies was broadened and included new data such as international studies, the number of funded projects, and funding agencies. The number of studies reviewed was cited as impressive (Dyrenfurth and Householder, 1979) but the quality of research was still questioned in both reports. Other issues that were starting to be recognized as areas of need included improved access to research through database development, consensus on definitions of terms (including technology education), development of a comprehensive research agenda, and more classroom research (McCrory, 1987).

The fifth and final report supported by the (currently titled) Center on Education and Training for Employment was undertaken by Zuga (1994). This study found that the research spanning 1987-1993 focused on curriculum, was conducted mostly by graduate students, and was centered on teachers, teacher educators,

and supervisors. Several other noteworthy characteristics were identified by Zuga (1994) including the overwhelming lack of females and minorities in the field, the reliance on survey methods, and the lack of research on technological literacy. Overall recommendations were to expand research methods, demonstrate technology education's inherent value, research the ideology and biases in content and practice, develop innovative curricula, and to promote professional development (Zuga, 1994, p. 67).

A more recent review by Johnson and Daugherty (2008) focused exclusively on research published in scholarly journals associated with technology education. The journals and the number of empirical articles spanning the review period 1997-2007 are listed in Table 1. Consistent with Zuga's (1994) study, teaching and curriculum were primary research areas during the period under review by Johnson and Daugherty (2008). Recommendations from this analysis include the need for more scientific research as defined by Weiss, Knapp, Hollweg, and Burrill (2002) and a stronger balance between qualitative and quantitative methodologies. Engineering, integrative practice (e.g. STEM), cognitive science, creativity, and problem solving were identified as areas of needed research.

Table 1: Number of empirical articles examined in each journal (Johnson & Daugherty, 2008)

Title of Journal	Years Reviewed	Empirical Studies
International Journal of Technology and Design Education	1998-2007	68
Journal of Industrial Teacher Education	1998-2007	48
Journal of Technology Education	1997-2006	54
Journal of Technology Studies	1997-2006	29
Total Number of Articles Reviewed		199

Similar, but narrower reviews of published research have been conducted on the *Journal of Technology Education* (LaPorte, 2007; Petrina, 1998) and the *International Journal of Technology and Design Education* (Vries, 2003). Published research and graduate studies in the United States have also been reviewed to see how critical problems and issues (e.g. Wicklein, 1993, 2005) are being addressed (Reed, 2006). This study, like all other reviews, found that scholars are addressing key research topics but the need for more synergy and focus among researchers continues to be a pressing issue.

GRADUATE RESEARCH

Research conducted by graduate students clearly documents the history of the profession and provides the foundation for technology education. Laborious efforts have been made by Jelden (1981), Foster (1992b), and Reed (2001) to track

graduate research since much of this work goes unpublished. These researchers searched databases and relied on students and advisors to compile comprehensive lists of graduate research. Reed (2001) assembled these efforts into an electronic list titled the Technology Education Graduate Research Database (TEGRD). Additionally, Dissertation Abstracts Online (ProQuest) was searched using the following terms: Manual training, industrial arts, industrial education, technology education, industrial technology, trade & industrial education, and industrial vocational education. The TEGRD initially contained 5,259 entries spanning 1892-2000, however, this database has been updated for this chapter and Figure 2 displays graduate research by year. Several points are interesting to note. First, there is consensus with Dyrenfurth and Householder's (1979) review that research output increased considerably during the decade encompassed by their review. Secondly, graduate research appears to have leveled off during the past decade with approximately twenty studies being conducted annually.

Although a large amount of graduate research is not published, the proliferation of electronic databases, websites, and other tools has provided an increased level of access. Jelden (1976) was a pioneer in this area by compiling graduate research and helping others retrieve information from early information systems. Foster's (1992b) bibliography was the first effort placed online (see http://scholar.lib.vt.edu/ejournals/JTE/) and the TEGRD built on this effort and remains accessible through the CTTE website (see http://www.ctteonline.org). A logical step is to house full-text graduate research papers online. Common databases such as UMI/ProQuest and ERIC have housed full-text documents for years but a concerted effort should be made to provide wider access to technology education graduate research. An example has been developed by Ritz and Reed (2006) that contains master's research papers, not theses and dissertations which is a requirement for inclusion in the TEGRD. Nevertheless, this database contains over thirty-five years of full-text papers, many that investigate contemporary technology education issues:

- The Effects of Technology Education on Science Achievement (Filossa, 2008).
- Effects of Technology Education on Middle School Language Arts (Reading) Achievement (Bolt, 2005).
- Middle School Equipment Needs to Teach the Standards for Technological Literacy (Warner, 2005).
- The Demand for Industrial Technology and Technology Education Faculty Professors at United States Universities (Hicks, 2005).
- Directions of Dissertation Research at Universities Preparing Future Technology Education Teacher Educators (Sontos, 2005).
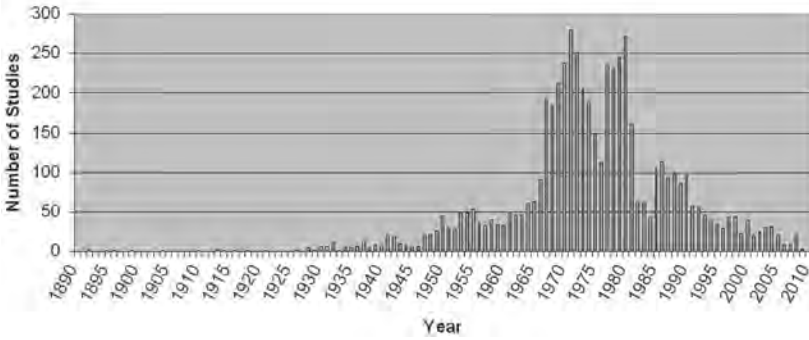
Figure 2: Graduate Research by Year

Efforts to broaden access to graduate research are important since traditional graduate universities (e.g. land grant institutions) in the United States are shrinking and regional institutions are expanding their graduate offerings (LaPorte, 2002). A recent survey of International Technology and Engineering Educators Association (ITEEA) university members, PATT participants, and universities listed in the *Industrial Teacher Education Directory* (Schmidt, 2004) investigated the state of graduate technology education. Seventy-eight institutions were contacted and sixty-three (80.7%) responded. Forty-five of these institutions offer graduate programs with forty-three offering master's degrees, six offering specialist degrees, and eighteen offering doctoral degrees in Australia (2), Canada (1), France (1), South Africa (1), and the United States (13) (Ritz & Reed, 2008).

Graduate research related to the profession is often conducted at universities that do not have programs in technology education (Reed & Sontos, 2006). This highlights the importance of not only tracking the quantity of graduate research but also the methods and topics in order to help reduce repetition and fragmentation in the research being conducted. For example, Table 2 highlights a study that analyzed graduate research over a recent five-year period using classifications similar to those used by Zuga (1994). Sontos (2005) discovered an increase in the research being conducted on instruction and a decline in curriculum studies. Trend analysis such as this must continue to help build on the reviews and research of the past and to help guide future research.

Table 2: Technology education dissertations in the United States, 2000-2005 (Sontos, 2005)

Categories	Number of Studies	Percentage
Attitudes	7	12%
Instruction (how)	17	29%
Curriculum (what)	5	8%
Continuing Education	2	3%
Professional Develop.	8	14%
Foreign	11	19%
Work-based Education	9	15%

PUBLICATIONS

There has never been a more opportune time for technology educators to publish their research: New journals have emerged, electronic publishing has come-of-age, and other disciplines are broadening the scope of their journals to reflect STEM research. Table 1 above gives an overview of published research in major technology education journals and Chapter 13 provides a comprehensive review of publications in several of these scholarly journals. This section is designed to highlight many of the publishing opportunities and challenges facing technology education researchers. Readers seeking a more detailed history of specific publications are encouraged to review Sanders' (1995) chapter on professional technology education publications.

The *Journal of Technology Education* (JTE), *Journal of Technology Studies* (JTS), and *Journal of Industrial Teacher Education* (JITE) have been cornerstone journals for peer reviewed research in technology education. Additionally, these publications made an early transition to electronic publishing by joining the Virginia Tech Digital Library and Archives (DLA) EJournals (see http://scholar. lib.vt.edu/ejournals/). The DLA "provides access to scholarly electronic serials that are peer-reviewed, full text, and accessible without charge" (Digital Library and Archives, 2010, ¶1). The *Journal of the Japanese Society for Technology Education* is also available on the DLA EJournals site as well as these journals that have ancillary goals to technology education: *Techné: Research in Philosophy & Technology*, *Career and Technical Education Research*, and the *Journal of Career and Technical Education.*

There are many other online tools such as Google Scholar (http://scholar. google.com/) and JSTOR (http://www.jstor.org) as well as subscription databases (e.g. ProQuest, EBSCOhost, FirstSearch, etc.) that provide full text theses, dissertations, and articles. Publications from the *International Journal of Technology and Design Education* (IJTDE), *The Technology Teacher* (TTT), *Technology and Children*, *Tech Directions*, *ties*, and *Techniques* can be accessed using one or more of these online tools. The availability and search capabilities of

these databases has many advantages and can even lead to extensive reviews of research such as that produced by Petrina (1998).

Publishers and organizations are increasingly using their websites to publish and market research. These arrangements vary from complete open access, restricted access for fee/members, or a combination between the two. The Council on Technology Teacher Education (CTTE) is an example of an open access provider with its monographs and other publications are available to anyone[1]. The *Journal of Design and Technology Education: An International Journal* (formerly *The Journal of Design and Technology Education*) is an example of a subscription-only publication (see http://www.trentham-books.co.uk/). A mixed approach for electronic publishing and marketing is used by the International Technology and Engineering Educators Association (ITEEA). Some research is available to anyone but the majority of ITEEA's monographs, task force reports, and other publications are available only to members.

Technology educators must make a concerted effort to publish research outside the professions' main journals in order to broaden exposure and help advance the discipline. Research from McLaughlin (2005) found over ninety journals that were considered to be receptive to technology education scholarship. Many publications such as the *Journal of STEM Education* (see http://www.auburn.edu/research/litee/jstem/index.php), which is in its tenth year, have a clear mission that encompasses technology education. However, other publications such as *Technology and Culture* and American Heritage's *Invention and Technology* also have a compelling contribution to technology education but one would be hard pressed to find a manuscript that focuses on technology education in these journals. Such a dilemma poses a challenge for the profession: In addition to focusing on what to research, the same amount of attention should be placed on where to publish.

CONFERENCES

The amount of scholarship exchanged at conferences, like publishing opportunities, is at an all-time high. The Mississippi Valley Conference is recognized as the oldest continuing technology education conference, having started in 1907 (Barlow, 1967). The conference chair assigns topics months in advance and proceedings take place in a single-session format where the presenters are thoroughly questioned by the membership. The Southeastern Technology Education Conference (STEC), established in 1962, is also a single - session scholarly conference but presentation proposals are submitted and reviewed Both of these conferences have strong histories of scholarship but one limitation is that proceedings are not widely shared beyond the conference participants.

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1   The exception remains the CTTE Yearbook which is provided to members and sold to non-members. However, the CTTE Yearbook Committee and the CTTE Executive Committee both agreed at the 2010 ITEEA conference that all Yearbooks should be openly available on the Virginia Tech Digital Library and Archives website. The *Council* was researching the feasibility of this initiative at the time this Yearbook went to press.

Several conferences provide limited access to conference proceedings. The American Industrial Arts Association (AIAA, later ITEA and now the ITEEA) annual conference was started in 1938 and published selected proceedings through the 1970s. In the 1980s and 1990s some ITEEA conference papers were offered through the association's product catalog. Currently, the ITEEA collects presentation materials and archives them on the Member's Only section of its website. A twenty-five year content analysis of the AIAA/ITEA conference program looked at the number of research presentations (Figure 3). During the period under review, 1978-2002, there was an average of 10 research presentations over the first twenty years and an increase to an average of 17 during the last five years (Reed & LaPorte, 2004).
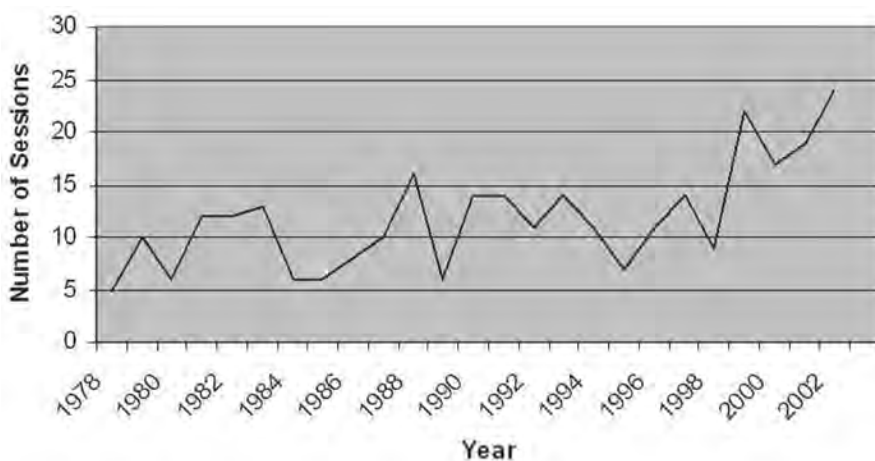
Figure 3: Research presentations by year (1978-2002) at the annual conference of the ACIATE/ITEEA (Reed & LaPorte, 2004).

Two other conferences that provide varying access to their proceedings are the Technology Education New Zealand (TENZ) Conference and the Technology Education Research Conference (TERC). The TENZ conference is a biennial conference that occurs on odd years. Early conference papers were provided on disk to participants but the past two conference archives are available online (see http://www.tenz.org.nz/). The TERC is also a biennial conference which is held on even years. Proceedings are provided to participants on CD and select proceedings are archived on the CTTE website (http://www.ctteonline.org). TERC program and other information may be found on the conference website (http://www. griffith.edu.au/conference/technology-education-research-conference-2010).
Several conferences maintain comprehensive archives of their proceedings. The International Conference on Design and Technology Educational Research

(IDATER) was held annually from 1988-2001 and then went online. Archives for the traditional and electronic conferences are available at http://www.lboro.ac.uk/ departments/cd/research/groups/ed/idater/. Additionally, the PATT conference has partnered with the ITEEA to host conference materials and proceedings back to 1988 (see http://www.iteea.org/Conference/pattproceedings.htm).

Several other organizations host conferences pertinent to technology education. The American Society for Engineering Education (ASEE) hosts regional division conferences, an annual conference, and an annual global colloquium. Research papers are reviewed for these conferences and accessible on the ASEE website (http://asee.org/conferences/paper-search-form.cfm). More detail on the ASEE and engineering education research in general is provided in chapters five and eight. The American Association for the Advancement of Science (AAAS) has also hosted two conferences on technology education research. The first conference in 1999 was held "to consider what kind of research would enhance the goal of achieving universal technological literacy" (AAAS, 2010, ¶2). The second AAAS conference in 2001 was to help set research priorities in order to establish a research agenda for technology education. The proceedings of both AAAS conferences are available online and establish a solid foundation for a research agenda (see http://www.project2061.org/events/meetings/technology/ default.htm).

RESEARCH PRIORITIES, FRAMEWORKS, AND AGENDAS

The technology education profession has been in existence for well over 100 years yet it continues to dance around the issue of establishing unified research priorities and carrying them out in a systematic manner. The preceding sections of this chapter document that research has effectively been reviewed and synthesized, published, and is shared among scholars in increasing ways. These foundations provide an opportunity for the profession to move forward with a focused research agenda. This section is intended to show how existing recommendations can build upon this foundation and set the course for a unified research agenda.

Several notable organizations have published research priorities, frameworks, and agendas for technology education. The proceedings of the two AAAS conferences previously mentioned were synthesized into research categories and priorities (Householder & Benenson, 2001). Additionally, the National Academies have published a general research agenda as far back as 1985 (Committee on Research in Mathematics, Science, and Technology Education). More recently, the National Research Council published *Investigating the influence of standards: A framework for research in Mathematics, Science, and Technology education* (Weiss, Knapp, Hollweg, & Burrill, 2002). Figure 4 illustrates this framework and shows how contextual forces, channels of influence, teachers, and teaching practice all impact student learning. The National Academies also have publications concerning research on undergraduate STEM teaching (Fox & Hackman, 2003)

and technological literacy (Garmire & Pearson, 2006). Unfortunately much of the research has never come to fruition, despite the detailed organization and researchable questions outlined in these publications.
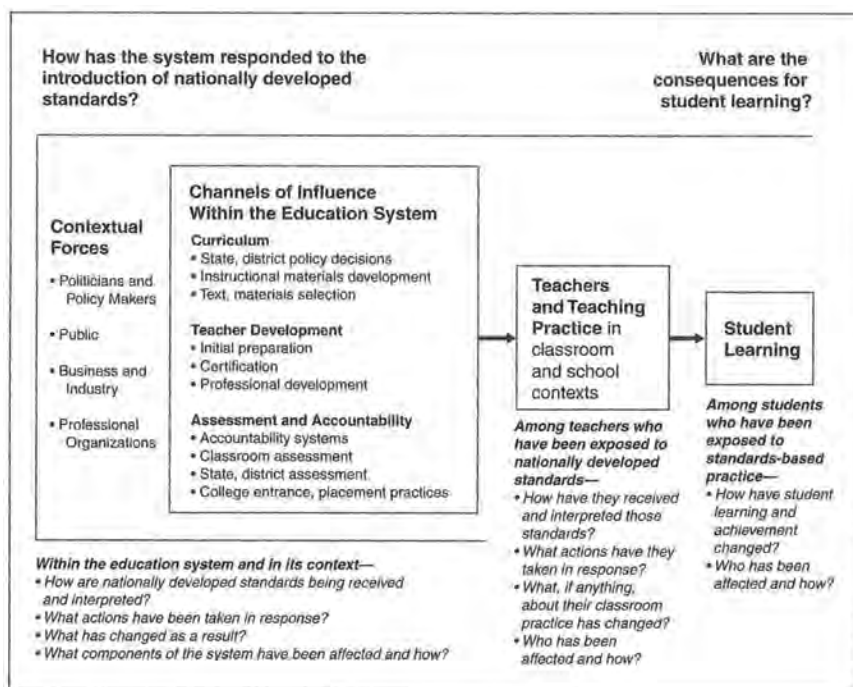
Figure 4: A framework for investigating the influence of nationally developed standards for mathematics, science, and technology education (Weiss, Knapp, Hollweg, & Burrill, 2002).

There are also compelling priorities, frameworks, and agendas within the technology education literature. Waetjen (1991) outlined research priorities focused on student impact, teaching, and educational decision makers. Broad research topics were also identified in the literature and prioritized through a survey of technology education scholars by Foster (1996). The ten research recommendations (highest to lowest priority) are:

> Integration of educational disciplines.
> The role of technology education as general education for all students.
> Rationale for technology education.
> The capability (i.e. effectiveness) of technology education programs to deliver technological literacy.
> Nature of technological literacy.

Need for technological literacy.
Impacts of technology on people and society.
The nature and effectiveness of applied instructional techniques.
Effectiveness of various instructional techniques
Definition of constructs (Foster, 1996, pp. 32-33).

Hoepfl (2002) also created a framework for research in technology education that contains themes (skills development conundrum, process of design, and science/technology interface) as well as strands (teachers, students, assessment, and content). A matrix (Figure 5) demonstrates the interaction of the themes and strands. Additionally, sample research questions were developed from the literature and placed in the matrix to highlight the use of this framework.

Themes	Strands			
	Teachers	Students	Assessment	Content
Skills Development Conundrum				
Process of Design				
Science/Technology Interface				

Figure 5: Themes and strands for a research framework in technology education (Hoepfl, 2002).

The National Center for Engineering and Technology Education (NCETE) also developed a research framework with three main themes, each with several sub-themes:

1. How and What Students Learn in Technology Education
   Sub-themes: Learning and Cognition, Engineering Processes, Creativity, Perceptions, Diversity and Learning Styles
2. How to Best Prepare Technology Teachers
   Sub-Themes: Teacher Education and Professional Development, Curriculum and Instruction, Diversity, and Change.
3. Assessment and Evaluation
   Sub Themes: Student Assessment, Teacher Assessment (NCETE, 2005).

The NCETE framework, like Hoepfl's (2002) and the NRC's (Weiss, Knapp, Hollweg, & Burrill, 2002) frameworks, contains multiple research questions in each area.

The Council on Technology Teacher Education (CTTE) *Strategic Plan* (2004) established five priorities with one on research and scholarship to "develop a research agenda to serve as a foundation for curriculum, program, and professional development as well as assessment through research and scholarship" (p. 2). The 2007 CTTE Yearbook, *Assessment in Technology Education* (Hoepfl & Lindstrom), and Johnson, Burghardt, & Daugherty's chapter, *Research Frontiers – An Emerging Research Agenda*, in the 2008 Yearbook (Custer & Erekson)

help to address this priority but do not provide a comprehensive agenda. These publications, as well as the previously mentioned priorities, frameworks, and agendas, should be used to create a comprehensive agenda for the profession. Several publications from other disciplines would also aid technology education in the creation of a research agenda. Mathematics and science education each have two comprehensive handbooks on research (for mathematics, see Grouws, 1992; Lester, 2007; for science, see Gabel, 1994; Abell & Lederman, 2007). These handbooks are discussed in more detail in chapters nine and ten because of the many connections between mathematics, science, and technology education. However, even an un-related discipline such as dance education provides a useful model (see Bonbright & Faber, 2004) for setting research priorities and developing an evaluation matrix that could be emulated by technology education.

CONCLUSIONS

The continued push for higher standards and accountability in education requires everyone involved to use scientific principles and focus their research (National Research Council, 2004). For technology education, this must be more comprehensive than past efforts. The profession does have a sustained history of research, over 40 years of research reviews, and increasing access to research, publications, and conferences, but it is no longer sufficient to hedge our future on disjointed research efforts that are mostly conducted by graduate students. A focused and sustained effort must be made, one using accepted scientific principles that:

1. pose significant questions that can be investigated empirically,
2. link research to relevant theory,
3. use methods that permit direct investigation of the question,
4. provide a coherent and explicit chain of reasoning,
5. replicate and generalize across studies, and
6. disclose research to encourage professional scrutiny and critique (Shavelson & Towne, 2002, pp. 3-5).

Such an effort will require scholars within technology education to not only develop a research agenda but to implement an action plan. The chapters that follow indicate that the foundations for a comprehensive research agenda have been laid. Key areas of technology education research as well as research from areas that inform technology education are analyzed. It is now time for all of us to come together and not rely on others to define our future.

REFERENCES

Abell, S.K. & Lederman, N.G. (Editors). (2007). *Handbook of Research on Science Education*. New York, NY: Lawrence Erlbaum Publishers.

American Association for the Advancement of Science (AAAS). (2010). *Technology education research conference*. Retrieved from http://www.project2061.org/events/meetings/technology/default.htm

Barlow, M. L. (1967). *History of industrial education in the United States*. Peoria, IL: Charles A. Bennett Co., Inc.

Bolt, M. (2005). *Effects of technology education on middle school language arts (reading) achievement*. Retrieved from: http://digital.lib.odu.edu:8000/dspace/handle/123456789/1

Bonbright, J. M. & Faber, R. (2004). *Research priorities for dance education: A report to the nation*. Retrieved from http://www.ndeo.org/content.aspx?page_id=22&club_id=893257&module_id=56865

Barella, R. & Wright, R. T. (Editors). (1981). *An interpretive history of industrial arts*. American Council on Industrial Arts Teacher Education Yearbook Thirty. Bloomington, IL: McKnight & McKnight Publishing Company.

Cajas, F. (2000). Technology education research: Potential directions. *Journal of Technology Education, 12*(1), 75-85.

Committee on Research in Mathematics, Science, and Technology Education. (1985). *Mathematics, science, and technology education: A research agenda*. Washington, DC: National Academies Press.

Council on Technology Teacher Education (CTTE). (2004). *Strategic Plan for CTTE*. Retrieved from http://www.teched.vt.edu/ctte/

Custer, R. L. & Erekson, T. L. (Editors). (2008). *Engineering and technology education*. Council on Technology Teacher Education Yearbook Fifty-seven. Bloomington, IL: Glencoe-McGraw Hill.

Digital Library and Archives. (2010). *EJournals Home*. Retrieved from: http://scholar.lib.vt.edu/ejournals/

Dyrenfurth, M. & Householder, D. (1979). *Industrial arts education: A review and synthesis of the research, 1968-1979*. Columbus, OH: Center for Vocational & Technical Education.

Educational Testing Service (ETS). (2003). *Standards for what? The economic roots of K-16 reform*. Princeton, NJ: Author

Filossa, J. (2008). *The effects of technology education on science achievement*. Retrieved from: http://digital.lib.odu.edu:8000/dspace/handle/123456789/1

Foster, W. T. (1992a). Topics and methods of recent graduate student research in industrial education and related fields. *Journal of Industrial Teacher Education, 30*(1), 59-72.

Foster, W. T. (Editor). (1992b). *Electronic supplement #1 to the Journal of Technology Education: A partial bibliography of recent graduate research in technology education and related fields*. Retrieved from: http://scholar.lib.vt.edu/ejournals/JTE/.

Foster, W. T. (1996). A Research Agenda for Technology Education. *The Technology Teacher, 56*(1), 31-33.

Fox, M. A. & Hackman, N. (Editors). (2003). *Evaluating and improving undergraduate teaching in science, technology, engineering, and mathematics*. Washington, D.C.: National Academy Press.

Gabel, D. L. (Ed.). (1994). *Handbook of Research on Science Teaching and*

Learning. New York, NY: Macmillan Publishing Company.

Garmire, E. & Pearson, G. (Editors). (2006). *Tech tally: Approaches to assessing technological literacy*. Washington, D.C.: National Academy Press.

Grouws, D. A. (Ed.). (1992). *Handbook of Research on Mathematics Teaching and Learning*. New York, NY: Macmillan Publishing Company.

Hicks, C. (2005). *The demand for industrial technology and technology education faculty professors at United States universities*. Retrieved from: http://digital.lib.odu.edu:8000/dspace/handle/123456789/1

Hoepfl, M. (2002). *A strategic framework for research in technology education*. Un-published manuscript. Department of Technology, Appalachian State University.

Hoepfl, M. & Lindstrom, M. R. (Editors). (2007). *Assessment in technology education*. Council on Technology Teacher Education Yearbook Fifty-six. Bloomington, IL: Glencoe-McGraw Hill.

Householder, D. & Benenson, G. (Editors). (2001). Setting priorities for research in technology education. Retrieved from http://www.project2061.org/events/meetings/technology/tech2/Householder.htm

Householder, D. & Suess, A. (1969). *Review and synthesis of research in industrial arts education*. Columbus, OH: Center for Vocational & Technical Education.

Jelden, D. L. (1976). ACIATE Monograph 6: *Research in Industrial Education: Retrieval of Data from Information Systems*. Reston, VA: Council on Technology Teacher Education.

Jelden, D. L. (Editor). (1981). *Summaries of studies in industrial arts, trade and industrial, and technical education*. Greeley, CO: University of Northern Colorado.

Johnson, S. D. (1993). The plight of technology education research. *The Technology Teacher, 52*(8), 29-30.

Johnson, S. D., Burghardt, M. D., & Daugherty, J. (2008). Research frontiers – An emerging research agenda. In Custer, R. L. & Erekson, T. L. (2008). *Engineering and technology education*. Council on Technology Teacher Education Yearbook Fifty-seven. Woodland Hills, CA: Glencoe/McGraw-Hill.

Johnson, S. D. & Daugherty, J. (2008). Quality and characteristics of recent research in technology education. *Journal of Technology Education, 20*(1), 16-31.

LaPorte, J. E. (2002). The deer or the driver? *Journal of Technology Education, 14*(1), 2-4.

LaPorte, J. E. (2007). Reflections, fabbers, and sharing intellectual property. *Journal of Technology Education, 18*(2), 2-6.

Lester, F.K. (Editor). (2007). *Second Handbook of Research on Mathematics Teaching and Learning*. New York, NY: Information Age Publishers, Inc.

Lewis, T. (1999). Research in technology education—Some areas of need. *Journal of Technology Education, 10*(2), 41-56.

Martin, G. E. (Editor). (1979). *Industrial arts education: Retrospect, prospect*. American Council on Industrial Arts Teacher Education Yearbook Twenty-eight. Bloomington, IL: McKnight & McKnight Publishing Company.

Martin, G. E. (Editor). (1995). *Foundations of technology education*. Council on Technology Teacher Education Yearbook Forty-four. Bloomington, IL: Glencoe-McGraw Hill.

McCrory, D. (1987). *Technology education: Industrial arts in transition*. Columbus, OH: Center for Vocational & Technical Education.

McLaughlin, C. (2005). *A resource guide of journals and publications from disciplines outside of technology education*. Un-published manuscript, Department of Educational Studies, Rhode Island College.

National Center for Engineering and Technology Education (NCETE). (2005). NCETE research framework. Retrieved from http://www.ncete.org/flash/research.php

National Research Council. (1985). *Mathematics, Science, and Technology Education: A Research Agenda*. Washington, DC: National Academy Press.

National Research Council. (2000). *How people learn: Brain, mind, experience, and school*. (Expanded Edition). Washington, DC: National Academy Press.

National Research Council. (2004). *Advancing scientific research in education*. Washington, DC: National Academy Press.

Passmore, D. L. (1987). There is nothing so practical as good research. *Journal of Industrial Teacher Education, 24*(2), 7-14.

Pearson, G. & Young, A. T. (Editors). (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC: National Academy Press.

Petrina, S. (1998). The politics of research in technology education: A critical content and discourse analysis of the Journal of Technology Education, Volumes 1-8. *Journal of Technology Education, 10*(1), 27-57.

Ravitch, D. (2010). *The death and life of the great American school system: How testing and choice are undermining education*. New York, NY: Basic Books.

Reed, P. A. (2001). CTTE Monograph 17: *The technology education graduate research database: 1892-2000*. Reston, VA: Council on Technology Teacher Education.

Reed, P. A. (2002). Research in technology education: Back to the future. *Journal of Technology Education, 13*(2), 68–72.

Reed, P. A. (2006). *What do we value? Research on technology education problems, issues, and standards in the United States*. Paper presented at the Biennial Technology Education Research Conference (TERC).

Reed, P. A. & LaPorte, J. E. (2004). *Twenty-five years of ITEA conferences: A content analysis*. Presentation at the 66th annual conference of the International Technology Education Association.

Reed, P. A. & Sontos, D. (2006). *A United States perspective: 112 years of graduate research in technology education. Paper presented at the PATT-*

16 conference. Baltimore, Maryland. Retrieved from: http://www.iteea.org/Conference/pattproceedings.htm

Ritz, J. M. & Reed, P. A. (2008). *Technology education graduate study: State of the art*. Paper presented at the 95th Mississippi Valley Technology Teacher Education Conference. St. Louis, Missouri.

Ritz, J. M. & Reed, P. A. (2006). Occupational & technical studies graduate research database. Retrieved from: http://digital.lib.odu.edu:8000/dspace/handle/123456789/1

Rowlett, J. D. (Editor). (1966). *Status of research in industrial arts*. American Council on Industrial Arts Teacher Education Yearbook Fifteen. Bloomington, IL: McKnight & McKnight Publishing Company.

Sanders, M. E. (1995). Professional publications in technology education. In Martin, G. E. (Editor). (1995). *Foundations of technology education*. Council on Technology Teacher Education Yearbook Forty-four. Bloomington, IL: Glencoe-McGraw Hill.

Sanders, M. E. (1987). On research. *Journal of Industrial Teacher Education, 24*(4), 57-59.

Schmidt, K. [Ed.]. (2004). *Industrial teacher education Directory, 42nd Edition*. National Association of Industrial and Technical Teacher Educators and Council on Technology Teacher Education. Retrieved from: http://teched.vt.edu/ctte/HTML/ITEDirectory.html

Shavelson, R. J., & Towne, L. (Eds.). (2002). *Scientific research in education*. Committee on Scientific Principles for Education Research, National Research Council. Washington, DC: National Academies Press.

Sontos, D. (2005). *Directions of dissertation research at universities preparing future technology education teacher educators*. Retrieved from: http://digital.lib.odu.edu:8000/dspace/handle/123456789/1

Streichler, J. (1966). *Review and synthesis of research in industrial arts education*. Columbus, OH: Center for Vocational & Technical Education.

Van Tassel, R. (Editor). (1960). *Research in industrial arts education*. American Council on Industrial Arts Teacher Education Yearbook Nine. Bloomington, IL: McKnight & McKnight Publishing Company.

Vries, M. J. de. (2003). Editorial, International *Journal of Technology and Design Education, 13(1), 199-205.*

Waetjen, W. B. (1991). A research agenda for technology education. *The Technology Teacher, 51*(2).

Warner, T. (2005). *Middle school equipment needs to teach the Standards for Technological Literacy*. Retrieved from: http://digital.lib.odu.edu:8000/dspace/handle/123456789/1

Wicklein, R. C. (1993). Identifying critical issues and problems in technology education using a modified-Delphi technique. *Journal of Technology Education, 5*(1), 54-71.

Wicklein, R. C. (2005). Critical issues and problems in technology education. *The*

Technology Teacher, 64(4), 6-9.

Weiss, I. R., Knapp, K. S., Hollweg, K. S., & Burrill, G. (Editors). (2002). *Investigating the influence of standards: A framework for research in Mathematics, Science, and Technology education.* Washington, DC: National Academy Press.

Zuga, K. F. (1994). *Implementing technology education: A review and synthesis of the research literature*. Columbus, OH: Center for Vocational & Technical Education.

Including Research Skills in the Preparation of Technology Educators

<div align="right">

Chapter
2
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INTRODUCTION

The call from the United States government through No Child Left Behind (2001) legislation asked that the education community provide scientific evidence to determine how best children can learn and how best teachers should be prepared. Most of these decisions prior to NCLB had been made using a philosophical or content experts approach. The technology education profession had, and continues to practice, a non-research approach to the guidance of its curriculum decisions other than some efforts undertaken where data-based decision making has been used to establish the selection of content and strategies, e.g., *Standards for Technological Literacy* (ITEA, 2000) and *Engineering byDesign™* (ITEA, 2009).

Technology education must use data-based decision making to show its importance to the educational community (politicians, parents, university administrators, accreditation agencies, state departments of education, etc.). Using data, our profession (teachers, supervisory personnel, and university faculty) can increase the popularity of its subject and also improve the education of students and pre-service teachers. Technology educators need to be taught how to conduct classroom research through both undergraduate and graduate programs. At the undergraduate level, they need to learn how to do technical research as well as research on student learning. Research at the graduate level should further guide curriculum and program development. Ritz and Reed (2007), however, found that many programs have eliminated the formal research project at the master's level and replaced it with other coursework or projects.

The Council on Technology Teacher Education (CTTE) has made research a topic of yearbooks four times prior to this edition. They include *Research in Industrial Arts Education* (Van Tassel, 1960), *Status of Research in Industrial Arts* (Rowlett, 1966), *Classroom Research in Industrial Arts* (Porter, 1964), and *Conducting Technical Research* (Israel & Wright, 1987). After reading these yearbooks, one will see that our profession would be better able to defend its content and methodologies if it would have followed the topics and strategies outlined by authors and editors in these volumes. Some of the statements made in

earlier yearbooks detail problems that persist in the profession:

"Of late, the profession has shown growing concern over the significance, the quality, and the quantity of its research" (Fuzak, 1960, Foreword).

"We need to publicize such research because so little has been done in this area and to show where further work needs to be done" (Kleintjes & Powell, 1960, p. 7).

> To assist in selecting and reporting significant studies, a letter was sent to one hundred and fifty-six institutions preparing industrial arts teachers, asking them to make a discriminating choice of those studies which they considered to be especially significant. The departments were asked to submit abstracts, annotations or bibliographies. We were impressed with the lack of response. In many cases a follow-up letter was necessary to solicit a response from those people charged with directing and exerting leadership in the development of programs and research. Replies were received from only forty-two institutions. Sixteen of the institutions responding reported that they had no studies of significance to report. Twenty-six sent abstracts, annotations, bibliographies or booklets that listed, in some cases, all of the research done at that particular school (Kleintjes & Powell, 1960, p. 7).

One institution reported to Kleintjes and Powell (1960), stating:

> Our graduate program has four options for written work. Very few students avail themselves of the opportunity of writing a thesis or special problem. Most of them take the graduate course paper route, which means that they do three quite substantial papers without credit. This permits them to take three electives (p. 8)

Past efforts have shown that our teaching profession has not set research as a priority for themselves or the students that they teach. It appears that most of our profession's M.S. programs have directed their curriculum to not require the completion of a special topics or thesis paper (Ritz & Reed, 2007). These researchers discovered that many of the institutions that offer M.S. programs for technology education no longer require research projects that result in theses or research project papers.

Santos (2005) found that dissertation research in technology education in the U.S. has also declined. From 2000-2005 there were ten Ph.D. granting institutions that produced 59 dissertations. Five institutions contacted indicated they no longer had degree programs that allowed students to focus on the study of technology education. Five other institutions did not respond after several follow-up attempts to make contact. Of the institutions responding, Table 1 identifies the categories that were the foci of their dissertations.

Table 1
Dissertations topics in technology education in the U.S. (Santos, 2005)

Topic	Number	Percentage
Attitudes	7	12%
Instruction (how)	17	29%
Curriculum (what)	5	8%
Continuing Education	2	3%
Professional Development	8	14%
Foreign Country Topic	11	19%
Work Force Education	9	15%
TOTAL	**59**	**100%**

The universities that did produce dissertations focusing on technology education, as determined through the Santos (2005) study, are included in Table 2. Idaho State University and Southern Illinois University produced the most studies during this time period (Sontos, 2005).

Table 2
Institutions with dissertations for technology education (Santos, 2005).

Institution	Number
Idaho State University	12
Southern Illinois University	12
North Carolina State University	10
Virginia Tech	8
Ohio State University	7
Utah State University	4
Clemson University	2
Old Dominion University	2
Purdue University	1
University of South Florida	1
TOTAL	**59**

The findings of Santos (2005) as well as Reed and Santos (2007) highlight the decline of student research in technology education. Hopefully this yearbook will help reverse this trend. A focus of this chapter is to review two types of research skills technology educators should possess as they progress through their career – technical research and professional research. Suggestions will also be made regarding how researchers can provide the empirical data needed by our profession as it moves forward in the 21st century.

TECHNICAL RESEARCH

Conducting technical research is a foundation of our profession. Teachers use tools and laboratories in their everyday instruction. At the K-12 level, our profession

has used an instructional methodology known as research and experimentation (Earl, 1960; Maley, 1973, 1986). In research laboratories in industry and higher education this is often referred to as primary research or technical research. Both will be explained, so one might use these strategies in technology education and in undergraduate teacher preparation and graduate research.

RESEARCH AND EXPERIMENTATION

There is a long history of conducting technical research in the technology education laboratory (Earl, 1960). The most recognized work in the past sixty years is that of Maley (1973, 1986). He had his students at University of Maryland undertake technical research in their teacher preparation classes. He summarizes this process in his book titled *The Maryland Plan* (Maley, 1973). Through this writing he proposed how technical research could be undertaken by middle school students, calling the instructional unit Research and Experimentation. Maley (1973) stated that the "research and experimentation (R & E) program is basically a problem-solving approach to the study of some object, process, or curiosity that is of particular interest to the individual" (p. 139). Maley (1973) went on to explain this process as one used by researchers in industry and business, and consisting of steps such as identifying the problem, using the scientific research approach, collecting data, etc. Maley believed that students could use the tools in the laboratory to test everyday products, e.g., abrasives, structures, airplane wing designs, etc.

Technical research or research and experimentation were methods that have been utilized in technology teacher preparation since the 1960s. In many cases, this approach was taught to new teachers through the efforts of faculty members who studied under Maley at the University of Maryland. The author can remember learning how to identify a problem and design the necessary apparatuses to conduct the research. There were also requests to gain access to university and industry instrumentation for the investigation of problems such as surface hardness of ceramic materials and using polyester resins to form single-stage cast products.

For those who elected to use the teaching strategies outlined by Maley in *The Maryland Plan* (1973), there were exciting times in their laboratories with students designing experiments and learning the methods of conducting industrial research. The basis of this approach was to understand how engineers and designers work in business and industry and to strengthen one's capacity to solve problems – a goal set by our profession, in cooperation with the U.S. Office of Education (1962). A review of literature shows that, in an attempt to redirect the profession toward a focus of general education, the USOE, in conjunction with the leaders of the profession, published a document titled *Improving Industrial Arts Teaching* (1962). Through this publication a more encompassing mission for technology education was proposed. This was the result of professional meetings that attempted to redirect the efforts of technology teachers to have instructional

programs that would use the following four goals to direct their instructional efforts:

1. To develop in each student an insight and understanding of industry and its place in our culture.
2. To discover and develop talents of students in the technical fields and applied sciences.
3. To develop technical problem-solving skills related to materials and processes.
4. To develop in each student a measure of skill in the use of the common tools and machines (USOE, 1962, pp. 19-20).

This publication was updated and edited with its fourth edition printed in 1968 (AVA, 1968). For those who worked with Maley, one must wonder if he used these goals to obtain Department of Education funding for his proposal to establish *The Maryland Plan* (Maley, 1973).

There are many places that technical research can be introduced into the undergraduate teacher preparation program. The faculty who teach technical courses need to plan instruction in concert with those who teach pedagogical courses. The Council on Technology Teacher Education NCATE/ITEA/CTTE Accreditation Standards (2008) is a good place to begin program planning. Possible courses in which to teach technical research methodologies include Technology and Culture or laboratory courses that focus on design, construction, information and communication, manufacturing, materials, etc. The faculty member could include a unit in the course that might be titled Product Testing or Using Research to Refine Technique.

Maley proposed the following guidelines for including research and experimentation in courses (1973, p. 155):

1. The student projects an idea in the area of his curiosity: *idea-curiosity stage*.

The teacher or faculty member would introduce the concept of research and experimentation and then suggest some example problems such as: Which sneakers have the longest sole life? Which carpet cleaner removes spots from everyday use? Which glue would provide the strongest wooden joint? Which types of batteries hold the longest charge? The teacher could discuss parallels to how industry does such studies. The instructor might draw from testing students may have seen on television or read about in the popular press such as the durability of paint samples under various weather conditions or the durability of highway marking paints. The discussion might also focus on how industry determines how manufacturers determine the length of warranties for their products. The discussion would then proceed to the possible topics the students would be interested in researching. To be successful, the instructor would need to set specific expectations and criteria for the research project based on the capabilities of the students – not too simple or complex. Time parameters for the research to be completed would also need to be specified. The students would then select their research topic, getting input

from the teacher and other students.

2. The student draws up a statement of the problem as a refinement of the idea about which he is curious: *problem stage*.

The instructor should review how problem statements are written. Guidance should be provided so that the questions of the who, what, and why are addressed. For example, "The problem of this study was to determine the most effective scouring powder to clean white enamel kitchen sinks" or "The purpose of this study was to determine if gasoline additives increase the horsepower of a 165 cc lawn mower engine." The instructor needs to work with each student to ensure that the problem statements are defined sufficiently so that the students have success in addressing the stated problem at the conclusion of the study.

3. The student gathers as much information as possible about the problem: *information stage.*

This stage will require the students to do some library and web research, including for example magazines such as *Consumer Reports* or manufacturer's websites. The student might also call the consumer product telephone number listed on the package of the product. One of the goals in gathering information would be to determine *what companies and others have to say about the quality and pledges about their products?* The instructor may wish to specify the number of references required.

4. The student establishes one or more hypotheses about the anticipated outcome of his/her research: *hypothesis stage.*

Hypotheses are projected outcomes. They are not hunches, but are informed projections. Usually a hypothesis is written for each variable that the student is analyzing. As an example, if one wanted to determine which ink marker is most permanent on clothing through repeated washing cycles, they might write the following hypothesis: H1: Marks from Sharpie® brand markers are the most permanent after repeated washing cycles.

5. The student designs a research approach and sets forth the procedures: *research design stage.*

This stage explains how the student will actually do the proposed research. It describes the procedures for testing and collecting data. If, for example, the study of testing the permanency of marking pens mentioned above was being investigated, the procedures to be followed would be carefully specified including the types/names of markers, nature and size of cloth, the detergent used, type and time of washing and drying cycles, how to measure the permanency of the marker, etc. The important part of this stage is to identify precisely what will be done and ensure consistency in the testing procedures. It is important as well to specify how many tests will be conducted.

The next two stages in the research and experimentation process are combined for presentation.

6. The student tests his/her research procedure: *testing or research stage*, and

7.   The student collects and organizes his/her data: *data stage.*

These stages are combined since they occur concurrently. The specified tests are performed and the data are recorded as the testing occurs. It is important that the data are recorded clearly and consistently for each test and should be accessible for later analysis. Photos, audio, and other media, along with computer software, may also be used to record the findings.

8.   The student evaluates the data: *data evaluation stage*.

During this stage the student analyzes the data collected. The analysis can range from simple descriptive analysis, such as visual inspection, to sophisticated tests using statistical software. This stage determines the findings of the study.

9.   The student states his/her conclusions: *conclusion stage*.

This is the stage where the student accepts or rejects their hypotheses based upon the data they collected and analyzed. A report is written to document their study. The report should include all the stages described above, including their literature review (information stage), the procedures followed to conduct the research, the design of any apparatus for experimentation, tables or figures reporting the data collected, and conclusions made based on the hypothesis and research problem. Projections for additional research should also be stated.

When students conduct research and experimentation studies, regular seminars should be scheduled during which their progress on the research is reported to the teacher and other students. A concluding seminar should be scheduled for the reporting of the complete research study. This concluding seminar provides an excellent opportunity to build public relations for the program. School administrators, school board members, other teachers, media representatives, and professionals from business and industry can be invited to provide expert feedback and to reinforce the value and meaning of the students' work and what they learned. It is an excellent time to celebrate student learning!

TECHNICAL RESEARCH PROJECTS

In the Council on Technology Teacher Education's yearbook, *Conducting Technical Research* (Israel & Wright, 1987), another approach to technical research was reported. Seymour (1987) described an eight-step approach to technical research. Chapter authors of this yearbook explained details of the processes outlined in Seymour's model:

1.   Conceptualizing the Project
2.   Selecting a Technical Research Procedures
3.   Finalizing the Technical Research Procedure
4.   Development of a Proposal
5.   Conducting the Technical Research Project
6.   Analyzing the Project Results
7.   Reporting the Results
8.   Evaluating and Applying the Results

The first step in the process, conceptualizing the project, is described

by Weede (1987). In this step the problem is clearly defined. This includes developing the written statement. All of the facts related to the technical problem are gathered. Defining the problem may be difficult for beginning students but it helps all involved in the project to conceptualize what will be studied. It includes examining the projected goals, determining the benefits of finding an answer, and projecting the costs that will be involved. Limitations to the research are also developed.

Selecting the technical research procedure is described in detail by White (1987). He outlined the technical means one would select to undertake the research. Laboratory equipment could be a limiting factor and one may need to purchase or lease testing equipment. The project may determine the apparatus and special instrumentation needed. Planning is necessary for the researchers to select the technical procedures required and might involve some initial trial and error to further refine and conceptualize the problem.

White (1987) described how researchers finalize the technical research design by exploring several avenues that might be followed to achieve the desired results. Several designs might be considered and then analyzed both mentally and using computer modeling. Results of previous research on related projects will be reviewed and the research team will brainstorm alternatives to arrive at the best research design. This is an important step since the selection of a faulty or inappropriate design can be costly and may not produce the desired results. This step is a major information-gathering process and it leads to the next step in which the full research proposal is developed.

Halfin and Nelson (1987) outlined the steps in the development of a technical research proposal. A written proposal is prepared that describes how the project will add "value to a product, service, or system" (Seymour, 1987, p. 52). The proposal should include: "(1) statement of the problem or purpose, (2) specific procedures, (3) methods of data collection, (4) data analysis techniques, (5) personnel, (6) budget, (7) resources, [and] (8) a timetable" (Seymour, 1987, p. 52). This stage is extremely important to document how the ideas developed and to provide an audit trail that others may follow if the research is to be replicated.

The proposal is presented in accordance with the procedures of the organization that might fund the project. Often there is a required presentation using media. Usually a board reviews the proposal and evaluates it using their collective knowledge. The funding agency provides a formal or informal response regarding whether or not the project is to be funded.

Shackleford (1987) indicated that when approved, the project staff can begin conducting the research. Prior to the actual collection of data a number of activities need to be undertaken. These include hiring staff, acquiring needed equipment/instrumentation/software, development of a project management system, and materials needed to undertake the research. A research team leader/ project manager must be appointed. After the team and material are obtained, the research and data collection can begin. Project management and data recording

are critical parts of the research.

Analyzing the results of a technical research project can be accomplished by visual inspection, statistical analysis, or other methods (Kovac, 1987). Visual inspection can require sophisticated instrumentation to review details such as material integrity, consistency of products produced, defects, etc. Statistical analysis can provide a good connection to mathematics through formulae embedded in computer programs that measure patterns or project results. Recommendations are made from the analysis of data.

Andrews (1987) detailed the procedures in reporting the results of technical research. In private industry the results may be considered proprietary and not shared outside of the company. This is especially true if the results of the research have a direct relationship to profit. Many companies perform technical research so that they have a leading edge in their industry. In other cases newsworthy breakthroughs are reported. This is particularly true for medical research and research done in a university setting where the motive is often to share ideas for the benefit of all.

The technical research project concludes with an assessment of the project (Kanagy, 1987). Included among the questions asked in the assessment include: Did the research achieve the problem and goals of the project? Can the results be used in the improvement of an existing product or service or are they completely innovative? Has the research led to a new line of needed research? Would it be better to sell the results of the research or apply them within the products or services offered by the company?

Teacher preparation students and faculty often undertake this type of research activity (Warner & Morford, 2004). A faculty member who begins a line of technical research may be able to continue it throughout their career. It will increase student interest as the faculty member integrates their current research within their teaching. Students can be motivated to do research upon seeing the enthusiasm for research that the faculty member exhibits. Such research could also lead to funding by outside agencies such as the National Science Foundation or university-industrial partnerships.

Technology teachers need to be taught research methodology so that it leads to creativity and problem solving techniques among the students they teach. It should also be acceptable for graduate students to conduct technical research to meet requirements for graduate degrees.

PROFESSIONAL RESEARCH

Technology teachers should apply research techniques to measure student learning and analyze the practices of the profession. Just as educational researchers in general administer pre-tests and post-tests to measure changes in student behavior or learning, technology education teachers should be doing the same. Although it has disappeared in many teacher preparation curriculums,

the National Council for Accreditation of Teacher Education (NCATE) requires student teachers to demonstrate that their students are learning and that they are taking steps to enhance this learning (NCATE, 2008). This is the purpose of achievement testing and the assessment of student design projects. It is essential for our profession to demonstrate that our programs actually do enhance the knowledge of learners. Teacher educators need to instill in the teachers they are preparing a clear sense of curriculum design, instructional design, and the importance of tests and measurements.

The profession has established content standards to serve as a basis for what students should know and be able to do (ITEA, 2000). Teachers and teacher educators must then design instruction to reach these goals and assess whether or not the objectives have been achieved. If the students do not reach the expectations established in the instructional design, then the instructional program needs to be redesigned (ITEA, 2003).

Teacher preparation programs must create a culture of research among the students they teach. The students in these programs are hungry for knowledge and guidance. Once they begin their teaching careers they will continually evaluate student progress through quizzes, tests, and projects. They can be taught to experiment with changes in teaching methodology or activities relative to student learning. For example, teachers can teach two sections of the same class differently while attempting to achieve the same objectives, determining whether one approach is superior to another. Last year's class could be compared to this year's class relative to methodology and achievement.

Another way that teachers can be educated in research is if their technology education students perform better on standardized tests than did students in the same school who did not take technology education. Research by Frazier (2009), Dyer, Reed, and Berry (2006), and Settar (2006) showed that instruction in technology education improved students' mathematics scores on state standardized tests. More of this type of research is needed to show the value of technology education.

When educating teachers to determine if there is a difference in performance between two groups basic statistical tests can be introduced. For example, Microsoft's Excel can perform a t-test on data to determine if there is a difference in performance between two groups. In addition, the Web provides access to statistical calculators and data analysis software. Teachers can be taught how to use such analyses to assist them in action research that leads to logical program revision decisions. The only way that this can happen, though, is to include such competencies in the teacher preparation curriculum. If teacher educators convinced the prospective teachers that they were preparing of the importance of this type of assessment, one would likely see more technology education teachers using these tools. With conclusions based on research, technology education teachers could defend the value of their programs to principals, other teachers, counselors, and especially parents (Frazier, 2009; Dyer, Reed, & Berry, 2006; Settar, 2006).

EXAMPLES OF PROFESSIONAL RESEARCH

There are many research projects that teachers of technology education and graduate students can undertake. There is also a long history of proposed research priorities (Van Tassel, 1960; Porter, 1964; Rowlett, 1966; National Research Council, 2002). Rowlett (1966) proposed appropriate topics as goals, program evaluation, teaching methods, teacher preparation, and staff studies on topics to further the profession.

The *Standards for Technological Literacy* (ITEA, 2000) has codified the content necessary to achieve technological literacy, but what are the school goals to deliver this content? Our profession has had research studies and focus groups that have established these goals. However, when was the last time our profession agreed on such program outcomes? During the 1960s when a wide variety of proposals for teaching technology education were designed, each had a defined set of outcomes. Since our programs have changed direction in recent times, we need goals that we can benchmark the extent to which they have been achieved. Teachers and researchers of technology education need to undertake studies to see if we are meeting our goals in school based programs. With the establishment of *Standards for Technological Literacy* (ITEA, 2000), Ritz (2010) conducted a modified Delphi study to develop new goals for the profession.

> Describe social ethical and environmental impacts associated with the use of technology.
> Become educated consumers of technology for personal professional and societal use.
> Apply design principles that solve engineering and technological problems.
> Use technological systems and devices.
> Use technology to solve problems.
> Describe relationships between technology and other areas of knowledge.
> Develop abilities to live in a technological world.
> Develop an appreciation for the role technology plays in the designed world.
> Troubleshoot and repair technological systems and devices.
> Make informed career choices related to the designed world.
> Describe the nature of technology.
> Extend creative abilities using technology. (Ritz, 2010, p. 59)

This area has excellent potential for research. The profession needs to start a national status study based on goals and universities need to collect data from their graduates to determine the extent to which the goals established for teacher preparation programs have been reached. NCATE (2008) requires accredited teacher preparation units to do this to demonstrate that their graduates are properly prepared.

Program evaluation should be a personal goal that each prospective teacher

seeks when they graduate. Are students performing up to standard? Each teacher needs to be taught how to measure student progress and determine if their programs are meeting standards. This could be as simple as measuring the grades that their students earn. It could also involve the use of survey techniques to measure student's attitudes toward the technology education program. Follow-up studies could also be undertaken to see if technology education teachers assist their students in career exploration, consumerism, problem solving, and other goal-related benchmarks.

With the ITEA/CTTE/NCATE (2003) standards, technology teacher education programs are required to show evidence that their graduates are properly prepared by the program. Follow-up studies of graduates are one way to gather these data. Alumni can provide answers to survey questions and aid a program in determining its strengths and weaknesses.

When teaching each unit of instruction, the teacher should become a researcher to determine if students can master the new content presented to them. This can be rewarding and productive research. If the teacher teaches three identical courses, for example, different projects can be required for each class. Research can then show which of the projects help the students the most in attaining the objectives of the unit. As an alternative, different teaching strategies could be used with each class. Lectures might be used in one group, independent study of the textbook might be used in another, and the third group might use interactive video to learn the content. Using the same unit objectives and the same unit test, did one group perform better than the other two? Many variations of this concept can be designed, such as group vs. individualized instruction, team teaching, collaborative learning, homework vs. no homework, etc. Chapter 4 deals with instructional strategies and provides more depth regarding teaching methods and the potentials for research.

Graduate students could undertake status studies of teacher preparation programs. These could include determining the focus of programs (technology education, engineering concepts, standards-based programs), performance of students on Praxis II, the number of graduates, the teaching performance of standard licensure compared to alternative licensure graduates. The students conducting such research will hone their research skills and satisfy their intrinsic curiosity while professors could use the data for joint publications and modification of the teacher preparation curriculum.

Special Interest Research Topics

One very important topic for researchers to consider is determining if the study of technology and engineering better prepares students for life, i.e., are graduates better prepared to solve problems, purchase consumer products, increase their mechanical aptitude, and at a higher level in science and mathematics. Instruments are available to measure mechanical aptitude (e.g., PAR Inc.), technical aptitude (e.g., Armed Services Vocational Aptitude Battery, ASVAB*),* and state standard

tests in science and mathematics. Many of these and other instruments can be used in studies to show the contributions of technology and engineering education. The National Assessment of Educational Progress (NAEP) will soon have a test available to measure technological literacy. Engineering by Design™ has tests developed to evaluate student progress in its courses.

A CHARGE TO TEACHER EDUCATION

Research on technology education graduate institutions (Ritz & Reed, 2008) showed that professors are often not supportive of the value of research for themselves or the graduate students with whom they work. Adding to the dilemma is the fact that most technology education teacher preparation universities do not offer advanced graduate study. Good teaching and service to the institution are typically the primary criteria for faculty evaluation at non-research oriented universities. Therefore, the faculty members at these universities question the value of doing research and publication if they are not a significant part of the evaluation. Moreover, the teaching load for faculty at teaching-oriented universities may not be reduced if they are involved in research. Graduate students at many institutions are required to take research courses from faculty in a department that focuses on research methodology. There is often little connection between what the students do in these research courses and technology education. There is little incentive for the technology education faculty to work with the students to connect what they are learning in the research courses to technology education. Thus, the control over what the students learn about research rests with faculty outside of technology education.

The charge for teacher educators is to work with the faculty member in the departments who teach the research courses. To make the research experience more relevant, the research faculty might be provided with a list of research topics that technology education students might want to pursue. If a thesis is planned, technology education faculty need to get involved at the initial stages. In addition, students need to understand the research needs and priorities for technology education so that they can contribute directly to the field through their work. If the responsibility to connect the student's experience in research courses to the field, then much potential is lost.

At the doctoral level, technology education faculty members should closely oversee students' selection of research topics. They should require students to conduct mini-studies as they progress through their coursework. They should also be taught the publication of the results of their work is as important as the work itself. There experiences will lead to a higher quality dissertation. The faculty members and students need to see the applicability of their research and how it will contribute to our profession. Narrowly focused research does not contribute to the profession or further development of the doctoral candidate.

In the sciences, most university faculty members within a department focus their research on a specific area such as joint replacement, internet security,

atomic physics, and port logistics. Can technology education teacher preparation programs also do the same? Perhaps engineering design and STEM integration will lead to a focus of research unlike what has occurred in the past. If our profession can develop clearly identified tracks of research the faculty and graduate students conducting research would more likely make a positive contribution to the field.

SUMMARY

Research is an important topic to the technology education teacher preparation profession. This is the fifth yearbook of the Council on Technology Teacher Education dedicated to this topic. Many efforts have been undertaken to address the topic of research yet so few of our members of the profession are engaged in research in their professional practice. Individuals outside of our immediate profession who have worked with us (e.g., Waetjen, 1992; Pearson & Young, 2002) have sent a clear message to us that we need to undertake more research in our field. Yet those who are actively engaged in research can be included in a rather small circle. The bottom line is that we need research data to support the value of our programs and what we do. This requires a change in the culture of our profession.

REFERENCES

American Vocational Association (AVA). (1968). *A guide to improving instruction in industrial arts* (Rev. ed.). Washington, D.C. Author.

Andrews, W. D. (1987). Reporting the results. In E. Israel & R.T. Wright (eds.), *Conducting technical research* (pp. 171-184). Mission Hills, CA: Glencoe Publishing Company.

Dyer, R. R., Reed, P. A., & Berry, R. Q. (2006). Investigating the relationship between high school technology education and test scores for algebra 1 and geometry, *Journal of Technology Education, 17*(2), 7-17.

Earl, A. W. (1960). *Experiments with materials and products of industry*. Bloomington, IL: McKnight and McKnight.

Frazier, M. T. (2009). *The effect of technology education on student's state standardized test scores*. Unpublished doctoral dissertation, Old Dominion University, Norfolk, VA.

Fuzak, J. (1960). Foreword. In R. Van Tassel (ed.), *Research in Industrial Arts Education* (n.p.). Bloomington, IL: McKnight & McKnight Publishing Company

Halfin, H. H., & Nelson, O. W. (1987). In E. Israel & R.T. Wright (eds.), *Conducting technical research* (pp. 88-106). Mission Hills, CA: Glencoe Publishing Company.

Hicks, C. (2005). *The demand for industrial technology and technology education faculty at United States universities*. Unpublished master's thesis, Old Dominion University, Norfolk, VA.

International Technology Education Association (ITEA). (2009). *Engineering*

by Design™ (EbD) A Standards-Based Model Program. Retrieved from http://www.iteaconnect.org/ EbD/ebd.htm

International Technology Education Association (ITEA). (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

International Technology Education Association (ITEA). (2003). *Advancing excellence in technological literacy: Student assessment, professional development, and program standards*. Reston, VA: Author.

Israel, E., & Wright, T. (Eds.) (1987). *Conducting technical research*. Mission Hills, CA: Glencoe Publishing Company.

ITEA/CTTE/NCATE. (2003). Curriculum Standards: Initial Programs in Technology Teacher Education. Retrieved from http://www.ctteonline.org/accreditation/ncate_documents.shtm

Kanagy, M. E. (1987). Evaluating and applying the results. In E. Israel & R.T. Wright (Eds.), *Conducting technical research* (pp. 143-170). Mission Hills, CA: Glencoe Publishing Company.

Kovac, R. J. (1987). Assessing the results. In E. Israel & R.T. Wright (eds.), *Conducting technical research* (pp. 143-170). Mission Hills, CA: Glencoe Publishing Company.

National Council for Accreditation of Teacher Education (NCATE). (2008). *Professional Standards for the Accreditation of Teacher Preparation Institutions*. Washington, DC: Author.

National Research Council (NRC). (2002). *Investigating the influence of standards: A framework for research in mathematics, science, and technology education.* Washington, DC: National Academy Press.

No Child Left Behind Act of 2001, 20 U.S.C. § 6319 (2001).

Maley, D. (1986). *Research and experimentation in technology education*. Reston, VA: International Technology Education Association.

Maley, D. (1973). *The Maryland plan*. New York: Bruce.

Pearson, G., & Young, A.T. (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC: National Academies Press.

Porter, C. B. (Ed.). (1964). *Classroom research in industrial arts*. Bloomington, IL: McKnight & McKnight Publishing Company.

Powell, P. E., & Kleintjes, P.L. (1960). Significant research in industrial arts teacher education. In Van Tassel, R. (Ed.) *Research in industrial arts education* (pp. 7-33). Bloomington, IL: McKnight & McKnight Publishing Company.

Reed, P. A. & Sontos, D. (2007). *A United States perspective: 112 years of graduate research*. Paper presented at the PATT 16 conference, Baltimore, Maryland.

Ritz, J. M. (2010). A new generation of goals for technology education. *Journal of Technology Education, 20*(2), 50-64.

Ritz, J. M. & Reed, P. (2008). Graduate study in technology education: State-of-

the-art. In J. Daker, W. Dow, & M. de Vries (eds), *Teaching and learning technological literacy in the classroom* (pp. 406-414). Glasgow: University of Glasgow.

Rowlett, J. D. (Ed.). (1966). *Status of research in industrial arts*. Bloomington, IL: McKnight & McKnight Publishing Company.

Seymour, R.D. (1987). A model of the technical research project. In E. Israel & R.T. Wright (Eds.), *Conducting technical research* (pp. 46-57). Mission Hills, CA: Glencoe Publishing Company.

Settar, S. S. (2006). *The relationship between pre-engineering courses and increased success on the Virginia Algebra II and Geometry Standards of Learning examinations*. Unpublished master's thesis, Old Dominion University, Norfolk, VA.

Sontos, D. (2005). *Directions of dissertation research at universities preparing future technology education teacher educators*. Unpublished master's thesis, Old Dominion University, Norfolk, VA.

Shackleford, R. L. (1987). Conducting the technical research project. In E. Israel & R.T. Wright (Eds.), *Conducting technical research* (pp. 122-142). Mission Hills, CA: Glencoe Publishing Company.

U. S. Office of Education (USOE). (1962). *Improving industrial arts teaching*, OE-33022. Washington, D.C.: U.S. Government Printing Office.

Van Tassel, R. (Ed.). (1960). *Research in industrial arts education*. Bloomington, IL: McKnight & McKnight Publishing Company.

Waetjen, W. B. (1992). *Shaping the future of a profession*. Critical issues in technology education Camelback symposium: A compilation of papers. Reston, VA: International Technology Education Association.

Warner, S. & Morford, L. (2004). The status of design in technology teacher education in the United States. *Journal of Technology Education, 15*, (2) 33-45.

Weede, G. D. (1987). Conceptualizing the research topics. In E. Israel & R.T. Wright (Eds.), *Conducting technical research* (pp. 58-67). Mission Hills, CA: Glencoe Publishing Company.

White, M. R. (1987). Selecting a technical research design. In E. Israel & R.T. Wright (Eds.), *Conducting technical research* (pp. 68-87). Mission Hills, CA: Glencoe Publishing Company.

Curriculum Research in Technology Education

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Chapter
3
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INTRODUCTION

The first two chapters of this yearbook review the state of the art in technology education research and synthesized it in general terms. This is the first in a series of chapters that delve deeper into specific areas or fields of research in technology education. It must be noted that, due to the laboratory based nature of our curriculum, its high degree of integration or correlation with other subjects, and our heritage with grounding in general education, engineering, design, and even social sciences, there is some degree of overlap to be expected among the chapters that follow. Research into what topics to teach will necessarily involve an examination of the facilities for teaching; opportunities for integration require examination of our goals and the subject matter of study; and clear lines between these research topics and approaches are difficult to draw. The approach in this chapter is to briefly examine the history of our field, describe what curriculum research is, describe how curriculum research is done in general, and then apply these baseline understandings to review the curriculum research agendas, methods, and findings that pertain specifically to technology education. Lastly, some direction for continued curriculum research in technology education is proposed.

HISTORY OF TECHNOLOGY EDUCATION CURRICULA

Technology education has long been a part of both general education and vocational education. Even the apprenticeship system, beginning as far back as 4000 BCE in Egypt and representing nearly all more recent European cultures, had elements that transcended the conventional lines distinguishing classical (academic) general education and training for specific job skills. In that early system, it was the master's role to teach the apprentice both how to do a job and how to live successfully in the culture. As formal schools and systems of education developed, there was often a vocational purpose mingled with academic

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goals. In the 5th century, Basil organized a monastery school that included manual work and crafts (Anderson, 1926). Both Bennett (1926) and Anderson (1926) cited schools in Germany in the early 1700s in which education for work was delivered along with the academic learning. Pestalozzi was reported to have established several different schools that mixed tool skills and general education, influencing both Herbart and Fellenberg in their similar efforts of the late 1700's (Bennett, 1926). As the education movement inspired by Pestalozzi spread, in Scandinavia a crafts education movement termed Sloyd evolved during the mid 1800's (Bennett, 1937). The Sloyd movement likely contributed more to the "arts" dimension of "industrial arts" (US, 1950's – 1980s'), while other influences were more responsible for the "industrial" aspects. Chief among the latter influences would surely be Della Vos and his Imperial Technical School in Russia (Bennett, 1926, 1937; Struck, 1930).

The more modern antecedents of technology education curricula stem from applied educational strategies developed in Europe throughout the 18th and 19th centuries (Ritz, 2006). During this period, practical application and activity were incorporated into course curricula to construct frameworks with the intent of creating purposeful and meaningful learning. John Dewey's experimental schools employed similar practices, emphasizing learning through doing. Embracing this philosophy, the U.S. Office of Education allocated resources for the development of programs of study in trade, industrial, and industrial arts education that were aimed at improving the technical education of high school graduates. This focus on cognitive and performance competencies in vocational and technical education evolved over time into some of the broad-based technological literacy programs and curricula of modern technology education (Ritz, 2006).

While the preceding synopsis is necessarily brief and omits many influential people, movements, and schools, it does reveal three important elements of the heritage of the technology education curriculum popularly represented by the name "Industrial Arts" in the U.S.A. in the 1950's: There has always been a blending of vocational and general education in leading programs; there have also been influences from both the aesthetic (arts and crafts) and the industrial aspects of technology; and there has always been tension within the field regarding its identity with leaders holding strong, competing beliefs (vocational, aesthetic, general education, industrial, etc.).

Another thing to note is that most of the curriculum evolution in the field of industrial arts took place as a result of good ideas by leaders and tacit knowledge tested in practice. For the most part these curriculum development efforts were not based on formal educational research. Rather, a leader developed an idea and put it into practice. Its success or failure rested on the relative merits of the idea, resources available for implementation, and, in most cases, the unpredictable elements of timing and sheer luck rather than planned, careful research.

The industrial arts of the 1950's in the U.S. reflected its heritage well, including a mixture of courses based in skills and crafts with a somewhat industrial thrust

(Sredl, 1964). The courses were most often identified with a particular material (woods, metals, etc.), a group of related processes (drafting, graphic arts, etc.), or even infrastructures which supported industry and technology (electronics, power-mechanics, etc.). Courses had little or no standardization of curriculum and teachers customized their courses to their own liking as they generally formed the curriculum to enable students to build certain projects (Olson, 1963). In the 1960's a wealth of new resources and influences enabled the field of industrial arts to examine itself more critically and with a more investigative approach than previously employed. The new resources included financial support partly due to growing programs nationwide combined with post WW-II and post Sputnik financial support for innovation and improvement in both general and vocational education.

Evolution Towards a Study of Technology

Despite the ongoing professional arguments concerning the extent to which industrial arts was vocational or general education, vocational funds supported many programs. The opportunities for professionals to network blossomed during the 1960s with growing numbers of professional societies and publications as well as interest in them. Finally, the number of professionals with doctoral degrees in the field of industrial arts, a rarity before 1960, increased along with expectations for faculty members to publish. All of these influences, resources, and new expectations helped the field develop a more defensible, research-based approach to curriculum development, yielding several local and state curriculum plans and programs which were well documented in Cochran (1970) and Householder (1972). Among these innovative approaches, two have had a significant and lasting effect on current technology education curriculum: the Industrial Arts Curriculum Project and the Maryland (Maley) Plan. In common, they were based on research, introduced new topics to the curriculum, changed the nature of the "learn by doing" approach that was universal in the field, and had rather widespread adoption or adaptation by entire school districts or even states. Moreover, both are still having an impact on the modern technology education curricula of the early 21st century.

The Industrial Arts Curriculum Project (IACP - Towers, Lux, and Ray, 1966) was one of the largest curriculum efforts ever in our profession. It was funded by the United States Office of Education - Department of Health, Education, and Welfare. The initial project co-directors were Donald G. Lux, Willis E. Ray, and Edward Towers. The project resulted in the development of two new courses intended for junior high level industrial arts programs, The World of Construction (Lux and Ray, 1970) and The World of Manufacturing (Ray and Lux, 1971). The development of the courses was chiefly inspired by the project leaders. The topics were organized conceptually, drawing on the earlier work of Warner (1948) and Olsen (1963), rather than by the names of materials or processes. It also narrowed the curriculum to only two organizers: construction and manufacturing. This was

a significant departure from the curricula of the time.

Much of the supportive work of developing and field testing the actual learning activities for the two new courses was actually carried out through dissertation research by graduate students. By employing a large number of graduate students focused on a singular effort, IACP was clearly the largest and most fully research-based curriculum development effort in our profession. The origin of courses with names such as Manufacturing Systems or Construction Systems, along with the group-based learning activities that they employ, can be traced directly to IACP. Moreover, such courses and units of study are common in many areas of the U.S. today.

The late Donald Maley, a professor for several decades at the University of Maryland, also greatly influenced the technology education programs of today. His work culminated in what he titled the "Maryland Plan" (Maley, 1973). In contrast to the collaborative nature of IACP, his curriculum was principally the result of his own personal study and analysis of research and ideas from other academic areas rather than empirical research he conducted. The fields of anthropology and communication heavily influenced his ideas. Arguably, his greatest contribution was the development of learning activities for students that forced them to conduct their own research into topics of importance to technology and of interest to them. An earmark of Maley's approach was the development of a display or diorama, along with the presentation of a research paper. Some present day courses such as the middle school course often titled Exploring Technology or something similar still incorporate this approach. Most often the activities are group-based rather than individual projects. The result was that the work of the students mutually supported Maley's curriculum research. The Maryland Plan had a significant impact on the field, especially in the states that were in proximity to Maryland, for the primary means of implementing Maley's ideas was through professional development efforts rather than printed curriculum materials.

TECHNOLOGICAL STUDIES: THE HALLMARK SINCE THE 1980'S

The Jackson's Mill Industrial Arts Curriculum Symposium assisted in planning a unified direction for the discipline through the clear identification of concepts, competencies, and learner outcomes. The symposium resulted in the foundation being laid "for the reconstruction of industrial arts as a building block toward technological literacy" (Snyder and Hales, 1981, p. 65). The "theory" document created through the symposium highlighted the interrelationship of philosophy and classroom practice, setting the stage for state planning, curriculum development, and professional development. This effort added "communication" and "transportation" as organizers along with the manufacturing and construction of the IACP.

The Standards for Industrial Arts Programs Project was directed by William E. Dugger, Jr. at Virginia Polytechnic Institute and State University. The project

commenced in 1978 with a focus on program standards rather than curriculum. Previously, in 1966, the Schmitt and Pelley study, consisting of a major national survey, had determined that drafting, metalworking, and woodworking had long been and remained the most often studied topics in industrial arts. The 1978 Standards Project began with another major survey to determine status and plan for change. Next, a team of experts was assembled to develop the standards relative to student organizations, equity, and special needs. A series of workshops was conducted to gain further input from the profession, with representatives from all 50 states and three territories. The project culminated in 1981 with a series of publications including the *Standards for Industrial Arts Programs*, the *American Industrial Arts Student Association Guide for Industrial Arts Programs*, the *Sex Equity Guide for Industrial Arts Programs*, and the *Special Needs Guide for Industrial Arts Programs* (AIAA, 1981). In the end, over 400 professionals were involved in the process and a total of 235 specific quality measures were identified under ten major headings:

1. Philosophy
2. Instructional Program
3. Student Populations Served
4. Instructional Staff
5. Administration and Supervision
6. Support Systems
7. Instructional Strategies
8. Public Relations
9. Safety and Health
10. Evaluation (AIAA, 1981)

Unlike previous large-scale curriculum efforts, the Standards Project did not prescribe specific courses. The rationale was to provide program standards, but allow states and local school districts the freedom to meet the standards in whatever way best met their needs. In response, many programs across the nation did base their curriculum development on the four systems that evolved from the Jackson's Mill Curriculum Symposium: Communication, Construction, Manufacturing, and Power/Energy/Transportation even though they were not required to use these words in course titles. This practically insured alignment with the competencies identified in the standards. The standards were never intended to mandate a unified national curriculum and a wide variety of approaches emerged. Nonetheless, the impact of the Standards Project in providing criteria for the assessment of programs and bringing consistency to programs in much of the U.S. was significant. Furthermore, there was a definite "technology" thrust throughout the standards, even though the name of the project and the discipline itself still retained the word "industrial." (Once the American Industrial Arts Association changed its name to the International Technology Education Association in 1984, the guides were updated to officially embrace "technology.") Traditional programs that were taught in "shops" did not embrace emerging computer technology, and

did not include cognitive content about technology and its impacts, simply could not stack up well when reviewed with the Standards.

The Technology for All Americans Project was initiated in 1994 by the International Technology Education Association (ITEA) to provide curriculum standards to support students in a study of technology (ITEA, 2008). In 1996 the project published a guiding document, *Technology for all Americans: A Rationale and Structure for the Study of Technology,* the result of extensive debate and review by the writing team, project staff, and hundreds of participants who were concerned about technology education and its role in schools in the United States (Satchwell and Dugger, 1996).

In an effort to afford opportunities for practitioners to evaluate and provide feedback for the developing standards, the project staff engaged in numerous consensus building activities at national, regional, and state technology education meetings throughout the United States. Contemporary content and methods were paired with the detailed benefits of studying technology. The second phase of the Technology for All Americans Project culminated with the publication of *Standards for Technological Literacy: Content for the Study of Technology*. These standards presented a vision of what students should know and be able to apply in order to be technologically literate (ITEA, 2000). The standards do not attempt to define a curriculum for the study of technology, but describe K-12 content in technology education in an effort to increase program consistency in schools around the United States. In phase three of the project, *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* was published (ITEA, 2003). It was created as a companion document to *Standards for Technological Literacy: Content for the Study of Technology*, presenting guidelines for student assessment, guidelines for teacher professional development, and program infrastructure associated with the study of technology.

A balanced curriculum incorporates experiences in cognitive, affective, and psychomotor domains (Jackson's Mill Industrial Arts Curriculum Theory, Snyder and Hales, 1981). In consideration of these domains, instructional structuring and preparation requires systematic organization of content into an effective and efficient scope and sequence. It is essential to recognize that the instructional process coincides with educational philosophy from which the content is organized in the scope and sequence.

RECENT INFLUENCES EXPAND THE STUDY OF TECHNOLOGY

There have been a variety of traditional approaches and curricular efforts in technology education that have served as the underpinnings of one another. Technical skills, craft approaches, technical production, engineering apprentice approaches, modern technology approaches, science and technology, design, problem-solving, and technology and society approaches are among the foundational components

of the global curricular efforts in technology education (Black, 1998). Black summarizes recent developments and approaches in many other countries. In Finland, technical skills approaches span beyond their traditional sense in which students study and apply techniques to systems and materials. Visual elements, redesign, and efficiency are incorporated into the existing study and application. A combination of manual skill, aesthetic sensibility, and traditional design all factor into many of the Swedish craft approaches. Eastern Europe employs technical production with an emphasis on skills associated with contemporary mass production, its control, and organization. The engineering apprentice approach, employed globally, prepares technicians and engineers through a rigorous training system. An approach heavily integrating modern technologies focusing on information technology is utilized by the French. Denmark and others rely on a science and technology approach that highlights the close associations between the areas. Emphasis is placed on *design* as the vital concept of the study and application of technology in the United Kingdom (Black, 1998). The increasing influence of the U.K. design-centered approach is helping balance the engineering driven thrust in many programs in the U.S. Problem-solving approaches in the United States define and resolve queries focused on social needs using a cross-disciplinary approach. The technology and society approach engages students in the study of technological innovation as it associates with social change. Included in previous curricular efforts are apparent organized clusters of engineering, design, research, and development. Engineering has an established relationship with the content taught in technology education. With many educators expressing a need for further curricular action and consideration of renaming the profession, technology education is trending toward an even deeper reflection of engineering content and processes (Ritz, 2006).

CURRICULUM RESEARCH APPLIED TO TECHNOLOGY EDUCATION

The classic educational research text of Borg and Gall (1989) did not specifically identify a chapter or unit on curriculum research, but it did include curriculum research in the form of evaluation research. In essence, this type of research involves development of a curricular approach or array of topics and then field testing to assess the value of the program. Key elements of evaluation research include: Identifying the stakeholders, determining what to evaluate, examining program goals, reviewing resources and procedures, and considering program management. The specific approaches and sources of data are partially determined by who is conducting or has requested the evaluation (individual, funding agency, oversight agency, etc.) and the resources available for the evaluation. Hallmarks of effective evaluation research include utility, feasibility, propriety, and accuracy. These parameters guide researchers in their efforts to accurately find and safeguard information which has maximum impact in

answering the research questions from the perspective of the individual or agency seeking the evaluation. In other words, if an individual or group develops a new curriculum or program and then field tests it without an independent assessment, they must be very careful not to warp their evaluation procedures in such a way as to only enable finding what they hope to find. Some of the previous curriculum research in our discipline could be faulted on this point—it was not independently evaluated or assessed other than by the proponents of the new curriculum or program. This lack of oversight was more characteristic of small scale efforts than of those backed by major funding.

The most frequently employed approach of curricular research in technology education has been the Delphi study or variations of the same approach. Simplistically stated, a Delphi is a form of survey in which individuals who should be in a position to know and care about a topic are initially surveyed and then follow-up rounds of the survey force them to consider input from their peers to refine the ideas. Multiple rounds of input are used. Delphi studies can be of extraordinary importance in research to develop or revise curricula only when the pool of respondents is adequate in number, is diverse, and all identified members of the pool actually fully participate. These three considerations are important to insure that all valid points of view are represented and full participation requires that all respondents consider every item carefully in each round and respond thoughtfully. However, the technique becomes much less valid and valuable when the pool is restricted to like-minded individuals or a group limited in some other way (such as geographic area, representing some particular bias, or a demographically homogenous group) or when individuals in the group tire of the process and either fail to respond to some rounds or do so with minimal consideration/effort. The process should be most valid when fully employed with four rounds of input from the participants, but the greater the workload for participants, the more likely there will be attrition before the end of the study, or the participants will devote less energy to their responses in later rounds. On the other hand, for those participants who truly do care deeply about the subject at hand, their level of participation will remain high throughout the investigation. In essence, then, it is likely the opinions of the outsiders that will be watered down or lost by a lengthy process. If those outside opinions are truly important and valuable, losing them makes the entire process boil down to what would have been obtained if the researcher simply went and asked his/her friends for their opinions. Therefore, modifying the process to use fewer rounds and incorporating all practical means to encourage full participation by everyone in the pool should be seriously considered.

Leaders in technology education have used the Delphi technique in studies related to curriulum and have helped others who chose to employ it (i.e. Clark & Scales, 2003; Clark & Wenig, 1999; Wicklein, 1993). These projects identified assessment practices, quality characteristics, and critical issues and problems in technology and engineering education by merging ideas from key stakeholders.

Though not formally published as an independent Delphi study, there were significant elements of the Delphi approach in the first standards project and in the Technology for All Americans work (AIAA, 1981; ITEA, 2008). Using various methods of data collection, survey, comment, and cross-checking by professionals at professional meetings consensus was drawn from key professionals with input from important stakeholders outside the profession. At its best, the Delphi technique is valuable to bring consensus among professionals from diverse perspectives. At its worst, it promotes the status quo and could lead to formation of professional cliques which are resistant to new ideas—always of concern to a small professional community such as ours.

Another type of research of value for curriculum development and evaluation is the quasi-experimental study. Haynie (1998) noted that experimental and quasi-experimental research only represented 12% of the entries in the first 9 volumes of the *Journal of Technology Education* while library papers (45%) and surveys (17%) dominated the journal. Delphi studies (5%) and other curriculum research efforts (4%) were also far overshadowed by the large number of library papers. Haynie admonished *JTE* readers and contributors that new information is not found by the sorts of articles that examined or argued over the history of the field nor by efforts that asked for opinions of leaders (both surveys and Delphi studies) but only when something new was developed and actually tested as in an experiment or field test of some sort. He admitted, however, that to be adequately controlled and insure that extraneous variables do not distort findings, each experiment must ask tightly defined questions that might individually hold little value. It is when many related experiments with compatible findings are obtained in slightly different settings and conditions that truthful and useful conclusions are achieved. This is a long and slow process, so depending upon experimental research findings as the prime mover for curricular revision is not practical. Still, individual experiments are helpful for testing new ideas and approaches.

Establishing, maintaining, and evaluating connections between curricula and research is a necessary process in the development of curricula (Clements, 2007). A common claim among curriculum developers is that the materials are research-based, although some projects fall short of fully explicating their claims.

CURRICULA IDENTIFICATION IN TECHNOLOGY EDUCATION:

Curricular elements vary within the range of academic levels and offerings in technology education. Elementary curricula have an exploratory element that incorporates design, targeting social development, while secondary curricula lend focus to open-ended design utilizing a variety of means and engineering processes. Academic structure and sophistication in K-12 education vary with level and setting, but essential components of standards-based competencies must be addressed. Knowledge of materials and processes and incorporation

of problem solving and design elements seem to be somewhat universal across academic levels in technology education.

ELEMENTARY

Everyday products, radio and television programming, reading materials, the internet, and other media have virtually become the customary means of providing children with information and experiences in science and technology. With the nation and world more accessible than ever, many children have exploratory experiences with new inventions and technologies in the elementary grades. To be successful in planning and implementing a technology curriculum, one must not consider only the technological aspects, but the social and cultural factors must be considered as well. The backgrounds of students, society's perceptions of technology, expectations of children who learn about technology, and the approach and method of teaching and learning technology all now play essential roles in the development of elementary technology education curricula (Siu and Lam, 2005).

Visual literacy to enhance proficiency in academic content areas is an emerging method found in contemporary elementary schools. The involvement of maps, pictures, views, photographs, etc. in curricula promotes engaged learning (Wu and Newman, 2008). Visual materials permit study and use of contextual information to conduct component inquiry into conceptual learning. These types of materials require students to utilize existing information to form associations, conduct investigations, and reach conclusions, adding to the significance of the content. Supplemental to visual engagement in elementary classrooms is constructive engagement (creating, inventing, developing, etc.). Many elementary programs are beginning to incorporate design and technology activities into their curriculum to further include the learn-by-doing approach of Dewey (Linnell, 2005). Design-and-build approaches in elementary classrooms not only help students actively experience learning, but engage students in cooperative approaches that assist in social and cultural development (Linnell, 2007). Despite the large foundation of project-based learning research that promotes active learner participation, little is established on implementation approaches in the cross-disciplinary structure found in most elementary classrooms (Muniandy, Mohammad, and Fong, 2007).

ENGINEERING DESIGN

Some have proposed systematizing technology education high school curricula around the study of engineering design. Focusing on engineering design presents the possibility of achieving technological literacy while simultaneously creating a well-defined framework that is understood (Wicklein, 2006). Infusing engineering design into technology education represents a redirection and fundamental change within the field. There are several general challenges associated with this fundamental change. Well-established conventional views of K-12 technology education identify it as a vocational preparatory sequence

(Gattie & Wicklein, 2007). Additionally, there is an inconsistent interpretation of engineering design within the field.

In a recent Delphi study conducted by Childress and Rhodes (2008), engineering outcomes for high school pre-engineering students were identified. Reverse engineering, research and development, and fabrication of prototypes were processes deemed necessary to best prepare students for postsecondary engineering education, while preserving the mission of technology education. Additional implications highlighted for technology education curriculum are engineering communication activities, design and data presentation, data control, and the application of mathematics and science principles to student design solutions.

EARLY APPROACHES TO INTEGRATED CURRICULA

Integrating the curriculum around a technology theme is not a new idea. Cochran (1970) lists five innovative programs of the 1960's in his chapter on "Integrative Programs":

1. Correlated Curriculum Project
2. Interdisciplinary Vocational Education
3. Introduction to Vocations
4. Partnership Vocational Education Project
5. Richmond Plan

Cochran's book, *Innovative Programs in Industrial Education*, examined the field broadly, including all of vocational education rather than restricting itself to the industrial arts programs of its day. Nonetheless, there were clear implications for industrial arts. In particular, the first phase of the Correlated Curriculum Project, which was mainly exploratory in nature (pre-vocational rather than specific job oriented), and the Richmond Plan, are closely related and merit discussion as we consider curriculum research in modern technology education. These approaches included a great deal of interdisciplinary correlation of the curriculum, continuing to have contemporary relevance. Team teaching was included as much as possible. Mathematics, science, and communication were studied in the context of technology and problem solving. The Richmond Plan was characterized by Cochran as "a two-year pre-engineering technology sequence of four integrated and correlated courses beginning in eleventh grade. These courses provide experiences in English, physics and chemistry, mathematics, through trigonometry, and technical laboratories." (1970, p.35) If this same description were applied to a newly developed program today, it would be very closely aligned with the direction in which our field appears to be heading. With funding from both the Rosenberg Foundation of San Francisco and the Ford Foundation, the Richmond Plan, developed in Richmond, California by a team led by Marvin J. Feldman in 1961, must be considered by those who seek to truly maximize the integration of the curriculum around a technology and engineering theme. Yet, it must be admitted that its success was limited and it no longer exists

in its full, original form. The Correlated Curriculum Project, also no longer in full bloom, came a short time later in New York City Schools under the direction of Superintendent Joseph O. Loretan in 1966. It also received funding from the Ford Foundation and it especially targeted "marginal" students who were not likely to succeed in the traditional high school. In lieu of the engineering thrust, this program concerned business, health, and industry occupations. Nine New York City public high schools included the program by the 1967-68 school year. The innovative approaches included time block scheduling, intensive guidance services, and team teaching.

Don Maley was another proponent of curricular integration in the 1960's and 70's. He described industrial arts and its anticipated configuration as being "multi-structured to meet the needs of all levels of students" and "multi-disciplinary in its approach to content". (Maley, n.d., p.3) In his concluding statement, Maley quoted Sir Winston Churchill to challenge his colleagues that vision was needed to make the large scale changes required to bring industrial arts into better integration with other school subjects as a central element rather than an "appendage" (p. 31).

RECENT APPROACHES TO INTEGRATED CURRICULA

Expanding and modernizing on the integrative approaches of the 60s and 70s, many current leaders in technology education espouse the merits of integrating our curriculum with other fields today. Much of the recent curriculum research in technology education involves some aspects of integration of the curriculum. The integration of science, technology, engineering, and mathematics content (STEM) has become a mainstream topic within educational systems. For successful integration, many factors must be considered when using technology education as a key focal point of integrated curricula. Many conditions and opportunities must be in place for a true integration of subject matter to transpire, such as academic collaboration, hands-on approaches, and the use of creativity and problem solving.

Curriculum taught in an integrated format assists students in the association of content and ideas to form a cohesive knowledge structure. Student learning increases as associations between ideas are made. (Brooks and Brooks, 1993; Sunal, Sunal, and Haas, 1996). As noted by Vars in an examination of theory of integrative and multidisciplinary models of curriculum integration, observational results over a seventy-year period indicate that students enrolled in integrated programs experience academic achievement that equals or exceeds that of students in conventional programs (Vars' 1997 work was cited by Dowden, 2007).

Academic collaboration prepares instructors to provide students with hands-on, open-ended, real-world problem-solving experiences that are linked. Curriculum materials that are merely standards-based are not considered true integrators unless they address competencies that are directly measurable in technology education and other disciplines. In a 2002 curriculum integration

project by Venville, Wallace, Rennie, and Malone (cited by Venville, Rennie, and Wallace, 2004), it was concluded that students refer to specific subject-based content knowledge to help them solve problems, but also find it necessary to consult other sources of knowledge such as parents and other teachers. This finding clearly argues in favor of going beyond subject-based standards to evaluate the degree and depth of learning that occurs in integrated educational environments (Venville, Rennie, and Wallace, 2004). Technology education has the potential to become the catalyst for integrated curricula. Technology is diverse enough in nature that it can be addressed by a variety of content areas, bringing along with it the means to integrate mathematics and science.

DESIGN

"Design and technology" is a curriculum in the United Kingdom designed for students of ages 5-14. The design and technology curriculum is a required core subject initially. Supplemental courses in graphics, electronics, and communication technologies, alongside a variety of other design and technology courses, can be offered (Hull, 2007). Much like the model in the United Kingdom, design has become a clear provision of technology education curricula in the United States.

To many, a common approach in teaching technological processes is to develop activities into prescriptive procedures for students to follow. Williams (2000) notes several examples of this approach: design-make-appraise (citing the Australian Education Commission, 1994), identify-design-make-evaluate (drawn by Williams from the UK Department of Education, 1995), and define problem-ideas-model-test (in the U.S. citing International Technology Education Association, 1998). On the other end of design-based curricular approaches in technology are the open-ended design investigations. The open-ended design problems have developed into frequent challenges in technology education curricula. In this approach, students utilize divergent-thinking practices to recognize an assortment of potential results and then select one to further investigate and develop. However, open-ended design challenges do not holistically reflect the anticipated intent of design (Lewis, 2006). Quantitative analysis to predict performance is often overlooked; instead a trial and error technique is implemented that evades technical facets of the conceptual design stage.

Design and inquiry uncover many direct relationships between science and technology education curricula, as evidenced by the content standards for these disciplines serving as the basis for the development of curriculum. The new design focus in technology education curricula situates it more closely with science and engineering than ever before (Lewis and Zuga, 2005).

COMPUTATIONAL SCIENCE

Additionally, others have proposed implementing technology education

via computational science, targeting problem-solving associated with complex engineering, mathematics, and science problems. Through a series of studies on economics in the U.S., the "Computational Science: Ensuring America's Competitiveness" report determined that computational science areas are critical to scientific leadership and economic competitiveness (Clark, 2008). Looking into skills for the 21st century, authors Murnane and Levy (2004) stated that for the United States to remain competitive globally, two new skills need to be brought into curricula at all levels: 1) expert thinking and 2) complex communication. Expert thinking addresses the abilities students need to solve problems that cannot be solved by following specified criteria and constraints, but includes the need for critical thinking skills and creativity for success. There is limited evidence that technology education curriculum has been based on expert thinking for the past 30 years (Reed, 2007). The second skill, complex communication, addresses the need to have students breakdown information and be able to communicate it in a variety of forms and ways to a diverse set of audiences (Clark, 2006). Critical constructivism presents a base of study pertaining to complex communication in computational science. Educational evaluation of the use of digital means to support learning through complex communication was developed from the social practices of new media users. Employing social practices to serve as foundational components supports a student participatory culture. Integral skills in a participatory culture enhance traditional literacy, research, technical, and analytical skills taught in contemporary classrooms and broaden those practices through new media environments and digital modes of learning (Pascarella, 2008).

Computational science in technology education uses the Universal Design for Learning model. Wu and Newman (2008) described Universal Design for Learning as using inclusive practices based on the expectation of diversity in student learning needs in classrooms (citing in their discussion McGuire, Scott, and Shaw, 2003). Universal Design for Learning used in curriculum development has three basic principles: multiple means of representation, expression, and engagement (McGuire, Scott, and Shaw, 2006, also a secondary source here as cited by Wu and Newman).

CURRICULUM THEORY AND DEVELOPMENT MODELS

Curriculum theorists can be classified into three major groups: traditionalists, conceptual empiricists, or reconceptualists (Glatthorn, Boschee, & Whitehead, 2009). These three groups vary in their outlooks as explained below.

Traditionalists are those curriculum theorists who focus on the most efficient method of conveying the importance of cultural heritage and society through a predetermined body of information (Glatthorn, Boschee, & Whitehead, 2009). Ralph Tyler is considered a traditionalist. Tyler's (1949) model is the most widely recognized framework for curriculum development. Tyler suggests four basic preparatory areas for investigation in curriculum development: intention of the

preparatory system, educational experiences directly associated with function, organization of experiences, and evaluation. The Tyler Model of Curriculum Design focuses on the nature and structure of knowledge, the demands and desires of society, and specific learner needs (Madeus & Stufflebeam, 1989). In Tyler's model, the local education agency or school directs the learning experiences to reach identified educational goals. Taba proposed a more complex model that builds on Tyler's view of effective curriculum development. Taba's model (1962) includes supplemental stages in the process such as defining characteristics of anticipated students and their needs, identifying instructional objectives in cognitive and psychomotor domains, selecting the scope of content, organizing the sequence and structure, selecting methods of presentation, designing assessment activities, and implementing formative evaluation (Chou & Tsai, 2002).

Conceptual empiricists employ research methodologies in efforts to enhance predictability and therefore better guide and control curricula in schools. Robert Gagne is considered a conceptual empiricist. Curricular structures proposed by Gagne consist of sequenced content units in which new skill or knowledge can be acquired through a single act (Glatthorn, Boschee, & Whitehead, 2009). This structure assumes student mastery of previously addressed material. Gagne's model heavily relies on researched curriculum materials. In this approach, learner progression is identified and content is effectively sequenced.

Reconceptualists emphasize subjectivity, existential experience, and the art of interpretation to relationships in society (Glatthorn, Boschee, & Whitehead, 2009). Many theorists have elements of reconceptualist curriculum theory in methodology, model determination, political views, and practice; just as with the foci of curricular structure, process, and content are blended. Curriculum theory, models, and organization are all integral components in the development of effective educational curricula.

Curriculum in technology education is developed through a variety of sources. States, vendors, and schools all serve as curriculum and assessment providers. Ernst (2008) conducted a survey of technology education state supervisors and found that 18 states design their own curriculum, 29 states develop curriculum at the local school system level, 18 use materials from the Center to Advance the Teaching of Technology and Science (CATTS) materials, 22 use materials from Project Lead the Way, and 16 use materials developed by commercial vendors (many states reported multiple sources). Similarly, when asked about assessment the state supervisors reported that 18 states design their own curricular assessments, 28 states develop curricular assessments at the local school system level, 10 use CATTS assessments, 21 use Project Lead the Way™ assessments, and 10 use assessments developed by commercial vendors.

CURRICULAR IMPLEMENTATION IN TECHNOLOGY EDUCATION

One classic text on curriculum development is Tanner and Tanner (1975). In an effort to promote carefully considered curriculum reform rather than faddish trends they cautioned:

> Curriculum reforms have tended to be undertaken as responses to societal crises. Insufficient attention has been given to curriculum reconstruction based upon sound research and theory. Educational researchers have been prone to engage in narrowly based empirical studies that have little bearing on the wider conceptual problems of the curriculum field. The demand for innovation and reform has led to the establishment of educational programs that are labeled "experimental" in the absence of a sound theoretical base and a commitment to experimentation. In the absence of practices founded on theory to be tested through working hypotheses, these programs are energized by a spirit of improvisation and deviation. However energetic this spirit may be, improvisation and deviation are not substitutes for theory and experimentation. The result is that innovations and reforms are short-lived, as each era of societal crisis calls for yet another turn about in the direction of educational change
>
> Yet, despite these shortcomings, no other society has made education so accessible to its people as the United States, and no other society has managed to provide within a unitary educational system such a diversified and comprehensive curriculum for such a pluralistic population. In this sense, education in the United States is indeed a laboratory in which philosophical distinctions become concrete and are tested. For it was not by chance that the United States gave birth to experimentalist theory. (p. 94-95)

With both internal and external forces pulling for higher standards, educational reform, attention to diversity issues, the needs of individual learners, and ever advancing technology, the leaders of tomorrow's technology education programs will not be those who blindly follow the current trend—they will be the ones who develop curricula based on identified needs and ideas that have been carefully tested.

Lewis (1999), stated that "subject matter and the conceptual structure of technology education still remains [sic] an unsettled issue and a preoccupation of leaders of the field in the United States" (p.46). The broad range of proposed technology education programs presents a lack of uniformity, and often clarity, concerning curriculum (Daugherty, Klenke, & Neden, 2008). Lewis (1999) expressed that standards-based curricular alignment that details experiences,

abilities, and knowledge that students must have experienced or possess in order to be categorized as technologically literate contributes to a lack of specificity for the field. Further, this approach does not consider the universals underlying technology: processes, knowledge, and contexts (Lewis, 1999). In a 2008 study analyzing technology and science curricula, Demiraslan identified that aesthetic judgment, basic experimental design for problem solving, and social and cultural appreciation require further curricular emphasis. Design and higher-order processing are not the only unsettled components necessary for appropriate technology education curricula. Since adopted curriculum ultimately dictates facility design, classrooms and laboratories range in structure and resource (Daugherty, Klenke, & Neden, 2008). Some school systems use contemporary modeling and automated prototyping laboratories while others still maintain facilities for trades such as carpentry, cabinetmaking, masonry, and automotive courses.

With its entire history as a "learn through doing" curriculum, technology education has always been laboratory based. In yesteryear the facilities were termed "shops," reflecting the industrial nature of the previous curriculum and its name, industrial arts. In the 1950's nearly all facilities were actually "unit shops" in which one material or body of techniques were studied with tools, machinery, and equipment that mirrored (often in smaller forms) industrial equipment. Schools had wood shops, metal shops, drafting rooms, print shops, and the like. In the 1960's some movement was made toward "general shops" which allowed work on a variety of materials and processes in the same room. As the IACP—Jackson's Mill era cluster courses of manufacturing, construction, communication, and transportation came into vogue, facilities changed somewhat and the term "laboratory" was recommended as the appropriate designator. The labs for these courses were developed in two ways: Either an old traditional unit or general shop was revamped and updated to some extent in order to support the new curricula, or a new lab was built when a new school was constructed. Needless to say the new schools with their purposefully-built labs better reflected and supported the new programs while updated existing labs still retained many items of outdated equipment for the sake of tradition or cost cutting. However, this approach, taken in far too many schools, did not help eradicate the "shop" and "industrial" image of the entire program. This problem continues today. To fully present modern technology education it is clear that computers are essential. These machines require some protection from harsh environments, but there are many examples in schools today where computers are operating very well with a coating of dust from lab equipment.

Programs vary greatly in the amount of production capability required. Some programs use computers exclusively while others still retain the hands-on building approach. A blended approach is recommended in which computers are used to accomplish research, planning, and modeling while small scale production equipment, such as that found in a model shop, is used to make prototypes. A

good assortment of testing and evaluation equipment is needed so that solutions to problem solving challenges may be assessed by the students, data may be collected and analyzed, and true, constraint-based modeling approaches can be implemented. If engineering and design are the hallmarks of modern technology education, which they currently appear to be, then the laboratories must reflect this approach. Large scale, intimidating facilities filled with huge, heavy, gray and green painted machines, permanently mounted to the floor, must be replaced. In their stead should be a broad array of flexible, smaller scale equipment for the production of models and prototypes. Modern testing equipment, linked to computers, enables the student to easily collect and analyze data. Advanced communication and 3d modeling software is essential to a modern technology education facility. The lab should be inviting and clean. The appearance of a lab and the equipment in it portrays to a visitor what occurs in the curriculum better than a printed brochure.

Research to determine what is needed in the facility should include visits to vendors' displays at conferences, examination of vendors' catalogues, and visits to schools with similar programs. Due to the high costs involved, lack of appropriate facilities has often delayed or even prevented curriculum revision efforts. Curriculum research efforts in technology education must include the practical considerations of curriculum implementation relative to facilities and equipment.

ASSESSMENT OF CURRICULUM INNOVATIONS

Assessment contributes to determining if intended student learning outcomes have been achieved and is an integral process in curricular design. In fact, there must be a deliberate attempt from the onset of the curriculum development process to align curriculum and assessment (McDonald & Van Der Horst, 2007). Assessments derived from student learning objectives produce information that is beneficial in determining the overall success of curriculum design and implementation (Chou & Tsai, 2002). However, prior to the formal implementation of new curricula, a sequence of formative evaluation processes should be performed to identify and assess the strengths and weaknesses of the proposed curriculum. This enables designers to improve the curriculum before it is implemented by analyzing the curriculum as it is being actually delivered.

One dimension of technological literacy is knowledge and includes both factual knowledge and conceptual understanding. Another dimension is technological capability. It refers to how well a person can use technology and carry out a design process to solve a problem. A third dimension is critical thinking and decision-making which includes how a person approaches technological issues (Garmire & Pearson, 2006). Knowledge transfer and metacognition are key assessment components of the evaluation of technological literacy. Therefore, these factors must be measured as part of the assessment efforts of any major curriculum research effort in technology education.

CONCLUSIONS

It can be argued that all research in our discipline is, in fact, curriculum research because most of it is done with the intention of having an impact on what is taught in the schools and how it is taught. However, much of this research is often rather informal. For example, when a teacher develops a new project or activity for teaching and reports it in a professional magazine like *Tech Directions*, that teacher has actually conducted "research" even though it does not meet the standards of formal research in social science. Much of the formal research related to curriculum in our discipline is somewhat esoteric and often not readily available to teachers working in the schools. A significant amount of curriculum development relies upon the input from experts in the field rather than testing new ideas under experimental conditions.

Though few in number, large scale funded projects such as the Industrial Arts Curriculum Project, the Standards for Industrial Arts Programs Project, and the Technology for All Americans Project have had a major impact on our profession and represent the state-of-the-art in research with regard to curriculum in technology education. More of these large scope projects, with a comprehensive research, development, and implementation plan are desperately needed. Even though the benefits for sponsoring agencies and institutions conducting the research are far-reaching and their impact on changing our profession is undeniable, the monetary resources necessary fluctuate depending on the economy and the agenda of the federal government at the time. Graduate students best learn how to conduct research by participating with mentor faculty on these major projects. The results of large scale studies have far greater impact than those conducted by one or two investigators.

"There is probably more international agreement among technology educators about the activity of technology than about the content of technology" (Williams, 2000, p. 48). Distinctions between content and activity are helpful when designing curriculum and in collaboration with practitioners. It is important that students, however, perceive the curricula as a balanced and thoroughly integrated whole rather than divided into content and process, theory and practice, or lecture and lab.

Though the future cannot be predicted with certainty, it appears now that modern curricula in technology education will be structured to allow for an integrated and spiraling approach to instruction in technology in concert with science, engineering, the arts, and with an ongoing consideration of society at large. New curricula will use authentic design activities that employ state-of-the-art technologies while applying, problem solving strategies, collaboration and teaming practices, creativity, and higher order thinking. These enduring skills allow students to participate in technological design, engineering design, and experimentation. Students can apply creativity in the invention and innovation of new products, processes, and systems as well as investigate their impact on society. A self-directed, original, and creative workforce seems to be the societal

need (Petrina, 1992). Curricular efforts in technology education should consider these aspects as essential components. In order to engage students with the finest educational experiences possible, both the content and the context must be considered in curriculum development and related research (Scales, Petlick, and Clark, 2005). The diversity of learners must also be considered of utmost importance in curriculum development as well as in the design of instruction (Ernst and Clark, 2007). Technology education professionals must continue to respond with curricula that address the depth, rate, and direction of change.

The technology education curriculum of the future will be optimized if it is formed on the basis of well conceived and properly conducted curriculum research incorporating all of the essential techniques discussed in this chapter. Such research will require the continued collection of demographic data, obtaining consensus among experts, historical research, and thorough reviews of literature to insure a firm base for the work. Moreover, quasi-experimental studies coupled with thorough field testing should be the standard for new curricular efforts. Careful attention to the realities of the schools and the facilities within them must be carefully considered to better assure that wide-spread adoption and adaptation can occur. Finally, carefully designed and implemented assessment programs are essential to demonstrate accountability and thereby increase acceptance by professionals in other subject areas. The goal of developing a technologically literate populace can only be attained with a well conceived, dynamic curriculum supported by sound research.

REFERENCES

AIAA. (1981). *Standards for industrial arts programs and related guides.* Standards for Industrial Arts Project. Reston, VA. Goodheart-Wilcox.

Anderson, L. F. (1926). History of manual and industrial school education. New York: Appleton.

Bennett, C. A. (1926). History of manual and industrial education up to 1870. Peoria, IL.: Bennett.

Bennett, C. A. (1937). History of manual and industrial education 1870 to 1917. Peoria, IL.: Bennett.

Black, P. (1998). An international overview of curricular approaches and models in technology education. *Journal of Technological Studies, 24*(1), 24-30.

Brooks, J. G. & Brooks, B. G. (1993). *The case for constructivist classrooms.* Alexandria, VI: Association for Supervision and Curriculum Development.

Borg, W. R., and Gall, M. D. (1989) *Educational research: An introduction.* 5th ed. New York: Longman.

Childress, V. & Rhodes, C. (2008). Engineering student outcomes for grades 9-12. *The Technology Teacher*, *68*(4), 5-12.

Chou, C. & Tsai, C. (2002). Developing web-based curricula: Issues and challenges. *Journal of Curriculum Studies*. *34*. 623-636.

Clark, A.C. (October, 2006). STEM-Based computational modeling. Paper

presented at the Annual meeting of the Mississippi Valley Technology Teacher Education Conference in Chicago, IL.

Clark, A.C. (2008). Computational science as part of technology education. *The Technology Teacher*, *67*(5), 18-22.

Clark, A. C., Scales, A. Y. (2003). A Delphi Study of Assessment Practices in Engineering Education. *Engineering Design Graphics Journal, 67*(2).

Clark, A. C., & Wenig, R. E. (1999). Identification of quality characteristics for technology education programs: A North Carolina case study. *Journal of Technology Education, 11*(1), 18-26.

Clements, D.H. (2007). Curriculum research: Toward a framework for research based curricula. *Journal for Research in Mathematics Education*, *38*(1), 35-70.

Cochran, L. H. (1970). Innovative programs in industrial education. Bloomington, IL.: McKnight.

Daugherty, M.K. Klenke, A.M., & Neden, M. (2008). Creating standards-based technology education facilities. *The Technology Teacher*, *68*(2), 19-26.

Demiraslan, Y. (March, 2008). Investigating the propriety of a science and technology curriculum in Turkiye. Paper presented at the Annual Meeting of the American Educational Research Association New York City, NY.

Dowden, T. (2007). Relevant, challenging, integrative and exploratory curriculum design: Perspectives from theory and practice for middle level schooling in Australia. *The Australian Educational Researcher*, *34*(2) 51-71.

Ernst, J.V. (February, 2008). State supervisor's report. Report presented to the Council of Supervisors Division of the International Technology Education Association Annual Conference, Salt Lake City, UT.

Ernst, J.V. and Clark, A.C. (2007). Scientific and technical visualization in technology education. *The Technology Teacher, 66*(8),16-20.

Garmire, E., & Pearson, G. (Eds.). (2006). *Tech tally: Approaches to assessing technological literacy*. Washington, DC: National Academy Press.

Gattie, D.K. & Wicklein, R.C. (2007). Curricular value and instructional needs for infusing engineering design into k-12 technology education. *Journal of Technology Education*, *19*(1), 6-18.

Glatthorn, A.A., Boschee, F., & Whitehead, B.M. (2009). *Curriculum leadership: Strategies for development and implementation* (2nd. ed.), Thousand Oaks, CA: Sage Publications.

Haynie, W. J. (1998). Experimental research in technology education: Where is it? *Journal of Technology Education. 9*(2),78-83.

Householder, D. L. (1972). *Review and evaluation of curriculum development in industrial arts education.* Columbus, OH: Eric Clearinghouse on Vocational and Technical Education.

Hull, G. (2007). Model program: The British schools of America. *The Technology Teacher*, *67*(10), 26-30.

IACP rationale—A brief description. (1968). Columbus, OH: Industrial Arts

Curriculum Project.

ITEA. (2008). Technology for all Americans Project. Retrieved December, 15 2008, from http://www.iteaconnect.org/TAA/TAA.html.

International Technology Education Association (2000). Standards for technological literacy: Content for the study of technology. Reston, VA: ITEA.

International Technology Education Association (2003). *Advancing excellence in technological literacy: Student assessment, professional development, and program standards*. Reston, VA: ITEA.

Lewis, T. (1999). Content or process as approaches to technology curriculum: Does it matter come Monday morning? Journal of Technology Education, 11(1), 45-59.

Lewis, T. (2006). Design and inquiry: Bases for an accommodation between science and technology education in the curriculum? *Journal of Research in Science Teaching*, *43*(3), 255-281.

Lewis, T., & Zuga, K. F. (2005). A conceptual framework of ideas and issues in technology education. Retrieved November 28, 2008 from http://teched. vt.edu/ctte/HTML/Research1.html

Linnell, C. (2005). Introducing an elementary design challenge into a TECA regional competition. *The Technology Teacher*, *65*(10), 23-26.

Linnell, C. (2007). Designing and Building a cardboard chair: Children's engineering at the TECA Eastern Regional Conference. *The Technology Teacher*, *67*(4), 25-28.

Lux, D. G. & Ray, W. E. (1970). The world of construction. Bloomington, IL: McKnight and McKnight.

Madeus, G.F., & Stufflebeam, D.L. (1989). Educational evaluation: The works of Ralph Tyler. Boston, MA: Kluwer Academic Press.

Maley, D. (n.d.). The challenge of industrial arts in education. Unpublished manuscript, University of Maryland, College Park, MD.

Maley, D. (1973). The Maryland plan. New York: Bruce.

Martin, G. E. (Ed.). (1995). *Foundations of technology education*, 44th Yearbook of CTTE. Council on Technology Teacher Education, New York: Glencoe.

McDonald, R. & Van Der Horst, H. (2007). Curriculum alignment, globalization, and quality assurance in South African higher education. *Journal of Curriculum Studies*, *39*(1), 1-9.

Muniandy, B., Mohammad, R., & Fong, S.F. (2007). Synergizing pedagogy, learning theory and technology in instruction: How can it be done? *US-China Education Review*, *4*(9), 46-53.

Murnane, R. J. & Levy, F. S. (2004). *The new division of labor: How computers are creating the next job market.* Princeton, NJ: Princeton University Press.

Olson, D. W. (1963). Industrial arts and technology. Englewood Cliffs, NJ.: Prentice-Hall.

Pascarella, J. (2008). Confronting the challenges of critical digital literacy: An

essay review critical constructivism: A primer. Educational Studies, 43: 246–255.

Petrina, S. (1992). Curriculum change in technology education: A theoretical perspective on personal relevance curriculum designs. Journal of Technology Education, 3(2), 37-47.

Ray, W. E. & Lux, D. G. (1971). *The world of manufacturing*. Bloomington, IL: McKnight and McKnight.

Reed, P. A. (2007). The journey towards technological literacy for all in the United States: Are we there yet? *The Technology Teacher, 67*(3), 15-22.

Ritz, J. (2006). Technology and engineering are both addressed through technology education. *The Technology Teacher. 66*(3), 19-21.

Satchwell, R.E. & Dugger, Jr., W.E. (1996). A united vision: Technology for all Americans. Journal of Technology Education, 7(2), 5-12.

Scales A., Petlick J.H. and Clark A.C. (2005). A Survey of Current Trends and Issues for Engineering/Technical Graphics Education: Results from a Five-Year Follow-up. Proceedings of the 2005 American Society of Engineering Education Southeast Section Conference.

Schmitt, M. L. & Pelley, A. L. (1966). Industrial arts education, a survey of programs, teachers, students, and curriculum. Washington, D.C.: U.S. Department of Health, Education and Welfare. (OE-33038-Circular No. 791).

Siu, K.W.M. & Lam, M.S. (2005). Early childhood technology education: A sociocultural perspective. *Early Childhood Education Journal*, *32*(6), 353-358.

Snyder, J.F. & Hales, J.A. (1981). Jackson's Mill industrial arts curriculum theory Charleston, WV: West Virginia Department of Education.

Sredl, H. J. (1964). A history of industrial arts from 1920 – 1964. Ph.D. dissertation, The Ohio State University.

Struck, F. T. (1930). Foundations of industrial education. New York: Wiley.

Sunal, C., Sunal, D., & Haas, M. (1996). Meaningful learning in social studies through conceptual reconstruction: A strategy for secondary students. *Inquiry in Social Studies*, *32*(1), 1 -17.

Taba, H. (1962) *Curriculum development: Theory and practice*, New York: Harcourt Brace and World.

Tanner, D. & Tanner, L. N. (1975). *Curriculum Development: Theory into practice*. New York: Macmillan.

Towers, E. R., Lux, D. G., & Ray, W. E. (1966). A rationale and structure for industrial arts subject matter. Columbus: The Ohio State University Research Foundation.

Tyler, R. W. (1949) *Basic principles of curriculum and instruction*, Chicago: University of Chicago Press.

Venville, G., Rennie, L., & Wallace, J. (2004). Decision making and sources of knowledge: How students tackle integrated tasks in science, technology and mathematics. *Research in Science Education, 34*(2), 115-135.

Warner, W.E. (1948). A Curriculum to reflect technology. Columbus, OH: Epsilon Pi Tau.

Wicklein, R. C. (1993). Identifying critical issues and problems in technology education using a modified-delphi technique. *Journal of Technology Education*, *5*(1), 54-71.

Wicklein, R.C. (2006). Five good reasons for engineering design as the focus for technology education. *The Technology Teacher*, *66*(4), 25-29.

Williams, J.P. (2000). Design: The only methodology of technology? *Journal of Technology Education*, *11*(2), 48-60.

Wu, X. & Newman, M. (March, 2008). Engage and excite all learners through a visual literacy curriculum. Paper presented at the Annual Meeting of the American Educational Research Association in New York City, NY.

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Chapter
4

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INTRODUCTION

Technology education has a long history of emphasizing the importance of hands-on activities and the incorporation of an interdisciplinary approach to teaching. These approaches or instructional strategies have been a key to the delivery of content for the discipline. It is important to be able to document that importance through research. Lauda (1988) in the CTTE Yearbook, *Instructional Strategies for Technology Education*, wrote "Even the best curriculum design will fail if the instructional strategies are inappropriate or inadequate" (p.14). Instructional strategies have been such an important topic for our profession that two CTTE yearbooks have been dedicated to this issue (Kemp & Schwaller, 1988; Helgeson & Schwaller, 2003). As we look at the topic of research and instructional strategies, one has to ask how successful have we been in the 22 years since the first yearbook on instructional strategies?

This chapter will look at the role research has played in the application of instructional strategies for technology education. Comparisons will be made to research in other disciplines on instructional strategies to see what can be learned from that research and how it might be applied to technology education. The significance of the chapter is to provide a framework of research to the profession and broader education community. There is also a great need to document the effectiveness of the instructional strategies used by technology teachers.

REVIEW AND SYNTHESIS OF RESEARCH

This section will provide a review of some of the research being conducted on instructional strategies at the different levels of education. Unfortunately, the published studies directly related to technology education instructional strategies are limited. As Johnson and Daugherty (2008) noted in a review of research in technology education:

> While there seems to be movement in a positive direction (i.e., a better balance of quantitative and qualitative research; more inclusive studies; and cognition studies) than in the past, the recent collection of technology education research is still dominated by descriptive studies that rely on self-reports and perceptions. As indicated by the national

movement toward more scientifically based research in education, the need to raise the quality and rigor of technology education research is apparent (pp. 27-28).

The majority of the research in technology education has focused on secondary and post secondary education. There has been a shift in the instructional methods used in technology education in the United States from building projects based on instructor provided plans to approaches such as the use of modular technology systems in middle school and problem solving activities in high school (Sanders, 2001). The research has not caught up to this shift. When instructional strategy research specific to technology education is not available, examples of research in other disciplines are provided. However, caution must be taken with regard to the generalizability of this research to technology education.

PRIMARY

The research at the primary level is almost exclusively in the areas of early childhood development and special education. The focus is on the early identification of developmental issues. Many of the elementary instructional strategies promoted by the Technology Education for Children Council (TECC) in *Technology and Children* have application for primary grades.

According to Mallory (1994), the social constructivist model stems from views of learning and development first articulated by Vygotsky and then expanded by Rogoff (1984) and others. Such a shift is supportive of the current press for more inclusive classroom practices through an emphasis on the sociocultural context, the role of social activity—including instruction—in learning, and the contributions of learners to their own development. Principles for inclusive early childhood practice are explicated based on the concepts of classrooms as communities, learning as socially mediated, curriculum as contextually relevant and problem based, and assessment as authentic and personally meaningful. National organizations have called for early childhood schools to place a greater emphasis on:

- Active, hands-on learning
- Conceptual learning that leads to understanding along with acquisition of basic skills
- Meaningful, relevant learning experiences
- Interactive teaching and cooperative learning
- A broad range of relevant content, intergraded across traditional subject matter divisions (Bredekamp, Knuth, Kunesh, & Shulmann, 1992).

ELEMENTARY

There is very little research at the elementary level due to the fact that most of the teachers at this level generally have very little, if any, preparation in teaching technology. The Technology Education for Children Council has

done considerable work to provide educational resources and professional development for elementary staff. Much of the review of the research at this level is related to instructional strategies used to teach other disciplines because of the interdisciplinary approach used at this level.

The National Staff Development Council (NSDC) (2001) outlined standards of professional development efforts that improve the learning of all students. According to NSDC (2001), organizing educators into learning communities and using student data to determine the learning priorities are fundamental components of high-quality staff development. These standards are embedded in the proposed professional development series by NSDC.

An example of professional development that leads to the improvement of instruction is to organize educators into learning communities. Eaker, Dufour, and Dufour (2002) provide a model for university faculty to develop a program to support K-8 administrators and teachers as they form district-level Professional Learning Communities (PLC) focused on increasing student achievement in mathematics. These learning communities create a district-level infrastructure to support teachers as they gain classroom experience with instructional strategies that assist all students in learning algebra.

The PLCs are combined with instruction on how to use student data to customize instruction. The National Mathematics Advisory Panel suggested that teachers' use of formative assessments benefits students at all levels. The positive effect is even greater when teachers are supported in their use of the data to inform instruction. For this reason, university faculty can design common formative assessments that all teachers can use to gather student data. The district-level PLCs gather and analyze student data prior to each institute. During the institutes, university faculty assist teachers in using this data to improve instruction (Goerdt, 2009).

As Prensky (2001) has argued, today's students – so called 'Millennials' – come to the educational enterprise with different interests and skill sets. Video games are now a widely embraced approach for creating a new learning culture that better corresponds with the habits and interests of today's children and young adults (Prensky, 2001). Due to students' familiarity with video gaming and related technology, it is important to integrate methods that match student interests with the intent of heightening student motivation and providing an additional dimension to assessment. In addition, immersive educational video games can improve students' mathematics understanding and skills, and significantly raise district-wide math scores. In a study conducted by Kunznia (2009) student use of Tabula Digital games was investigated over an 18 week period. Students in the experimental group scored significantly higher on district mathematics benchmark tests than students in the control group who did not play the video games ($p < .001$). In fact, the increase in scores for the test group was more than double the increase for the control group. According to the teachers, the games were effective teaching and learning tools because they were experiential in nature,

offered an alternative way of teaching and learning, and gave the students reasons to learn mathematics to solve the game problems. The teachers also commented that the games helped address students' math phobias and increased time on task. According to the students, the games were effective because they combined learning and fun, offered mathematics in an adventurous and exploratory context, and challenged students to learn math.

One pertinent research initiative at the elementary level is the Engineering is Elementary (EiE) project at the Museum of Science in Boston. According to their website (www.mos.org/eie), the EiE project aims to foster engineering and technological literacy among children. The project also helps elementary school educators enhance their understanding of engineering concepts and pedagogy through professional development workshops and resources. The EiE project has several formal research endeavors listed on their website as well. This research is focused on the effectiveness of the lessons developed by the project, outcomes of the professional development workshops, and summative findings about students at the end of the lessons related to STEM careers with a focus on engineering. Again, the focus is on understanding content and not the effectiveness of the instructional strategies.

SECONDARY

Standards for Technological Literacy: Content for the Study of Technology (ITEA, 2000) has the potential to change the content of technology education as well the instructional strategies (see Loveland, 2004). Sanders (2001), for example, found there was a fairly even split among the modular approach, the project approach, and a design and technology approach. Brusic and LaPorte (2000) investigated technology education laboratories at the secondary level in Virginia and found that 80% of their modular respondents were at the middle school level. Rodriquez and Schwaller (2003) conducted a survey to determine the relationship between modular technology instruction at the middle school and *Standards for Technological Literacy*. To aid the teacher in this process, the question was asked how much learning is taking place (in their opinion) concerning each *Standard for Technological Literacy* (Rodriquez & Schwaller, 2003).

Dugger (2001) referred to this alignment between learning and the *Standards* as "articulation" and recommended that articulation of instructional approaches be done in a K-12 education setting in a systematic way that aligns curriculum with both optimal and developmentally appropriate instruction. Disciplines such as science are already breaking down their standards into finer grains, known as learning progressions, to insure articulation and reduce redundancy (Reed, 2007).

FOCUSING ON BEST PRACTICES IN INSTRUCTION

The most effective instruction in technology education (or any other discipline) is often referred to as "best practice," which could be described as

the characteristics of outstanding teaching that are highly valued within the profession (Zemelman, Daniels & Hyde, 1998). Frederiksen, Sipusic, Sherin, & Wolfe (1998) further contended that to be highly valued by a profession, best practices must be based on nationally accepted work from that profession, such as national standards. Those standards, and in this case *Standards for Technological Literacy, Content for the Study of Technology* (ITEA, 2000), referred to as *Standards for Technological Literacy*, provide the criteria by which instruction can be judged as effective. While this seems a reasonable approach, it is important to realize that "what is highly valued by the profession" is a moving target: as standards and national curriculum recommendations change, instruction must parallel that change. Therefore, best practice in technology education is constantly changing and can be defined only within the context of a particular period of time. While the unveiling of the *Standards* began a new chapter in technology education instruction, in some ways it is better viewed as a break from tradition rather than a continued evolution. In terms of effective classroom instruction, *Standards for Technological Literacy* will likely require teachers to modify current methodology or devise new strategies altogether (DeMiranda & Folkestad, 2000), and *Standards for Technological Literacy* must become the criteria by which the effectiveness of instruction will be judged. To assist teachers in making these changes, the Technical Foundation of America published *Best Practices in Technology Education: A Collection of 21st Century Best Practices in Technology Education* (Martin & Martin, 2006).

Lindstrom (2003) noted there are many instructional strategies, each of which has the potential for varying levels of success. It is therefore essential to select the optimum instructional strategies to deliver each major technology concept. Although experience in teaching will allow teachers to view instructional variables (i.e. student prior knowledge, student learning styles, laboratory equipment, etc.) and select an appropriate instructional strategy, it is necessary to use some form of assessment to verify the optimization of strategies. In addition to the task of aligning content to instructional strategies, we are constantly reminded that each student brings a unique set of cognitive constructs to a learning situation, and each has a preferred learning style. Thus, while teachers must select an overall instructional approach to align with a concept to be taught, they must also remain flexible, adjusting instruction to meet the individual needs of students to the extent that can be managed. Assessment of instructional strategies may be placed along a continuum from informal (self-assessment) to formal (supervisory assessment). However, one cannot assume that less formal assessments are less valuable. In fact, as in most assessment plans, effective assessments will be frequent, embedded, and varied. Each type of assessment has a specific advantage in contributing to improved instruction and should be considered as part of a comprehensive instructional assessment plan.

As a second option for teacher reflection, Frederiksen, Sipusic, Sherin, and Wolfe (l998) have proposed the use of video portfolios for assessment and have

assembled a framework for this purpose. To apply this method, teachers video tape lessons and while these authors strongly promote a peer group review of the instructional portfolio, their framework would have individual teachers review their own instruction. Seven initial criteria developed for their model in critiquing instruction could easily be adapted to technology education:

a) Actively engaging students.
b) Adapting instruction to students' needs and interests.
c) Making the "big picture" clear.
d) Creating a climate of cooperativeness and helping.
e) Managing time well.
f) Monitoring how students are learning.
g) Making [Technological Literacy] the goal of the class (Lindstrom, 2003, p. 230).

The Third International Mathematics and Science Study (TIMSS) conducted large scale assessment over six years in the late 1990s. Over 1.3 million students in 49 countries were involved using tasks to assess understanding of hands on problem solving abilities in addition to standard paper and pencil tests. Unfortunately, the focus was on mathematics and science and not technological literacy (Petrina, 2007). TIMSS performance analysis also disclosed that most general science textbooks in the U.S. touch on many topics rather than probing any one topic in depth. The five most emphasized topics in 4th grade science texts accounted for 25 percent of total pages compared to an international average in the 70-75 percent range. General mathematics textbooks in the U.S. contained an average of 36 different topics; texts in Japan covered 8 topics, in Germany, 4-5. In middle school (grades 5-8), while the world proceeds to teach algebra and geometry, the U.S. continued to teach arithmetic. All high-performing countries showed student gains between grades 3 and 4, and again between grades 7 and 8 but the U.S. did not. The National Science Board (NSB) believed this reflected a muddled, unfocused, repetitious, and superficial curriculum.

What we have learned about mathematics and science teachers is dismaying. While most teachers embrace a vision of high standards for all students, cooperative learning (in small groups), and the use of technology (computers and calculators), their instructional strategies fall short of the vision. Many teachers lack support to plan and deliver quality instruction: 1 in 2 teachers felt inadequately prepared to integrate computers into instruction, and 2 in 5 felt inadequately prepared to use math or science textbooks as a resource rather than as the primary instructional tool, or to use performance-based assessments. Fewer than 1 in 3 teachers felt prepared to teach life science, and only 1 in 10 felt prepared for the physical science course they were teaching. In addition, more than a third of elementary teachers and more than half of high school mathematics and science teachers in 1993 felt unprepared to involve parents in the education of their children (National Science Board, 1999)!

Thus, in addition to teacher preparation, we have the continuing challenge of

professional development whereby school districts update the knowledge, skills, and strategies that teachers bring into the classroom. No professional is equipped to practice without ever receiving additional training (i.e., be an inexhaustible "vein of gold"). We cannot expect world-class student learning of mathematics and science if U.S. teachers lack the confidence, enthusiasm, and knowledge to deliver world-class instruction (National Science Board, 1999).

Intensive and rigorous professional development, with follow-up procedures, can overcome flaws in content and pedagogical training. Recently, a decade-long study clearly established the links among professional development, changes in teaching practice, and improved student achievement in California. However, school districts should not be left to shoulder the burden of training that undergraduate education failed to deliver. This becomes an expensive form of compensatory teacher education and a diversion of scarce resources that could be used for much-needed merit-based salary increases for teachers, the purchase of new materials and classroom equipment, and ongoing professional development (National Science Board, 1999).

POST-SECONDARY LEVELS

Research conducted in several areas supports the value of scaffolded instructional innovation. Scaffolding instruction is "the systematic sequencing of prompted content, materials, tasks, and teacher and peer support to optimize learning" (Dickson, Chard, & Simmons, 1993, p. 12). First, studies of teachers' beliefs point out that the relationship between pedagogical beliefs and practices is not unidirectional (Thompson, 1992). That is, while teachers' beliefs clearly inform their practices, we might also expect "alternative practices" to challenge their existing beliefs. This change is especially apparent when teachers observe their own students demonstrating a higher level of learning and thinking in non-traditional instruction than they did in traditional instruction.

The importance of scaffolded field experiences is also emphasized in Simon's (1994) learning cycles model of teacher development. Simon identified the planning and implementation of innovative instruction as a possible catalyst for the fifth and sixth stages of a teacher's learning cycle. At the same time, putting novel instructional techniques into practice presents a considerable challenge for most teachers, and many may fail in their first attempts unless they are supported appropriately. Some initial scaffolded practice is indeed recognized as a key component in the model developed by Collins, Brown, and Newman, (1989) to shed light on the process of learning complex tasks.

While it is difficult to evaluate the effect of scaffolded field experiences alone, many successful professional development programs have used this strategy extensively. For example, the changes in teachers' beliefs and instructional practices reported by Simon and Schifter (1991), Schifter and Fosnot (1993), and Borasi, Fonzi, Smith, and Rose (1999), document the success of combining experiences-as-learners with scaffolded field experiences. Furthermore, the latter

two studies include case studies and anecdotal evidence that point to the specific contributions of scaffolded field experiences.

Indirect evidence in support of scaffolded field experiences is found in the positive outcomes reported by projects that implemented some of the NSF-funded comprehensive curricula. These projects showed long-term gains in student achievement, especially when high-quality professional development helped teachers use these exemplary instructional materials appropriately (National Science Board, 1999).

SUMMARY OF REVIEW

While there has been an increase in the research conducted around instructional strategies, most of it has been outside of technology education. The following summary highlights what research exists and what still needs to be done with regard to instructional strategies.

STRENGTHS

Research tells us that teachers can make a tremendous difference in student achievement. The effectiveness of the teacher is the number one factor in determining student achievement (Danielson, 1996). As a result, many education reform efforts, including the No Child Left Behind Act of 2001, have focused on improving the quality of teachers.

McREL (2000) researchers noted that one key trait of effective teachers is their use of instructional strategies that work. Through a meta-analysis of more than 30 years of research on classroom instruction on student achievement, nine categories of instructional strategies were identified that have a high probability of improving student achievement and are listed in Table 1. The table includes connections of the categories to the instructional strategies identified by technology education researchers.

Table 1: Instructional practices associated with higher levels of student achievement (McREL, 2000)

Category	Definition
Identifying similarities & differences	Helping students compare, classify, and create metaphors and analogies
Summarizing & note taking	Helping students analyze, sift through, and synthesize information in order to decide which new information is most important to record and remember
Reinforcing effort & providing recognition	Teaching students about the role that effort can play in enhancing achievement and recognizing students for working toward an identified level of performance (see Nagel, 2003).
Homework & practice	Providing students with opportunities to learn new information and skills and to practice skills they have recently learned
Nonlinguistic representations	Helping students generate nonlinguistic representations of information, including graphic organizers, pictures and pictographs, mental pictures, concrete representations, and kinesthetic activity (see Westberry, 2003).
Cooperative learning	Creating opportunities for students to develop positive interdependence, face-to-face interaction, individual and group accountability, interpersonal and small group skills and group processing (see Reeve & Shumway, 2003 and Henak 1988).
Setting goals & providing feedback	Helping students set their own learning goals in order to establish direction and providing students with timely feedback about their progress
Generating & testing hypotheses	Helping students generate and test hypotheses through a variety of tasks, through systems-analysis, problem-solving, historical investigation, invention, experimental inquiry, and decision-making (see Reed, 2003).
Activating prior knowledge	Helping students retrieve what they already know about a topic

It's important to note, however, that these strategies are designed to be used at different times, in different contexts, and to address different learning objectives. Simply put, no instructional strategy works equally well in all situations.

Finally, it's important to bear in mind that while McREL (1998) researchers have attributed 13 percent of the variance in student achievement to teachers, classroom management and curriculum design are also significant factors.

WEAKNESSES

There are many great things happening in classrooms around the country related to activities that develop technological literacy including courses specifically in technology education as well as programs such as Project Lead the Way, STEM-based curricula, applied mathematics, and applied engineering. The weakness of the profession is a comprehensive system to document what is going on as well as an almost a complete absence of research on the effectiveness of instructional strategies. Cajas (2000) noted, "It is our responsibility to present a common argument to bring technology to the classroom. Such an argument demands that we clarify what we are trying to achieve....Without such a consensus, research in technology education and the efforts to bring technology into the school curriculum will remain an incoherent, fragmented, and ultimately ineffective endeavor" (p. 68).

AREAS OF NEED

The foregoing logically leads to a strong rationale for a research agenda for the profession. This is consistent with the CTTE strategic plan which has as one of the strategic priorities, "Research and Scholarship: CTTE will develop a research agenda to serve as a foundation for curriculum, program, and professional development as well as assessment through research and scholarship" (Council on Technology Teacher Education, 2004, p. 2). By clearly identifying the areas of needed research, a variety of teachers at different grade levels and types of school settings could conduct studies that support a common research agenda. The results could provide essential findings for the profession. Day and Schwaller (2007) identified 10 principles of program assessment that could provide a structure for both student assessment and research on program effectiveness. Through formative assessment, changes could be made by the instruction to better meet the needs of the learners as the instruction was occurring rather than as an afterthought. It is critically important that instructional strategies be assessed concurrently with the assessment of student learning.

RECOMMENDATIONS

There needs to be greater involvement in research by teachers of technology at all levels. Teachers, teacher educators, and independent researchers must join together to conduct essential research. The model of research being done exclusively by professors in the field must be changed. The profession continues to promote the importance of the discipline and the effectiveness of the teaching strategies, but rarely are quality data used to support the claims. Though the claims made about the importance of the discipline may be valid, there is simply a dearth of data to substantiate them. With this in mind, three recommendations for further research to support the field seem defensible:

1. The profession should establish research priorities for teachers. Additionally, teacher educators need to mentor teachers in the conduct of action research.
2. A systematic reporting system for research in technology education needs to be developed. Reed (2003b) has tracked graduate research back to 1892 but a comprehensive effort needs to be established and maintained.
3. The funds to support research need to be dramatically increased. The means by which teachers and teacher educators can reduce their ongoing workload to conduct research needs to be established. Moreover, consistency in the availability of funding needs to be increased so that the research agenda can be advanced regardless of the changing winds of external funding agencies.

CONCLUSION

Kemp and Schwaller (1988) noted in the summary of the yearbook on instructional strategies:

> Any developing discipline needs strong research to support it. In the field of technology education much work remains to be done in instructional strategies….A second area that requires more research in instructional strategies is disseminating ideas, methods, devices, etc. that have been worked in the secondary classroom… A third area that will require additional research is pre-service education… Research is needed to identify ways to update college methods of teaching courses which show pre-service technology education students how to use improved instructional strategies (p.207).

In reflecting back on the words from this 1988 yearbook and reviewing the research on technology education and instructional strategies, one would conclude that there has been work done, but there is still much more work to do. The second yearbook on instructional strategies by Helgeson and Schwaller (2003) included the following conclusions on the need for research on instructional strategies:

> Research needs to be continued on many fronts in the field of instructional strategies. The editors of this yearbook encourage continued research in the area of instructional strategies. A sampling of suggested topics by future technology teachers may include:
> * Best teaching practices,
> * New models of learning theory,
> * New models for conceptual learning,
> * Innovative methods of making the technology education classroom more interdisciplinary,
> * Improved models showing success in modular environments,
> * Innovative methods to include problem solving and inquiry in

the classroom,
- New models for cooperative learning,
- Improved methods to bring social and cultural impacts of technology into the classroom,
- Motivation in the technology education classroom as related to all instructional strategies,
- Success of instructional strategies in terms of learning, retention, and future use,
- The success of new and innovative instructional strategies not covered in this yearbook (p.235).

As John Goodland (1996) indicated through his work at the National Network for Educational Renewal, we cannot have good schools without good teachers and we cannot have good teachers without good schools. There is a need for the whole system to work together to improve and determine what is best for education. Research and assessment are the key to this improvement. This will require an understanding of the research base underlying instructional strategies and how those strategies are best applied relative to the diversity of students, classes, courses, and schools that exist. There is a long history of research in education, but it has primarily been focused on learning theory rather than the effectiveness of different instructional strategies. Changing the focus will be no easy task, but it is critically important for technology educators and those in other disciplines to embark upon in order to better assure student success.

REFERENCES

Borasi, R., Fonzi, J., Smith, C., & Rose, B. (1999). Beginning the Process of Rethinking Mathematics Instruction: A Professional Development Program. *Journal of Mathematics Teacher Education*, *2*, 49–78.

Bredekamp, S., Knuth, R.A., Kunesh, L.G. & Shulmann, D.D. (1992).*What does research say about early childhood education?* Oak Brook, IL: NCREL.

Brusic, S. & LaPorte, J. (2000). The status of modular technology education in Virginia. *Journal of Industrial Teacher Education*, *38*(1), 5-28.

Cajas, F. (2000). Technology education research: Potential directions. *Journal of Technology Education*, *11*(2), 75-85.

Collins, A., Brown, J.S. & Newman, S.E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics. In L. B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Erlbaum.

Council on Technology Teacher Education (CTTE). (2004). Strategic Plan for CTTE. Retrieved March 7, 2010 from http://www.teched.vt.edu:16080/ctte/ImagesPDFs/StrategicPlan.pdf.

Danielson, C. (1996). *Enhancing professional practice: A framework for teaching.* Alexandria, VA: Association for Supervision and Curriculum Development.

Day, G. & Schwaller, A. (2007). Assessment of teachers and programs. In M. Hoepfl & M. Lindstrom (Eds.). *Assessment of Technology Education.* Mission Hills, CA: Glencoe Publishing Company.

DeMiranda, M. & Folkestad, J. (2000) Linking Cognitive Science Theory and Technology Education Practice: A Powerful Connection Not Fully Realized. In, Howell, R. (Ed). *Journal of Industrial Teacher Education*, *37*(4).

Dickson, S. V., Chard, D. J., & Simmons, D. C. (1993). An integrated reading/ writing curriculum: A focus on scaffolding. *LD Forum*, *18*(4), 12-16.

Dugger, W. (2001). Phase III Technology for All Americans Project: Creating assessment, professional development, and program standards for technological literacy. *The Technology Teacher, 60*(4), 27-31.

Eaker, R., DuFour, R., & DuFour, R. (2002). *Getting Started: Reculturing Schools to Become Professional Learning Communities*. Bloominton, IN: National Educational Service

Frederiksen, J. R., Sipusic, M., Sherin, M., and Wolfe, E. (1998). Video portfolio assessment: Creating a framework for viewing the functions of teaching. *Educational Assessment*, *5*(4), 225-297.

Goerdt, S. (2009). NSF Grant Proposal, St. Cloud State University.

Goodlad, J. (1996). *A place called school*. Mission Hills, CA: Glencoe/McGraw-Hill

Helgeson, K. & Schwaller, A. (Eds.). (2003*). Instructional strategies for technology education.* Mission Hills, CA: Glencoe Publishing Company.

Henak. (1988). Cooperative interaction techniques. In W. Kemp & A. E. Schwaller (Eds.). (1988). *Instructional strategies for technology education.* Mission Hills, CA: Glencoe Publishing Company.

International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Johnson, S. D. & Daugherty, J. (2008). Quality and characteristics of recent research in technology education. *Journal of Technology Education*, *20*(1), 18-33

Kemp, W. & Schwaller, A.E. (Eds.). (1988). *Instructional strategies for technology education.* Mission Hills, CA: Glencoe Publishing Company.

Kunznia, S. (2009). NSF Grant Proposal, St. Cloud State University.

Lauda, D. (1988). Forward. In Kemp, W. & Schwaller, A.E. (Eds.), *Instructional strategies for technology education.* Mission Hills, CA: Glencoe Publishing Company.

Lindstrom, M. (2003). Assessment in Technology Education. In K. Helgeson & A. E. Schwaller (Eds.), *Instructional strategies for technology education*. Mission Hills, CA: Glencoe Publishing Company.

Loveland, T. (2004). Technology education content standards implementation in Florida. *Journal of Technology Education, 16*(1), 40-54.

Mallory,B.L. (1994). Social Constructivist Theory and Principles of Inclusion: Challenges for Early Childhood Special Education. *The Journal of Special Education*, *28*(3), 322-337. DOI: 10.1177/002246699402800307

Martin, G. E. & Martin, C. E. (2006). Best practices in technology education: A collection of 21st century best practices in technology education. Retrieved January 18, 2010 from http://teched.vt.edu:16080/ctte/ImagesPDFs/BestPracticesInTE.pdf

McREL, (1998). *A Theory-Based Meta-Analysis of Research on Instruction*. http://www.mcrel.org/topics/Instruction/products/110/ (Accessed July 1, 2009).

McREL, (2000). *What Works in Classroom Instruction*. http://www.mcrel.org/topics/Instruction/products/110/ (Accessed July1, 2009).

Nagel, (2003). Student competitions in technology education. In Helgeson, K. & Schwaller, A. (Eds.), *Instructional strategies for technology education*. Mission Hills, CA: Glencoe Publishing Company.

National Science Board (1999). *Environmental Science and Engineering for the 21st Century: The Role of the National Science Foundation* http://www.nsf.gov/nsb/committees/archive/tfe_cmte.jsp (Accessed June 15, 2009).

National Staff Development Council. (2001). *National Staff Development Council's standards for staff development, revised: Advancing student learning through staff development*. Oxford, OH: Author.

Petrina, S. (2007). Developing a large-scale assessment of technological literacy. In M. Hoepfl & M. Lindstrom (Eds.), *Assessment of Technology Education*. Mission Hills, CA: Glencoe

Prensky, M. (2001). Do They Really Think Differently? *On the Horizon*, 9 (6). Lincoln: NCB University Press.

Reed, P. A. (2003a). Inquiry in technology education. In K. Helgeson & A. E. Schwaller (Eds.), *Instructional strategies for technology education*. Mission Hills, CA: Glencoe Publishing Company.

Reed, P. A. (Editor). (2003b). *Council on Technology Teacher Education Monograph #17. The technology education graduate research database: 1892-2000*. Reston, VA: Council on Technology Teacher Education; An affiliate council of the International Technology Education Association.

Reed, P. A. (2007). The journey towards technological literacy for all in the United States: Are we there yet? *The Technology Teacher, 67*(3), 15-22.

Reeve, E & Shumway, S. (2003). Cooperative Learning in Technology Education In K. Helgeson & A. E. Schwaller (Eds.), *Instructional strategies for technology education*. Mission Hills, CA: Glencoe Publishing Company.

Rodriquez, D. and Schwaller, A. E. (2003). Using modular environments in technology education. In K. Helgeson & A. E. Schwaller (Eds.), *Instructional strategies for technology education*. Mission Hills, CA: Glencoe Publishing Company.

Rogoff, B. (1984). Instruction: Thinking and learning in social context. In B.

Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 1-8). Cambridge: Harvard University Press.

Russell, G. (1997). Hypertextual dichotomies: The evolution of two hypertextual pedagogies in school education. *Journal of Educational Multimedia and Hypermedia*,
6(3-4),394-412.

Sanders, M. (2001). New Paradigm or Old Wine? The status of technology education practice in the United States. *Journal of Technology Education*, *12*(2).

Schifter, D. and Fosnot, C.T. (1993). *Reconstructing mathematics education: Stories of teachers and children meeting the challenge of reform*. New York: Teachers College Press.

Simon, M. A. (1994). Learning mathematics and learning to teach: Learning cycles in mathematics teacher education. *Educational Studies in Mathematics*, *26*, 71-94.

Simon, M. A. & Schifter, D. (1991). Toward a constructivist perspective: An intervention study of mathematics teacher development. *Educational Studies in Mathematics*, *22*, 309-331.

Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. Grouws (Ed.), *Handbook of research on mathematics teaching*
and learning. New York, NY: Macmillan Publishing Company.

Westberry, R. (2003). Design and problem solving in technology education. In K. Helgeson & A. E. Schwaller (Eds.), *Instructional strategies for technology education.* Mission Hills, CA: Glencoe Publishing Company.

Zemelman, S., Daniels, H., & Hyde, A. (1998) *Best practice: New standards for teaching and learning in America's schools*. Portsmouth, NH: Heinemann.

Professional and Student Organizations

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Chapter
5

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INTRODUCTION

Professional and student organizations are often considered to have a strong influence on technology teaching and learning (Betts & Van Dyke, 1989; Starkweather, 2002). Technology education, as a discipline, is privileged to have numerous affiliated professional and student organizations. Professional organizations, like the International Technology Education Association (ITEA), The National Academies, the American Association for the Advancement of Science (AAAS), and the American Society for Engineering Education (ASEE), define and often influence the direction of the discipline through their leadership and research. While student organizations, like the Technology Student Association (TSA) and the Technology Education Collegiate Association (TECA), provide a platform for technology students to display and model the results of their learning as it relates to technology and leadership.

Professional and student organizations are often the voice that communicates across the nation and world. Their messages are documented and influence the profession over time. The professional and student organizations highlighted in this chapter directly impact technology teaching and learning through their work, their influence, and their research. This chapter will highlight historic and contemporary research involving the work of professional and student organizations associated with technology teaching and learning at the primary, elementary, secondary, and post-secondary levels.

The National Academies

The National Academies in the United States were established in 1863 under the direction of President Abraham Lincoln. Academy members are elected by their peers in recognition of their distinguished achievement in areas of scientific and technological endeavor and they perform an unparalleled public service as they address critical national issues and give advice to the federal government and the public. Four organizations comprise the Academies: the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), the Institute of Medicine, and the National Research Council (NRC) (National Academies, ¶

1&2). This section will focus on the research related to technology teaching and learning from the perspectives of the NAE and NRC.

Over the years, the Academies have provided direction for education as they have worked to define and assess technological literacy. Beginning in the mid 1980's, the Academies convened a committee comprised of scholars in education that established an agenda for research in the areas of mathematics, science, and technology education. The committee emphasized the importance of quality learning time devoted to active teaching and learning of relevant skills for the sciences, mathematics, and technology. The committee highlighted four broad categories of needed research related to mathematics, the sciences, and technology education: the development of reasoning, the improvement of instruction, the improvement in the settings for learning, and the development of new learning systems (Committee on Research in Mathematics, Science, and Technology Education, National Research Council, 1985).

A decade later, interest in K-12 educational issues resulted in the NAE and NRC providing input into *Standards for Technological Literacy* (STL) and adopting the term "technological literacy" to describe its activities used to foster a public understanding of technology (Custer & Pearson, 2007). With STL in place, the National Science Foundation (NSF), NAE, and NRC formed the *Committee on Technological Literacy*, which produced *Technically Speaking: Why All Americans Need to Know More about Technology* (National Academy of Engineering & National Research Council, 2002). *Technically Speaking* outlines the characteristics for a technologically literate citizen and defines three dimensions of technological literacy: capabilities, knowledge, and ways of thinking and acting.

The Committee on Understanding the Influence of Standards in K-12 Science, Mathematics, and Technology Education (2002), a subset of the National Research Council, developed a framework that guides the design, conduct, and interpretation of research regarding the influences of MST standards on the education system, on teachers and teaching practice, and student learning. The framework offers four key questions related to inquiry in this area:

> How are the nationally developed standards being received and interpreted? What actions have been taken? What has changed as a result? and Who has been affected and how? The framework developed by this committee views curriculum, teacher professional development and assessment and accountability as the major channels of influence (Committee on Understanding the Influence of Standards in K-12 Science, Mathematics, and Technology Education, 2002, pp 5-6).

In 2006, the National Academy of Engineering and National Research Council realized that not only should technological literacy be defined but it also needed

to be assessed. As a result, the *Committee on Assessing Technological Literacy* was formed and charged to determine the most viable approach or approaches to assess technological literacy in three distinct populations in the United States: K–12 students, K–12 teachers, and out-of-school adults. The *Committee on Assessing Technological Literacy* identified 28 instruments that had been used to assess technological literacy. Many of the instruments were developed in the United States and focused on K-12 students. After reviewing the instruments, the committee concluded that no single instrument existed that adequately assessed technological literacy, although many were thoughtfully designed. The committee considered the assessment of technological literacy to be in its infancy and realized that there was a need to improve assessment practices by modifying existing instruments and developing new approaches. The committee also recommended that assessments should be designed to measure higher order and design-related thinking. *Tech Tally* was the committee's concluding report and details twelve recommendations for assessing technological literacy (Committee on Assessing Technological Literacy, 2006, pp 6-18).

The National Academies have made numerous recommendations related to technology teaching and learning. The recommendations, for the most part, describe what technology education as a discipline should do in order to develop technological literacy, assess technological literacy, and link technology and engineering. The Academies recognize that technological literacy is something in which everyone must have a vested interest and should not be limited to a single field of study. It could be argued that, in essence, the Academies have built a backbone to support technology education while at the same time realizing that technology education is not capable to do the job alone.

There are numerous opportunities for research related to the recommendations made by the Academies. Many of these apply directly to technology teaching and learning. It is important that the Academies continue their endeavors related to technological literacy, teacher preparation, and K-12 education. It is also important that technology education, as a field of study, strives to facilitate research opportunities related to the Academies' recommendations. Universities that prepare technology education teachers need to make a commitment to focus their practice and research endeavors to augment the recommendations of the Academies. Professional organizations, like ITEA and the American Society for Engineering Education (ASEE), need to foster research initiatives related to these issues. Technology teachers and local and state administrators need to renew their commitment and become active participants with professional organizations as the discipline continues to define its role.

American Association for the Advancement of Science (AAAS)

The American Association for the Advancement of Science strives to "advance science, engineering, and innovation throughout the world for the

benefit of all people" (AAAS, 2009a, ¶ 1). AAAS founded Project 2061 in 1985 to propose recommendations for what all students should know and be able to do in science, mathematics, and technology by the time they graduate from high school. AAAS' publication, *Science for All Americans* (SfAA) (1989), laid the groundwork for the nationwide science standards movement of the 1990s and would become the model for the development of content standards for technology education. In 1993, Project 2061 released *Benchmarks for Science Literacy* which translated the science literacy goals in *Science for All Americans* into learning goals or benchmarks for grades K–12. Many state and national standards documents have drawn their science goals and objectives from the *Benchmarks for Science Literacy* (AAAS, 2009b, ¶ 1-2).

AAAS's report *Science for All Americans* (SfAA) included two chapters related directly to what students should know and be able to do in technology. Chapter three in SfAA provides recommendations related to what individuals should know and be able to do related to the nature of technology. It also looks at design and defines the issues in technology, how technological and social systems interact and oppose one another, and how decisions about the use of technology are often very complex (AAAS, 2006a). Chapter eight in SfAA describes what individuals should know and be able to do related to key aspects of technology and major human activities that have shaped our environment and lives by focusing on eight basic technology areas (AAAS, 2006a).

After the release of SfAA, Project 2061 worked to develop the *Benchmarks for Science Literacy* that detailed what all students should know and be able to do in science, mathematics, and technology by the end of grades 2, 5, 8, and 12. The recommendations at each grade level suggest reasonable progress toward the adult science literacy goals laid out in the project's 1989 report *Science for All Americans* (AAAS, 2006a, ¶ 1). *The Benchmarks* help educators decide what to include in (or exclude from) a core curriculum, when to teach it, and why (AAAS, 2006a, ¶ 3). Benchmarks 3 and 8 describe levels of understanding and ability that *all* students are expected to reach on the way to becoming science-literate as they relate to learning technology. Benchmark 3 focuses on the nature of technology and its objectives relate to technology and science, design, and systems and issues in technology. Benchmark 8 focuses on the designed world with objectives that relate to agriculture, materials and manufacturing, energy sources and use, communication, information processing, and health technology.

The AAAS, with the support from the National Science Foundation, hosted two Technology Education Research Conferences. The proceedings from these conferences were published on-line and they specify research that would support the goal of achieving universal technological literacy. The first conference held in December 1999 highlighted the research that is needed to improve students' technological literacy and the central importance of understanding how children learn the technological ideas and skills that were identified for literacy (AAAS, 2006b, ¶ 1). The list that follows was compiled by Fernando Cajas and includes

recommendations generated from presentations and discussions at the First AAAS Technology Education Research Conference that relate to technology teaching and learning:

- Priorities need to be set for what to research, how to do research, and where and when to do research.
- A productive research agenda should be planned around student learning of key technological ideas (concepts) and skills (processes) that are essential for literacy.
- There is a need for research on how well curriculum materials and classroom instruction actually help students learn specific technological concepts and skills.
- General research in science and mathematics education and cognitive research in general can be used as models, but it is important to recognize that the issues in technology are different from those in science and mathematics.
- As research in technology education develops, researchers should look for ways to work on common issues with researchers in science and mathematics education.
- It is important to study how teachers themselves understand—and come to understand—technology.
- Research is needed to determine the most efficient and cost-effective ways to provide professional development for technology educators.
- Educational research methods can vary greatly, e.g., from traditional surveys to design experiments, from multiple-choice questions to in-depth interviews. Case studies would be useful to create an adequate basis for later formal research (Cajas, 2006, ¶ 6 & 7).

The primary goal of the second conference held in April 2001 was to encourage good research on how students learn the ideas and skills identified for technology education and to discuss research priorities and the conditions needed to set a coherent and productive research agenda (AAAS, 2008, ¶ 3 &4). The proceedings from the Second AAAS Technology Education Research Conference outline specific concerns and research agenda items in technology education. Barlax (2001) identified the following areas of investigation in technology teaching and learning as important and open to scrutiny through curriculum development: how to plan a technology curriculum; how to develop and use appropriate pedagogy; how to assess learning and progress in technology education; how to develop creativity, problem solving and designing in technology education; how to introduce new and emerging technologies into the technology curriculum; how to enable the use of learning from other subjects in technology lessons; and how to bring new perspectives into technology education. He also noted that the extent to which technology education contributes to a young person's overall development, particularly their cognitive development, must be determined. Berrett (2001) restated the belief that investigating teaching practices and student learning can

best be done through naturalistic inquiry and qualitative measures, consistent with what many in the profession have argued previously. (Bennett, 1999; Cajas, 2000, 2001; Foster, 1992, 1996; Lewis, 1999; McCormick, 1999; Rowell, 1999; Zuga 1994, 1996). In the proceedings from the Second AAAS Technology Education Research Conference, Householder (2001) provided a long list of research topics and questions generated by this group and Benenson (2001) categorized them into six main categories: outcomes of technology education, methods of finding out what students have learned, assessment and evaluation of best practices, children's conceptions of technology, teacher education methodologies, and outcomes. Finally**,** Pellegrino (2001) outlined an agenda for technology education to work toward in order to understand how people learn about technology. He stated that in order for the research agenda to be orchestrated we must *build*

> … a cumulative knowledge base that supports learning and teaching about technology. This means defining the core knowledge constructs, conducting research on fundamental learning and teaching issues, as well as doing research on current instructional practices. It also means applying How People Learn (National Academies, 2000) to the systematic analysis of your existing educational materials, your teacher education practices, and educational policies influencing technology's role in the P-16 curriculum. A final piece, not to be underestimated, is public understanding of technology as a field, including the extent to which such understanding influences educational practice (Pellegrino, 2001, ¶ 41).

More recently, AAAS partnered with the National School Boards Association (NSBA) to provide support to local school board members as they address issues related to science, mathematics, and technology education. One of the results of this partnership was a website that is designed to help local school districts answer questions related to these three school subjects (see http://www.smartschoolboards.org). SMarT (Science, Mathematics, and Technology Education: Action and Resources for School Districts) includes general information about science, mathematics, and technology education, as well as a list of resources that include model programs, a message board for users to share their thoughts with other users, and a training program to help school districts and board members become more familiar with current issues affecting science, mathematics, and technology education (AAAS, 2008).

American Society for Engineering Education (ASEE)

Founded in the late 1800's as a nonprofit organization of individuals and institutions committed to furthering education in engineering and engineering technology, the American Society for Engineering Education

(ASEE) now represents an emerging theme found in technology teaching and learning - engineering education. With the creation of the K-12 and Pre-College Engineering Division, as well as the Technological Literacy Interest Group, ASEE has attracted a new breed of members: K-12 technology and engineering teachers and teacher educators. Although this division is still in its infancy, it has already started to play a major role in defining how technology teaching and learning occurs through engineering education. Its website is filled with resources related to teaching engineering and technological literacy at the K-12 level. The division also hosts an annual workshop where presentations are made related to these concepts. Proceedings and research journals can be found on-line through the association's website. ASEE's research related to engineering education is highlighted in chapter eight.

International Technology Education Association (ITEA)

The International Technology Education Association has focused research on public perceptions related to technological literacy, instructional materials development, defining technological literacy, and creating standards for the discipline. The *Standards for Technological Literacy* (STL) (ITEA, 2000) has served as an integral catalyst for dissertation studies, articles, and instructional materials development projects. ITEA's platform statements and collaborations have ignited interest in many areas of research related to technology teaching and learning at the K-12 level. Finally, ITEA's curriculum endeavors have defined and influenced local, state, national and international curriculum projects.

According to STL project director William Dugger, "our profession created its first set of standards in 1981, *Standards for Industrial Arts Programs*. It was made possible through a grant from the U.S. Department of Education. They were later revised to reflect a more contemporary focus in 1985 as *Standards for Technology Education Programs*. A later revision in 1988 was funded by the Technical Foundation of America (TFA) and distributed by ITEA" (Dugger, nd, pg. 1). ITEA, like many other professional organizations, led the charge to re-envision technology education standards starting in the late 1990's with the Technology for All Americans Project (TfAAP). TfAAP represents more than a decade of research and development related to technology teaching and learning at the K-12 level. TfAAP was administered by ITEA, funded by NSF and NASA, and mirrored AAAS's Science for All Americans Project. TfAAP consisted of three parts: 1) the development of a rationale and structure for the study of technology- *Technology for All Americans: A Rationale and Structure for the Study of Technology* (*R&S*) (ITEA, 1996), 2) the development of standards related to the study of technology - *Standards for Technological Literacy: Content for the Study of Technology* (*STL*) (ITEA, 2000), and 3) the development of standards and guidelines that address student assessment, professional development, and program enhancement - *Advancing Excellence in Technological Literacy: Student*

Assessment, Professional Development, and Program Standards (*AETL*) (ITEA, 2003).

Research related to the TfAAP has focused primarily around the development of the documents. Each of the TfAAP documents was reviewed by numerous individuals and populations. Specifically, STL was reviewed by thousands of people through focus groups at standards hearings and finally by the general population via the World Wide Web in order to establish consensus (Smith, 1998). Once STL was released in 2000, articles began to appear in *The Technology Teacher* that explained STL's purpose and application. A review of literature identified about a dozen studies related specifically to *Standards for Technological Literacy* (STL), technological literacy, and its companion guide, *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development and Program Standard*. Most of these studies were descriptive in nature. Two of the studies targeted administrators and/or teachers' perceptions of STL and its endorsement (Phillips, 2005; Donan, 2003). Holland (2004) targeted the elementary level gifted and talented students' perceptions of technological literacy outcomes related technology education activities and experiences. One of her findings suggested that both girls and boys demonstrated proficiency in the targeted Technology Content Standards. The researchers were also able to identify key technology features like problem solving, programming, connections to mathematics and science, and teamwork (Holland, 2004).

Taylor (2004) surveyed Technology Student Association (TSA) members at the 2003 TSA National Conference to assess their perception of how preparation for specific TSA competitive events helped them understand concepts found in STL. The majority of respondents agreed that being involved in their selected activity did increase their understanding of what technology is and how technology works. Participants also perceived their involvement in TSA activities increased their understanding of the effects of technology on society and how to solve technology-related problems. Additionally, participants perceived that they increased their understanding of how to use the design process and how to solve technology-related problems as a result of being involved in these selected TSA activities (Taylor, 2004). Each of these areas aligns directly with specific standards in STL.

A result of SfAA and TfAAP, the term technological literacy became associated with technology education. Several studies resulted from the need to define technological literacy and determine if individuals understood technology and were technologically literate. The Gallup Organization conducted a survey for ITEA (2001) on technological literacy in the U.S.

> Three major conclusions were drawn from the
> data in this study: 1) The American public is
> virtually unanimous regarding the development of
> technological literacy as an important goal for people
> at all levels 2) Many Americans view technology as

mostly computers and the Internet 3) There is a total consensus in the public sampled that school should include the study of technology in the curriculum (Rose & Dugger, 2002, pg.7).

A follow-up study was conducted again in 2004 with funding from NASA. The three conclusions drawn in the earlier study are both reinforced and extended by the additional data reported herein. They are repeated and slightly revised in the following: 1) The public understands the importance of technology in our everyday lives and understands and supports the need for maximizing technological literacy. 2) There is a definitional difference in which the public thinks first of computers when technology is mentioned, while experts in the field assign the word a meaning that encompasses almost everything we do in our everyday lives. 3) The public wants and expects the development of technological literacy to be a priority for K-12 schools. 4) Men and women are in general agreement on the importance of being able to understand and use technology and on the need to include technological literacy as part of the schools' curriculum (Rose, Gallup, Dugger, & Starkweather, 2004, pg.11)

Since its development, the survey administered by the Gallup poll has been replicated in various settings. Linkenheimer (2003) used five of the questions from the Gallup poll to survey high school students in a small rural school district located in the northeastern region of the United States. He noted that his school district poll also revealed that there is some confusion about the teaching of technology. Harrison (2009) also used the Gallup poll (Rose, Gallup, Dugger, & Starkweather, 2004) to survey three groups of high school students in North Carolina. He found differences in the way technology education, Project Lead the Way, and general education students perceive technology.

In 2003, the first Gallup Poll (Rose & Dugger, 2002) was also replicated in Hong Kong to compare cultures (Volk & Dugger, 2004). It is interesting to note that the Hong Kong sample had a much broader defnition of technology than the United States sample (Volk & Dugger, 2004). Daugherty (2005) examined the degree to which technology teacher educators support STL and determined whether there is a need and/or support for substantial change in undergraduate technology teacher education. He concluded that most respondents recognized their program's shortcomings but that it was unclear if the programs would address these issues. The findings from the study also suggested that all the respondents agreed that STL are a worthy target for technology teacher education.

Research related to the impact of STL has primarily been centered on descriptive data related to the needs of the teacher or students. Castillo (2007) worked to design and test an assessment instrument to measure eighth-grade student achievement in the study of technology. The instrument measured the impact of instruction in technology education to determine if technology education instruction guided by *Standards for Technological Literacy* enhanced students' technological literacy. The study utilized a two-group post-test only design, a treatment group who had received instruction in technology education in the form of a modular instructional delivery classroom and a control group who had not received any formal education in the study of technology. The study showed that eighth-grade participants taking a technology class performed better on the post-test (Castillo, 2007). There was also a significant difference on the post test when comparing the means of the two groups. As a result, Castillo (2007) suggested that standards-based modular instruction enhanced technological literacy for the students he studied. Scott, Washer, and Wright (2006) worked to identify, develop, and validate the critical biotechnology competencies that should be acquired by first year or initially certified secondary technology education teachers so that they could include STL Standard 15 content in their classrooms. The researchers used a web-based modified Delphi technique to apply the research to and identified 45 critical biotechnology competencies under eight content organizers.

The TfAAP and the ITEA Council of Supervisors conducted a survey in 2000-2001 to determine the status of technology education in the U.S. Forty-seven of the fifty states' supervisors responded and more than half noted having a state framework in place (Newberry, 2001). About 30% of the respondents stated that technology education was a required subject for students. State supervisors also felt that *Standards for Technological Literacy* was a document that provided them with support to continue to make the case that all students need to become technologically literate (Newberry, 2001). A follow-up of the 2001 survey by Newberry and Dugger (2004) noted that the increase in the number of states that include technology education in the state framework may be indicative that the United States is placing increasing importance on technology education.

Loveland (2004) looked at the status of STL implementation in Florida. His study used a correlational research design to look at the relationships between district size, enrollment density, district socioeconomic status, district supervisor length of service, as well as the teacher's participation in professional networks and their self-reported perception of the extent to which *Standards for Technological Literacy* had been implemented within their classrooms. The key findings of the study were that higher district enrollment and school enrollment density were linked to higher levels of perceived implementation of technology education standards in Florida schools. Schools with many technology education teachers increased the likelihood that some of the teachers have been exposed to the standards. A major finding was the challenge of implementing content standards and other educational innovations in smaller sized districts. A recommendation

was made for national educational associations to increase their outreach efforts to small districts through teacher training, local consensus building, and membership incentives (Loveland, 2004).

ITEA membership is often used as the population in many research studies with the rationale that one will find the voice of the discipline through its professional organization's membership. Wright (1991) designed a study at the request of the ITEA Board of Directors to identify reasons why teachers leave the profession and possible solutions. The survey was distributed to state supervisors and to presidents of ITEA affiliated state associations. The survey identified the lack of administrative support as the primary reason for leaving the profession. Recommendations were made for ITEA to help increase teacher satisfaction and retention (Wright, 2001).

Foster and Wright (1996) surveyed ITEA members to investigate the future direction of technology education at the elementary, middle and high school level as perceived by its leaders. Wright and Custer (1998) explored outstanding technology education teachers' attitudes about the rewards and frustrations of teaching. Engstrom (2000) surveyed ITEA's affiliate Council on Technology Teacher Education and a random sample of ITEA's general membership to identify essential and desirable technology education activities. Williams (2001) surveyed 1994-1999 ITEA Teacher Excellence Award recipients to determine effective teacher-leadership practices of outstanding local school technology education teachers in the United States. Warner and Morford (2004) surveyed ITEA Institutional members to investigate the status of design education in pre-service teacher education programs. They suggested that the current status of the study of design in the curriculum content experienced by pre-service technology teachers during their undergraduate studies indicated that the profession was deeply rooted in the narrow technical aspects of the design process.

ITEA also founded the STEM Center for Teaching and Learning (formerly the Center to Advance the Teaching of Technology & Science) in 1998 to strengthen professional development and advance technological literacy. STEM Center initiatives are directed toward four goals: development of standards-based curricula, teacher enhancement, research concerning teaching and learning, and curriculum implementation and diffusion (ITEA, nd). The STEM Center serves as the professional development arm of ITEA (ITEA, nd). Research for the STEM Center is primarily focused around the development of standards-based curricula at this time. Engineering by Design (EbD) is the standards-based program developed by ITEA through the STEM Center. EbD utilizes a network of teachers (EbD Network) to conduct action research based on student learning. The STEM Center has just started collecting data related to technology teaching and learning over the last few years from its EbD Network through a pre-test, design project, post-test assessment system. Currently, the EbD Network represents approximately twenty states across the United States.

ITEA's role in research is crucial to the field of technology education because

it is the voice of the field. In the last ten years, even though membership has dropped, the profession has developed standards, surveyed the U.S. public about their perception of technology multiple times, and started developing a standards-based model program for technology education that is currently utilized by twenty states. It is imperative for ITEA to continue to validate effective technology teaching and learning practices.

Technology Education Collegiate Association (TECA)

The Technology Education Collegiate Association (TECA) is a sponsored program of the International Technology Education Association. Its purpose is to promote leadership, fellowship, scholarship, and a philosophical foundation for future technology teachers, through college chapter coordinated activities at the campus, state, regional, and international level (TECA, 2006, ¶ 1).

For many pre-service technology education teachers, TECA is one of their first chances to learn about and experience teaching technology. Linnell (2005, 2007) described how TECA's elementary design problems are a good way to encourage standards-based learning and provide valuable learning experiences for the participants. Klenke (2007) described how TECA students can work with other program areas to raise funds to support the TECA chapter initiatives. Support for TECA and the belief in its benefits has been described over the years (Havice, 2001; Litowitz, 1995), however formal published research related to how TECA specifically supports technology teaching and learning is virtually non-existent. Litowitz stated, "Student associations like TECA help students develop their leadership abilities, professionalism, and competitiveness. They also contribute to program recruitment, curricular innovation, and personal satisfaction" (1995, p. 24). Havice and Lovedahl (2000) claimed "new teachers who participate in ITEA/TECA as an undergraduate are more likely to sponsor TSA chapters, be successful in teaching, and remain in the teaching profession" (2000, p. 72). More recently Seymour identified five points related to the role of TECA's competitive events in technology teacher education programs. He stated that competitive events motivate students, learn new content/concepts, promote professionalism, gain program recognition and have a social/recreational emphasis (Seymour, 2007). These statements by professionals in the field have very powerful implications for technology teaching and learning. However there is no formal research to support them.

One research study involved TECA members who attended the 2001 TECA Midwest Regional Conference in Peoria, Illinois (Gray & Daugherty, 2004). The study noted that most of the TECA members surveyed felt that maintaining a good rapport with their high school technology teacher encouraged them the most to pursue technology education as a career. Additionally, forty-two percent of

respondents stated that their high school technology teacher encouraged them to pursue a career in technology education. Another finding was that there are many varied perceptions about the effectiveness of recruitment techniques between students on the one hand and TECA advisors on the other. The study suggested that high school technology teachers have much greater potential to recruit future technology teachers than is realized. The students and faculty advisors agreed that using current majors to recruit is an effective technique, but is significantly underutilized by the profession (Gray & Daugherty, 2004).

In 2002, a Technology Education Research Symposium was held for the Midwest Technology Teacher Education Programs. The purpose of the symposium was to encourage guided research and the teaching of educational research concepts and techniques in order to sustain the growth of the profession. The symposium directors believed that the profession must develop researchers. The population of students for the symposium consisted of students who showed promise and interest in doing research and were from technology teacher education programs in the Midwest with TECA chapters. Over the course of three days, the participants learned about why research is important to the profession and their career, the status of technology education, potential research areas, and the relationship of *Standards for Technological Literacy* to research. These students used the knowledge they gained to identify areas of potential research for the profession and then replicated the symposium at the universities at which they were students (Merrill & et al., 2006).

TECA's annual conferences at the regional and national levels provide wonderful opportunities for participants to assess technology teaching and learning at the collegiate level. Researchers can also look at how these future teachers will use the cognitive, leadership, and team building strategies developed through TECA in their future professional endeavors. Finally, researchers can assess the role of the faculty advisor(s) in teaching and learning about technology.

Technology Student Association (TSA)

The Technology Student Association (TSA) is one of ten Career and Technical Student Organizations (CTSOs) recognized by the United States Department of Education (Scott, 2001). TSA is the only student organization dedicated exclusively to students enrolled in technology education classes, grades K-12. TSA serves more than 150,000 K-12 students in 2,000 schools in 47 states nationwide. The majority of TSA's membership consists of middle and high school students (TSA, 2009a). The Technology Student Association fosters personal growth, leadership, and opportunities in technology, innovation, design, and engineering. Members apply and integrate science, technology, engineering and mathematics concepts through co-curricular activities, competitive events, and related programs (TSA, 2009b). In his study of the status of technology education, Sanders (2001) noted that participation in student organizations was on the rise compared to the previous four decades. He noted that program participation in the TSA had increased by

about 4 percent from 1979 to 1999 (Sanders, 2001).

Determining how student organizations like TSA affect technology teaching and learning should be a primary goal for the technology education profession. Research related to this primary student organization is limited. Nonetheless, research related to TSA provides some of the most recent data related to learning about technology. Mitts (2008) found that gender preferences determined the activities in which students participated at the 2005 and 2006 North Carolina TSA State Conference. Mitts noted that males preferred activities where an artifact was created while females preferred activities that tended to have social significance. Blue (2006) used four of the TECH-know Project units to investigate the effects of standards-based education on a purposeful sample of technology education students. Findings from the study provided positive results in regard to student achievement in science, mathematics, and technology content. The study also found that the TECH-know instructional materials as well as the gender and grade level were significant variables relative to student gains in knowledge of technology, mathematics, and science content. Blue (2006) also used descriptive statistical methods to summarize data collected on student access to communication technologies outside the classroom. One finding was that access to certain communication technologies had a significant influence on specific student achievement between the pretest and posttest (Blue, 2006).

The TECH-know project was developed from 2001- 2007 and created standards-based materials related to TSA and twenty of its competitive events. TECH-know not only developed twenty standards-based instructional units related to TSA competitive events but also studied the project's impact on what students learn in the technology classroom and through TSA activities. Ernst, Taylor, and Peterson, (2005) stated that the students who participated in the TECH-know project showed significant gains in pre and post test assessments related to mathematics, science, and technology concepts. They also found that many students commented in their reflections that they had developed skills like problem solving, teamwork, and a desire to do their best (Ernst, Taylor, & Peterson, 2005).

In 2006, the Technology Student Association hosted a two-day symposium titled *Strengthening STEM Education Through The Use of Standards-Based Assessments for Robotics Competitions* at Georgetown University in Washington, DC. The event was funded by the National Science Foundation (NSF). TSA was the first and only career and technical student organization (CTSO) thus far to host an NSF-funded symposium related to STEM. Nearly 50 roboticists, STEM experts, and teacher educators worked to identify STEM concepts and objectives that should be addressed in a robotics curriculum and develop a robotics assessment rubric that can be incorporated into competitive event activities and instruction in the high school classroom (TSA, 2006). The assessment rubric that was developed addressed technology and engineering concepts as defined by *Standards for Technological Literacy*, as well as national science, mathematics,

and States' Career Cluster STEM standards (States Career Clusters Initiative, 2010).

Another related study found that Career and Technical Education (CTE) students, including those in technology education, involved in related student organizations started out and ended up the school year with higher levels of academic engagement, civic engagement, career self-efficacy, and employability skills than those not involved. CTE students with CTSOs also reported higher levels of participation in extracurricular activities, work, and volunteering than their CTE only and general education counterparts (Alfeld, Stone, Aragon, Hansen, Zirkle, Connors, et al., 2007).

Haynie, Deluca, and Matthews (2005) replicated their 1991 study at the 2003 TSA National Conference to find out TSA advisors' perceptions concerning characteristics of technology education programs with a TSA component and the relationship between participation in co-curricular organizations and the teaching methods technology teachers used. The use of computers and computer-based activities were evident among both teachers and students. While some teaching strategies remained the same as they were in the 1991 study, the 2003 study found that the use of problem solving activities was the preferred teaching strategy compared to the use of demonstrations in the 1989 study (Haynie, Deluca & Matthews, 2005).

Taylor (2004) assessed the perceptions of participants at the 2003 TSA National Conference on how twenty selected TSA activities affected their technological literacy. Skill development, motivation, effect on academic areas, and future career implications were also assessed. The participants perceived that the selected TSA activities do affect technological literacy in regard to what technology is, how technology works, the effects of technology on society, how to solve a technology-related problem, how to use the design process, and the technological subsystems related to the individual TSA activity. In regard to skill development, Taylor's findings suggest that the participants involved in the selected TSA activities perceive the activities as contributing to their skill development in the following areas: problem solving, working with a team, use of leadership skills, ability to use science, ability to use math, ability to learn more about technology, hands-on skill development, working with rules and specifications, communication skills, ability to design, and the ability to be creative. Taylor's (2004) findings also suggest that involvement in these selected TSA activities can have positive implications in other areas of the student's life and education, including the facilitation of learning in mathematics, science, and/or technology classes, future career choices, and motivation to do their best work.

Busby (1999) compared quality indicators, as defined by Clark (1997), of technology education programs in North Carolina among low performing and high performing schools. Student involvement in the Technology Student Association was the only quality indicator for which there was a significant difference between the two school classifications. This difference suggests that involvement in

TSA has a significant impact on quality.

Trainer (1996) researched the potential of the National Technology Student Association Curricular Activities to promote creative problem solving and critical thinking skills. Her study concluded that all four TSA Activities selected for the study were identified as promoting thinking skills.

Territo (1993) studied the use of activities intended to improve communication skills in all 293 of Louisiana's technology education programs. The study suggested that sponsoring Technology Student Association chapters and utilizing TSA guidelines for competitive events represents the most fruitful actions which can be undertaken by technology education teachers to increase the utilization of communication skills activities in their classes.

Deluca and Haynie (1991) studied the perceptions and practices of TSA advisors as related to how they implemented TSA in the curriculum and their teaching practices. Their research suggests that the co-curricular approach altered the characteristics of the technology education program. Teachers implementing the co-curricular approach used short lectures more frequently and incorporated seminar, role-play, and lab experiments more frequently. "Correlation analysis showed that these items were associated with small group discussion, class discussion, and discovery method among others" (Deluca & Haynie, 1991, pg. 13).

TSA has provided a population of interest in research related to technology teaching and learning for almost thirty years. Research opportunities related to TSA are plentiful; however in order to strengthen TSA's presence in research, initiatives related to the role of competitive events and participation in student organizations must be supported. In addition, research on the impact of student involvement in TSA relative to STEM related career choices must be brought to the forefront. Weber and Custer (2005) also recommended that the extensive use of student competitions should be examined in more depth by the profession. They note that while the findings of their research support competitions by females, this contradicts previous research. Finally, Haynie, Deluca, and Matthews (2005) recommended that future investigations should compare TSA enhanced programs to programs without TSA, focusing on differences in instructional approaches.

Conclusions and Chapter Summary

Over the decades, many professional and student organizations have laid the groundwork for research related to technology teaching and learning. While much of the research reported is descriptive in nature and limited in scope, it does highlight the contributions of professional and student organizations. Hopefully, scholars will move forward in pursuing the research opportunities presented by these organizations.

References

Alfeld, C., Stone, J. R., Aragon, S. R., Hansen, D. M., Zirkle, C., Connors, J., Spindler, M., Romine, R. S., and Woo, H. (2007). Looking inside the black box: The value added by Career and Technical Student Organizations to students' high school experience. St. Paul, MN: National Research Center for Career and Technical Education. Retrieved on May 20, 2009 from http://136.165.122.102/mambo/index.php?option=com_ content&task=view&id=172

American Association for the Advancement of Science (2009a). About AAAS. Retrieved May 14, 2009 from http://www.aaas.org/aboutaaas/.

American Association for the Advancement of Science (2009b). About Project 2061. Retrieved May 14, 2009 from http://www.project2061.org/about/ default.htm.

American Association for the Advancement of Science (2006a). Benchmarks for Science Literacy. Retrieved May 14, 2009 from http://www.project2061. org/publications/bsl/default.htm.

American Association for the Advancement of Science (2006b). Programs. Retrieved May 14, 2009 from http://www.project2061.org/events/meetings/ technology/default.htm.

American Association for the Advancement of Science (2008a). About SMarT. Retrieved May 14, 2009 from http://www.smartschoolboards.org/Pages/ AboutSmart.aspx.

Bennett, D. T. (1999). Themes in technology education research. *Proceedings of the AAAS technology education research conference*. Retrieved on May 14, 2009 from http://www.project2061.org/meetings/technology/papers/ Bennett.htm

Blue, C. N. (2006). The effects of standards-based communication technology education units on the achievement of selected standards for technological literacy by middle and high school students in technology. Unpublished Doctoral Dissertation, North Carolina State University, Raleigh, NC.

Busby, J. (1999). Measuring Clark's quality characteristics for technology education for a relationship with student achievement. Unpublished Doctoral Dissertation, North Carolina State University, Raleigh, North Carolina.

Cajas, Fernando (2000a) Research in Technology Education: What Are We Researching? A Response to Theodore Lewis. [Electronic version]. *Journal of Technology Education*, *11*(2). 61-69.

Cajas, F. (2000b). Technology education research: potential directions. [Electronic version]. *Journal of Technology Education, 12*(1), 75-85.

Cajas, F. (2006). Proceedings of the AAAS technology education research conference. Retrieved on May 14, 2009 from http://www.project2061.org/ meetings/technology/Overview.htm

Camp, W. G., Jackson, R. S., Buser, B. R., & Baldwin, E. T. (2000). *Vocational student organizations and student achievement*. Berkley, CA: National Center for Research in Vocational Education (MDS-1317).

Clark, A. C. (1997). Identification of quality characteristics for technology education programs in North Carolina. Unpublished Doctoral Dissertation, North Carolina State University, Raleigh, NC.

Committee on Research in Mathematics, Science, and Technology Education, National Research Council (1985). *Mathematics, science and technology education: A research agenda*. Washington DC: National Academy Press.

Committee on Technological Literacy; National Academy of Engineering; National Research Council (2002). Recommendations. In G. Pearson and A. T. Young, Eds. *Technically Speaking* (pp. 103-114) Washington DC: National Academies Press.

Custer and Pearson (2007) Assessing technological literacy: a national academies perspective. In Hoepfl, M. & M. Lindstorm (eds*). Assessment of Technology Education.* 56th Yearbook of the Council on Technology Teacher Education. Woodland Hills, CA: Glencoe/ McGraw Hill Publishing.

Dailey, D.W. (1996, August) TSA Conference-technology academics, and leadership. *Tech Directions*, *56* (1), 10-11.

Daugherty, Michael (2005) A changing role for technology teacher education. *Journal of Industrial Teacher Education*, *42*(1), 41-58.

Deluca, W.V., & Haynie, W. J. (1991). Perceptions and practices of technology student association advisors on implementation strategies and teaching methods. *Journal of Technology Education, 3*(1), 4-15.

Dugger, W. (nd) *A historical perspective of ITEA's Technology for All Americans Project.* Retrieved on March 12, 2009 from http://www.iteaconnect.org/TAA/History/TAA_History.html.

Ernst, J., Shown, T. & G. Kane (2008) State supervisor's report: status of technology education within the United States. *A report presented at ITEA National Conference in Salt Lake City, UT*. February 26-28, 2008.

Ernst, J. V., Taylor, J. S., and R. E. Peterson (2005) TECH-know: Integrating engaging activities through standards-based learning. *The Technology Teacher*. *65*(2), 15-18.

Fitzgerald, M. (2008) Communicating membership matters: a report on the status of affiliate membership and communication in the United States*, The Technology Teacher electronic*; Retrieved from on March 12, 2009 http://www.iteaconnect.org/mbrsonly/Library/TTT/TTTe/10-08fitzgerald.pdf.

Foster, Patrick and Wright, M. (1996) Selected leaders' perceptions of approaches to technology education [Electronic Version]. *Journal of Technology Education. 7*(2), 13-27.

Foster, T. W. (1992). Topics and methods of recent graduate student research in industrial education and related fields. *Journal of Industrial Teacher Education, 30(1),* 59-72.

Foster, T. W. (1996) A Research Agenda for Technology Education. Research Brief. *Technology Teacher, 56*(1), 31-33.

Gray, Michael and Daugherty, Michael (2004) Factors that influence students to enroll in technology education programs [Electronic Version]. *Journal of Technology Education, 15*(2), 5-19.

Greer, William David (1991) *Industrial arts to technology education: a movement in secondary public schools.* Unpublished Doctoral Dissertation. East Texas State University.

Harris T. & Sweet, G. (1981). Why we believe in vocational student organizations. *Vocational Education*, 56(3), 33-35.

Harrison, H. L. (2009). Comparing High School Students' and Adults' Perceptions Of Technological Literacy. Un-published doctoral dissertation, Old Dominion University, Norfolk, Virginia.

Havice, William. (2001) ITEA/TECA membership: what's in it for me? *The Technology Teacher, 60*(8), 27-28.

Havice, W.L. & Lovedahl, G. G. (2000). Igniting the passion through TECA. In Martin, G. E. (ed). *Technology Education for the 21st Century, 49th Yearbook of the Council on Technology Teacher Education*. Peoria, IL: Glencoe/ McGraw Hill Publishing.

Haynie, W. J. (1999) Cross-Gender Interaction in Technology Education: A Survey [Electronic Version]. *Journal of Technology Education*, *10*(2), 27-40.

Haynie, W. J., Deluca, V. W and Matthews, B. (2005) Perceptions and practices of Technology Student Association advisors on implementation strategies and teaching methods. [Electronic Version]. *Journal of Technology Education*. *16*(2), 25-36.

Howell, R. T., & Busby, J. R. (2002). Student organizations: how important are they to technology education? *The Technology Teacher. 62*(1). 24-27.

International Technology Education Association. (nd). *CATTS information*. Retrieved on May 14, 2009 from http://www.iteaconnect.org/EbD/CATTS/catts.htm.

International Technology Education Association. (1996). *Technology for all Americans: A rationale and structure for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2000/2002). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2003). *Advancing excellence in technological literacy: Student assessment, professional development, and program standards*. Reston, VA: Author.

International Technology Education Association. (2004). *Measuring progress: A guide to assessing students for technological literacy*. Reston, VA: Author.

Kalk, Richard Dowling (1992). Exploratory technology education: a forecast of the content of for communications at the turn of the century (twenty first century, technology education). Unpublished Doctoral Dissertation. Clemson University, Clemson, SC

Klenke, Andrew & Dell, T. (2007). Tool storage problem SOLVE*D!*. *Tech Directions; 66 (8),* 16-18.

Lewis, T. (1999) Research in technology education –some areas of need [Electronic Version]. *Journal of Technology Education, 10*(2), 42-56.

Lewis, T. & Zuga, K. F. (2005). *A conceptual framework of ideas and issues in technology education.* Retrieved October 30, 2008 from www.teched.vt.edu/ctte/HTML/Researchl.html.

Linnell, Chuck, (2005) Introducing an elementary design challenge into a TECA regional competition: there is a place in the early years of school for teaching about t*echnology. The Technology Teacher, 65*(2), 23-30.

Linnell, Charles. (2007). Designing and building a cardboard chair: children's engineering at the TECA Eastern Regional Conference. *The Technology Teacher, 66*(7), 25-28.

Litowitz, Len, (1995) Technology student organizations: the benefits. *The Technology Teacher, 55*(1), 24-27.

McCormick R. (1999). Theoretical and empirical issues of technology education research. *Proceedings of the AAAS technology education research conference*. Retrieved on May 19, 2009 from http://www.project2061.org/meetings/technology/papers/McCormick.htm .

Meade, S., & Dugger W. (2004). Reporting on the status of technology education in the
U.S,.*The Technology Teacher, 64*(2), 29-33.

Merrill, Chris; Cardon, Phillip L.; Helgeson, Kurt R.; Warner, Scott A. (2005) Technology education research symposium: an action research approach. *The Technology Teacher, 65*(4), 6-10.

Miller, K. (2000, January) Straight from the source. *Techniques, 75*(1), 24-25.

Mitts, Charles (2008) Gender preferences in Technology Student Association competitions [Electronic Version]. *Journal of Technology Education*, *19*(2), 80-93.

National Academy of Engineering (NAE) & National Research Council (NRC). (2006). *Tech Tally: Approaches to Assessing Technological Literacy.* Washington, DC: National Academies Press.

National Research Council. (2002). Investigating the influence of standards: a framework for research in mathematics, science, and technology education. In I. R. Weiss, M. S. Knapp, K. S. Hollweg, and G. Burrill (Eds.), *Committee on Understanding the Influence of Standards in K-12 Science, Mathematics, and Technology Education*, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academies Press.

Newberry, P. (2001). Technology education in the U.S.: a status report. *The Technology Teacher, 61*(1), 8-12.

Pearson, Greg (2004) Collaboration conundrum [Electronic Version]. *Journal of Technology Education, 15*(2), 66-76.

Petrina, S. (1998). The politics of research in technology education: A critical content and discourse analysis of the Journal of Technology Education, Volumes 1-8. *Journal of Technology Education, 10*(1), 27-57.

Rowell, P. M. (1999). Looking back, looking forward: Reflections on the Technology Education Research Conference. *Proceedings of the AAAS technology education research conference* Retrieved on May 19, 2009 from http://www.project2061.org/meetings/technology/papers/Rowell.htm .

Sanders, Mark (2001) New Paradigm or Old Wine? The Status of Technology Education Practice in the United States. [Electronic Version] Journal of Technology Education, 12(2), 35-55.

Seymour, Richard. (2007) *The role of competitive events in teacher education programs*. A paper presented at the 94th conference of the Mississippi Valley Technology Teacher Education Conference on November 8-9, 2007, Rosemont, IL.

States Career Clusters Initiative. (2010). Science, Technology, Engineering, and Mathematics. Retrieved January 18, 2010 from http://www.careerclusters.org/clusters/16cc.php?cluster=stem

Taylor, Jerianne S. (2004) *An analysis of the variables that affect technological literacy as related to selected Technology Student Association activities*. Unpublished Doctoral Dissertation, North Carolina State University, Raleigh, NC.

Technology Education Collegiate Association (TECA). (2006) TECA Bylaws [PDF document] Retrieved on May 14, 2009 from http://www.iteaconnect.org/Membership/Councils/TECAbylaws.pdf.

Territo, Peter Anthony, Jr. (1993) *Communication skills activities utilized in Louisiana technology education programs.* Unpublished Doctoral Dissertation. The Ohio State University, Columbus, OH.

Technology Student Association. (2006). *Standards based robotics competition curriculum framework.* Retrieved on October 30, 2008 from http://www.tsarobotics.org/images/robotics_framework.pdf

Technology Student Association. (2009a). Our Story. Retrieved on May 14, 2009 from http://www.tsaweb.org/Our-Story .

Technology Student Association. (2009b). Our Mission. Retrieved on May 19, 2009 from http://www.tsaweb.org/Our-Mission .

Warner, Scott A and Morford, Laura. (2004) The status of design in technology teacher education in the United States. [Electronic Version]. *Journal of Technology Education, 15* (2), 33-45.

Weber, K. & Custer, R. (2005). Gender-based preferences toward technology education content, activities, and instructional methods. [Electronic

Version]. *Journal of Technology Education, 16*(2), 55-71.

Williams, Robin Smith (2001) *An analysis of award-winning local school technology education teachers and their use of effective leadership practices.* Unpublished Doctoral Dissertation, North Carolina State University; Raleigh, NC.

Wright, Michael (1991*)* Retaining teachers in technology education: probable causes, possible solutions. [Electronic Version]. *Journal of Technology Education, 3*(1), 1-15 .

Wright, Michael and Custer, Rodney (1998) Why they enjoy teaching: the motivation of outstanding technology teachers. [Electronic Version]. *Journal of Technology Education, 9*(2), 60-77.

Zuga, F. K. (1994). *Implementing technology education: A review and synthesis of research literature information.* (Series No. 326) Columbus, OH: ERIC Clearinghouse on Adult Career, and Vocational Education.

Zuga, F. K. (1996). Review of technology education research. Paper presented at the *Technology Education Issues Symposium*, Maui, Hawaii.

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Chapter
6

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INTRODUCTION

Up until the 1960s, the field that is now known as technology education was predominantly based on the development of tool skills with prescriptive project plans developed or adapted by teachers. Since this period, there have been many changes in proposed and implemented curricula in the field. These changes, often funded by the federal government through agencies like the National Science Foundation, can be viewed within the context of research in innovation and change.

The study of how innovations are diffused by business, industry, and academia has occurred for well over four decades (Rogers, 2003). Everett Rogers has been a key researcher in the diffusion of innovations. According to Rogers (2003), diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system. It is the process by which alteration occurs in the structure and function of that *social* system. It includes both the planned and spontaneous spread of new ideas. Innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption. This definition of the diffusion of innovations does not focus specifically on education. Theories of change often target different aspects such as the role of the participants, the stages of change, and the effects of change.

This chapter gives an historical review of change theory in general with a focus on education. The chapter concludes with issues related to change in technology education. With 1960 as a starting point, there is limited research that analyzes the adoption of new techniques and ideas from the perspective of change theory. Therefore, extrapolations are made from research done in parallel and corollary fields. The rationale for this chapter is based on the belief that an understanding of how change theory can be applied to research and practice in technology education will prepare future professionals to better address the issues, concerns, and opportunities that the field will face in the future.

HISTORY OF CHANGE THEORY

The recognized history of change theory begins research on corn in Iowa (Rogers, 2003). This famous study (Ryan & Gross, 1943) focused on the adoption of hybrid corn seeds by farmers in Iowa. Data for the study were collected through

in-depth interviews with 259 farmers as they adopted the hybrid corn seed between 1928 and 1941. Key elements in the diffusion of innovations were identified and included the nature of the innovation itself, communication channels, time, and the social system into which the innovation was introduced. During the first five years of the study, only 10% of farmers planted the hybrid seed corn. Over the next three years, the adoption rate increased, reaching 40% as farmers saw their neighbors' success with the new corn seed. After 14 years, all but two of the 259 farmers were using the hybrid seed corn. Since early adopters were believed to be key elements in getting the hybrid corn adopted, Ryan and Gross (1943) focused on these farmers and found that they had larger farms, higher incomes, and more years of formal education.
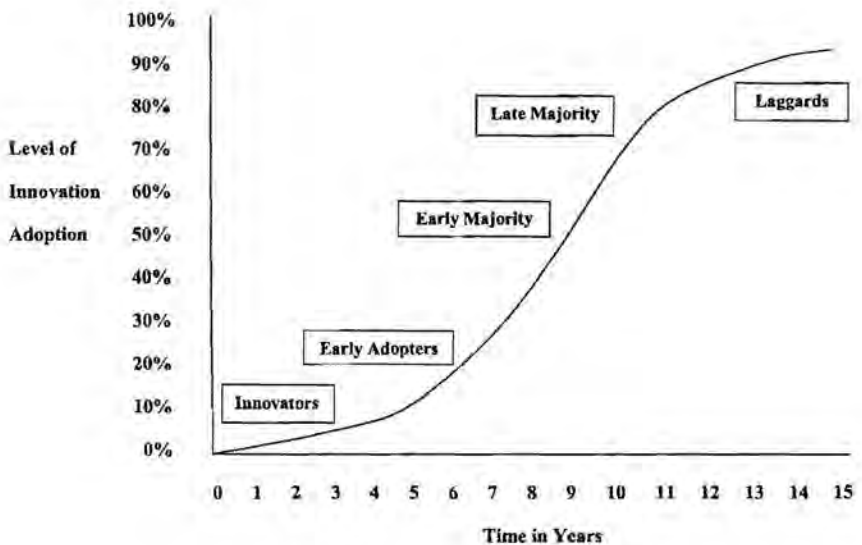

Figure 1: Sigmoid S Curve Based on Hybrid Seed Corn Study.

Rogers (2003) generalized that the sigmoid curve that Ryan and Gross (1943) found was typical of the diffusion of most innovations. He consequently developed five classifications of adopters, representing various segments of the adoption curve: innovators, early adopters, early majority, late majority, and laggards. In addition to the attributes described by Ryan and Gross (1943), Rogers concluded that innovators and early adopters tend to have higher social status, more exposure to mass media communication and interpersonal channels, and more contact with change agents.

Grubler (1997) studied the historical trends of technological innovations and found that the non-linear S-curve pattern of implementation that Rogers (2003)

found was consistent throughout history with slow growth at the beginning, followed by accelerating and then decelerating growth, culminating in saturation or a full niche. Some of the factors Grubler found in innovation diffusion include:

- The neighborhood effect whereby an innovation occurs in a specific place and then spreads out. The diffusion of *Standards for Technological Literacy* (STL) to other countries would be an example of this.
- Organizational and institutional factors, including markets, can affect whether or not an innovation is adopted and, if so, the rate of adoption.
- Social norms and attitudes.
- Positive feedback about the innovation.
- Opposition or objections to change can cause the improvement of the innovation's performance or its rejection if it is an unsustainable solution.
- Performance, cost, fashion, and familiarity.
- Economic influences whereby technological change is accelerated during waves of economic growth and decelerated when the economy falters from recession or depression.
- Time (Grubler, 1997).

Grubler proposed that implementation of an innovation is an accumulation of small random events that coalesce into a particular configuration. They occur with a time lag that is often lengthy. Historically, rates of technology diffusion to move from an adoption rate of 10% to 90% required an average of 31 years; to move from 1% to 99% averaged 99 years. Newer technologies like the transition from horse and buggy and the adoption of the catalytic converter for automobiles averaged 12 years. Grubler (1997) studied 265 cases of technology innovation and found the mean time of diffusion was 40 - 50 years (1997). The largest number of innovations occurred in a period of 15 to 30 years.

Grubler (1997) concluded that no innovation spreads instantaneously, all innovations follow the S curve, diffusion spreads out from an initial center of innovation, innovation in the peripheral areas is quicker but with less intensity compared to the innovation center, diffusion is affected by crises that occur in transitional periods, and incremental changes occur more quickly than radical departures from the norm (p. 29).

According to Rogers (2003), early innovation studies focused on anthropology (adaptation of western technologies into indigenous cultures), public health (new drugs and medical techniques), marketing and business (launching new products), and technology adoptions by American businesses (innovations that produce a return on profit). Bass (1969) proposed a theoretical model for forecasting consumer acceptance of products which led to an explosion of articles and research on marketing.

According to Ben-Ari (2006), technology-based innovations in a given country are driven by military need or compelling economic gains such as increased competitiveness in global markets. This occurs when governments are "possessing proactive government policies targeted at enhancing innovation, an industrially focused education system, a well-established industry base, R & D consortia, a

modern communication infrastructure, and an efficient supplier infrastructure" (Ben-Ari, 2006, p. 275).

ADOPTION FACTORS

The role and respect of the capabilities of opinion leaders and change agents is very influential in the adoption of innovations. Change agents are individuals who influence the innovation decisions of people in a direction deemed desirable by the change agency, whether governmental, scientific, or educational. The fastest rates of adoption occur when the change agents are authority figures with power over others. Moreover, individuals with higher socio-economic status are more likely to adopt innovations. According to Rogers (2003), the communication of new ideas will occur more often and successfully when individuals or social groups share common meanings, a mutual sub-cultural language, and are alike in personal and social characteristics.

Rogers (2003) proposed five attributes of innovations that affect the rate of adoption. Relative advantage is the degree to which an innovation is perceived as better than the idea it replaces. Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters. Complexity is the degree to which an innovation is perceived as difficult to understand and use. Trialability is the degree to which an innovation may be experimented with on a pilot basis. Finally, observability is the degree to which the results of an innovation are visible to others.

Rogers (2003) posited that time interacts with all five attributes. Porter (2005) discussed the need to view time as a dictating factor in the implementation change process, stating that "if we truly want to implement change, we should not be concerned with how long it takes to achieve" (p. 1064). Full scale implementation of innovations should not be set as successful if it only occurs within a specified amount of time.

STAGES OF IMPLEMENTATION

There have been many innovation diffusion models that describe the process of implementation. Rogers (2003) described the innovation decision-making process as having five distinct stages: knowledge, persuasion, decision, implementation, and confirmation. Havelock (1976) proposed, from a rural sociologist's perspective, a five stage process that included awareness, interest, evaluation, trial, and adoption. Morehouse and Stockdill (1991) described a business-based adoption model that included front-end analysis, prototype development, small-scale implementation, organization adoption, and institutionalization.

Rogers (2003) acknowledged that there are legitimate criticisms of diffusion research studies. One criticism is a pro-innovation bias in the research itself. There may be a tendency for diffusion researchers to assume that an innovation will have a positive result and therefore it is foregone that it should be diffused and adopted as is by all members of the targeted social system. Practitioners to whom

an innovation is directed should not adapt or reject innovations. Studies therefore may underemphasize or ignore the rejection or discontinuance of innovations. Another bias is the tendency of the researcher to side with the change agent and to blame non-adopters as inept. Another significant criticism is that a proposed innovation is culturally biased and the results of research cannot be applied to other cultures, making the validity and reliability of the research questionable.

Larsen (1980) researched the utilization of information by organizations through a study of 735 mental health community centers. Information utilization was described as a complex process involving political, organizational, socioeconomic, and attitudinal components. This study indicated that organizations may use innovations in a new form, a form not intended by the change agents. Consequently, Larsen extended the dichotomous use or non-use dimensions to include partial use and positive non-use. Partial use occurs when the users of an innovation chose which features to use and which to discard. Positive non-use occurs when information about an innovation is studied and seriously considered but then rejected completely.

Larsen (1985) extended the conventional innovation adoption thinking of the time and proposed seven levels of implementation (Table 1) in a study of 27 mental health consultants who were observed presenting new information to clinical staff. Three months later, the clinics were assessed regarding their use of the new information. Through multiple regression analysis, Larsen compared the seven levels of implementation with independent predictor variables that included consultant characteristics as well as specific and general organizational characteristics. Larsen concluded that poor consultant preparation led to less information utilization. Also, strong, healthy organizations were more likely to fully use the innovation, and clinics at the highest level of use were connected to the use of consultants.

Table 1: Levels of Information Utilization (Larsen, 1985).

1.	Information considered and rejected. Some discussion took place, but the information was rejected.
2.	Nothing done. No action, not even discussion was taken.
3.	Information under consideration. The information had not been used; however, it was being discussed and considered.
4.	Steps taken toward utilization. Although the information had not been used, the decision to do so had been made and initial planning steps had been taken.
5.	Information partially utilized. Certain features of the information had been used, whereas others had been discarded.
6.	Information used as presented. The information had been used in the form it which it was originally presented.
7.	Information used and adapted to fit user's needs. The information was modified or adapted to fit the situation.

EDUCATION-BASED INNOVATION

In the past forty years, the American education system has been continuously reinventing itself with curricula changes. Some examples include "new" math, competency-based teaching, standards-based teaching, career centers, back-to-basics, brain-based learning, and reading literacy movements. Bybee and Loucks-Horsley (2000) stated that:

> In educational history, we have tended to change system inputs and assume these would result in greater student learning. Some examples include time (length of school days, year), content (additional courses), materials (new textbooks or activity-based programs), techniques (cooperative groups, project-based learning), and educational technology
>
> (computers in class-rooms and the use of the Web) (p. 14).

With innovation diffusion studies becoming more visible in the 1970s, it was only natural that the field of education began adapting diffusion models to study the adoption of new curricula. Innovative curriculum changes in education followed the sigmoid "S" curve typical of most innovations, with the exception of business models that emphasized improved output, standardization, and higher profits. According to Holloway (1996), important influences on adoption in school settings include the cultural beliefs of the school, how learning occurs, appropriate knowledge for schools, and teacher-student relationships.

Rogers (2003) stated that most early educational research on change is credited to Teachers College - Columbia University. In the 1960s, the federal government provided seed money for demonstration projects in school settings in 18 states. With the switch to accountability under the Nixon administration, redistributive programs such as desegregation, compensatory education, and bilingual education were analyzed for their effectiveness. The researchers found that when federal seed money ran out, the innovations ended. As a result, a national Dissemination Review Panel was created in 1972 by the federal government to review evidence of the quality and effectiveness of educational products, programs, and practices. Within two years, the federal role shifted from funding new innovations to distributing to school districts comprehensive materials and information about successful, best practice programs.

In 1974, the federal government contracted with the Rand Corporation to study the implementation of educational change. The Rand Change Agent Study focused on 293 federally sponsored projects in 18 states to determine the factors that most positively affected educational innovations (Berman & McLaughlin, 1976). The Rand study concluded that it is difficult to measure educational gains in short time frames, innovations occur in incremental steps, reinvention of innovations is the norm, and that institutional variables were not being taken into consideration in most studies. Based on this, the Rand Study recommended that success in innovation could not be measured by students' gains in learning, but must be measured by the perceived implementation of the project. Perceived

success is the relative extent to which project participants believed that the goals of the project were desirable and the extent to which they were achieved. Three types of change were measured in this research effort: the extent of the change in behavior by the teachers implementing the new curriculum, the fidelity or extent to which the project was implemented as originally planned, and the extent to which the local school continued the project activities after the federal funding ceased (Berman & McLaughlin, 1976).

The Rand studies concluded that the most significant factors in successful implementation were the institutional setting and the motivations of the individuals within that setting. Five independent variables were statistically significant: school size, district financial situation, source of district revenues, district socio-economic characteristics, and the tenure of the school superintendent. The Rand Study reached the following conclusions: First, the educational methods used by the project had limited effects on the implementation rates. Second, project resources were poor predictors of outcomes. Third, a more ambitious project scope would stimulate teacher change and involvement. Fourth, the commitment of leaders in the school district was essential for success. Finally, implementation strategies developed locally were more successful than top down projects originating outside of the educational setting.

Frank, Zhao, and Borman (2004) discussed the factor of social capital on diffusion of innovations in educational settings:

> Members of a school share the common fate of the
> organization and affiliate with the common social system
> of the organization. Thus, they are more able to gain access
> to each others' expertise informally and are more likely
> to respond to social pressure to implement an innovation,
> regardless of their own perceptions of the value of the
> innovation (p. 148).

Social capital is defined as the potential to access resources through social relations. Their report focused on implementation of computer innovations, the Internet, educational software and digital cameras. Information technologies are considered important innovations because of increased productivity and strong institutional legitimacy. Their conclusions are based on a qualitative study of six K-12 schools in three states. One hundred forty-three teachers were interviewed to determine their level of computer use, from whom they asked for voluntary assistance, the level of social pressure to adapt computer innovations, and the level of resources to which they had access. Additional background information was collected on job conditions, stress, gender, ethnicity and schools.

Among the important implications from this study included information about the role of change agents. Change agents can draw on social capital by creating professional development time for organizational members to interact and share their expertise. The study (Frank, et al, 2004) also found that when school organizations try to implement multiple innovations simultaneously, the

proponents of differing innovations tend to work against each other rather than be supportive. Impediments to change include job conditions and stress, and federal and state legislation that mandate standardized tests and the accountability that goes with it. A limitation of the study was their use of a small number of elementary schools, making it difficult to compare the effects of social capital at differing levels of school settings.

Henderson and Dancy (2005) reported that divergent expectations between change agents and faculty can lead to slower implementation of educational innovations. Their study was based on interviews with five physics professors at Western Michigan University and University of North Carolina at Charlotte. Change agents (educational researchers in this case) expect faculty to implement curricular innovations with minimal changes while faculty expect researchers to adapt the curricular innovations (knowledge and materials) based on faculty suggestions and their unique needs. The Henderson and Dancy change model includes four levels: Adoption – Adaption – Informed Invention – Invention. Most classroom faculty prefer the Informed Invention level in which researchers work cooperatively with teachers to implement innovations. A limitation of this study was the low number of professors interviewed at only two universities, making the conclusions of the study difficult to generalize to other settings.

INDUSTRIAL ARTS / TECHNOLOGY EDUCATION

The fields of industrial arts and technology education have seen many innovative curriculum developments since the 1960s. Prior to these changes, the industrial arts content was concentrated in the areas of woodworking, drafting, printing and metalwork. According to Householder (1972),

> Social, economic and educational events were clearly creating
> a dissonance between existing industrial arts courses and
> the demands of the sixties. The time was right for the most
> widespread efforts ever devoted to the reorganization of the
>
> content and activities in the industrial arts curriculum (p. 7).

Some of these emerging curriculum projects specific to industrial arts include:

- Industrial Arts Curriculum Project (1963), The Ohio State University and University of Illinois. A manufacturing and construction curriculum for the seventh and eighth grade levels. This project was the first to produce published materials, including textbooks, student workbooks, and audio-visual materials to support the implementation of the project.
- Functions of Industry (1963), Wayne State University. A course that included the topics of research, product development, production planning, and manufacturing.
- Industrial Arts as the Study of Technology (1963), Kent State University. A curriculum that included a wide range of areas: manufacturing, construction, power, transportation, electronics, industrial research, services, and management.

- The Georgia Plan (1964), Georgia Southern University. A technology-based program with distinct tracks at the secondary level.
- The Alberta Plan (1966), University of Alberta. A sequential, four phase project starting with Phase I (7th grade) including an introduction to tools, machines and materials. Phase II (8th and 9th grade) focused on technologies prevalent in the world of world. Phase III (10th grade) focused on simulated industrial applications. Independent study was the focus of Phase IV.
- The Maryland Plan (1970), University of Maryland. This curriculum centered on the development of the individual student rather than projects. The Maryland Plan is known for its focus on instructional methods.
- American Industry Project (1971), University of Wisconsin – Stout. Course units included industry today, evolution of industry, enterprise organization, production, product distribution, future of industry, and student business ventures.
- Standards for Industrial Arts Programs Project (1978), Virginia Tech. Program standards (not curriculum) for industrial arts and then revised for technology education.
- Jackson's Mill Industrial Arts Curriculum Theory (1982). Defined manufacturing, construction, communication, and transportation as content areas.
- British design and technology approach. Inventive product design and problem solving with an aesthetic emphasis.

Cochran (1970) researched innovative industrial education programs from the 1960s and provided a comprehensive analysis of seven projects from 35 reviewed. A 119-item checklist of industrial education content, methods, objectives philosophy, and practices was reduced to 50 core statements. Using a Q-sort research method with forced choice procedures, Cochran acquired data from the seven programs about course objectives, content, and instructional methods used in the seven innovative curriculum projects. The respondents indicated a general agreement in the need for an increased emphasis on research, development, and scientific activities, and a reduced emphasis on manipulative activities. The majority of the respondents reported that their objectives were skills, craftsmanship, and consumer knowledge. The use of multiple activities in the classroom was common. Finally, Cochran identified that the field of industrial arts was in a heightened era of modification and change beginning in the 1960s with wider implications than in previous decades. Several of the projects that Cochran studied are included in the list above.

The 1960 and 1970 curriculum projects caused professionals in the field to migrate into various "camps," representing increasing divergence in philosophy. They included integrative (interdisciplinary), industry-based, career and occupational, technology focused, evolutionary (incremental changes to curriculum), and individual development (Cochran, 1970; Householder, 1972).

Householder (1972) reported that curriculum development is largely a responsibility of state industrial arts supervisors. More experienced and better educated teachers were more favorable to using state-produced curriculum materials. Selection of textbooks by teachers and the development of curriculum innovations by vendors both have a strong impact on what is taught in classrooms.

Feirer (1969) emphasized two themes about change in industrial arts. One, change is evolutionary with most successful change built on incremental changes to current curriculum. Second, change must be initiated by teacher education programs that are directed by knowledgeable and involved professors who are committed to mentoring new teachers.

Dyrenfurth and Householder (1979) reviewed industrial arts research studies published between 1968 and 1979. They indicated that the Industrial Arts Curriculum Project (IACP) stood out as the best practice example of systematic curriculum reform in the field. Systematic reform was described as development of a rationale, full field testing, and dissemination efforts with a resulting significant increase in leadership and professional development at the state level. Barriers to the implementation of IACP included resistance from teachers and leaders due to inertia or commitment to other ideals. Other barriers were a lack of money, facilities, equipment, time, and unstable organizational structures at the school level.

Koonce (1968) noted that over half of the states in 1968 were revising their industrial arts curriculum. These states most often encouraged classroom teachers to adopt state curriculum benchmarks but 90% of teachers indicated that state developed curriculum materials were inappropriate for direct implementation. The study reported that the perceived value of the state developed curriculum materials was greater for experienced teachers and teachers with master's degrees than it was for beginning teachers or teachers with a bachelor's degree. This may indicate another barrier to change: teacher training programs at the university level.

McCrory (1987) reported on research studies conducted during the transition from industrial arts to technology education (1979 to 1987). Two influential innovations were the Standards for Industrial Arts Programs Project and the Jackson's Mill Curriculum Theory Model. McCrory identified 435 studies in the ERIC system and 295 studies in *Dissertation Abstracts International* that were coded as "industrial arts or technology education or industrial education". A significant reconceptualization of the curriculum structure of industrial arts occurred during this period. One of the studies cited (Snyder & Hales, 1981) identified Jackson's Mill as having had the most far-reaching influence on curriculum reform. McCrory (1987) stated that the new curriculum initiatives, especially Jackson's Mill, were effectively disseminated to school administrators and decision-makers.

Efforts by national organizations were designed to help increase the transition to the new technology education models being developed. The International

Technology Education Association published a guide (ITEA, 1985) for program implementation that included examples of best practices to assist technology education supervisors and classroom teachers in adopting innovative curriculum models. Snyder and Hales (1981) reported that funding efforts by the Technical Foundation of America resulted in a guidebook on developing contemporary technology education programs that was disseminated nationally.

Reed (2002) reported about the Technology Education Graduate Research Database (TEGRD) that highlights the history of industrial arts and technology education research. The database indicates a surge in research studies beginning in 1967 with a precipitous drop after 1982. Many of these projects were developed with federal funds through the 1958 National Defense Education Act, the 1963 Vocational Education Act, and through Ford Foundation private grants. In the late 1980s, the number of research studies increased although not to the levels seen earlier. Reed stated that this may be the result of activities associated with the Technology for All Americans Project and increased funding from the National Science Foundation.

After the change from industrial arts to technology education in 1985, new curriculum projects and ideas began to be proposed, debated, and studied. These post-1985 projects include:

- Modular technology education
- Integrated curriculum
- A Conceptual Framework for Technology Education (1990): Problem solving model.
- SCANS (Secretary's Commission on Achieving Necessary Skills) work-based competencies (1991).
- Technology for All Americans (1996).
- Standards for Technological Literacy (2000).
- Science, Technology, Engineering, and Mathematics (STEM) integration.
- Engineering
- Industry Certification through Perkins IV federal law

Zuga (1994) summarized 220 research studies or reports about technology education published in the United States from 1987 to 1993. When the studies were narrowed to curriculum, Zuga reported that the research could be broadly grouped into three categories: the status of the field, content, and change. The major renovation in curriculum at this time was the publication of *A Conceptual Framework for Technology Education* (Savage & Sterry, 1990) that defined and operationalized a structure for teaching technology based on human adaptive systems and the technological method of problem solving.

Zuga (1994) reported that the evolving technology curriculum began to change at the state level with increased numbers of state supervisors adopting national technology education standards and curriculum. There was a lack of research though as to whether change was being embraced at the classroom level by technology teachers. Factors that influenced change in technology education

curriculum included effective communication, support from school principals, availability of materials and resources, and teacher ideology.

Sanders (2001) sent out a Technology Education Programs Survey (TEPS) in 1999 to 1,468 technology teachers with a revised return of 36.4%. He compared the current responses to the survey results from a 1962-1963 survey of industrial arts teachers and a follow-up survey (Standards for Industrial Arts Programs Project) during the 1978–1979 school year. Sanders found that 60.3% associated their technology education program with general education and 39.7% with vocational education. This is compared to the 1978-79 study that showed that 54% of the respondents associated their programs with general education.

Based on these results, the defined purposes of technology education changed over the past three decades. The primary purpose defined by teachers in the first two surveys was to teach tool and machine skills. By 1999 this purpose dropped to eleventh place. Developing problem solving skills and using technology (knowledge, resources, and processes) to solve problems and satisfy human wants and needs were the top two purposes identified by teachers. These results indicated that the philosophy in the field and the corollary curriculum were changing.

LABORATORIES

Industrial arts facilities for woodworking and metalworking were modeled after industrial factories. The shops included OSHA-approved zones for machinery (band saws, table saws, lathes, planers, welding stations, etc.) and benches for student work. In some general shops, an area for book work and whole group instruction was included with tools and machines that could be used with multiple materials and processes. With the change in the 1980s to newer technologies and curricula, a need was established for "cleaner" laboratory settings with modern equipment, tools, and instructional approaches. After 1985, "modular labs" became increasingly prevalent, particularly in middle school settings (Reed, 2001). Based partially on programmed instruction, modular labs include self-contained instructional units with all the necessary curriculum, equipment, materials, and consumable supplies needed by student teams who worked at learning stations. These new labs often included carpeting, contemporary furniture, and other features that made the environment look comfortable and pleasing. Computers were an essential part of these labs and were used to provide instruction, software tools, and to assess student progress. Federal funding through Perkins grants and other sources that targeted middle school settings led to an explosive growth in vendor-provided, turn-key systems. These new modular labs did not look at all like the facilities they replaced.

Prior to 2000, there was very little research about implementation of changes in the facilities of industrial arts or technology education (McCrory, 1987; Zuga, 1994). Sanders (2001) reported that eighteen percent of technology education teachers described their laboratories as modular with most teachers reporting their labs as unit-based or general in structure. About half (48.5%) of the teachers

reported that they had vendor-developed work stations while 72.5% reported utilizing work stations that were developed by teachers. Teaching approaches included modular (35.4%), project approach (27.9%), and a design and technology approach (36.7%). None used the project-from-plans approach of the industrial arts era.

Brusic and LaPorte (2000) reported on the status of modular education in Virginia. Four hundred ninety-two surveys were received from the 962 Virginia Technology Education teachers, a 51.5% response. The distribution of labs reported by Virginia teachers was 50.3% conventional, 24.7% modular, and 24.9% mixed. Eighty-six percent of the modular labs were commercially developed. The three top advantages of modular laboratories reported by the respondents were that they promote universal skills and abilities (36.4%), initiated by the administration with teacher's input (26.8%), and required less teacher preparation time (15.2%). Teachers had frustrations with modular labs as well and included the cost of updating equipment (68.3%), repairing hardware (51.1%), the cost of consumable supplies (35.5%), boredom in teaching this method (22.6%), and low hardware reliability (21%). Brusic and LaPorte (2000) reported the greatest satisfaction in the modular approach was among those teachers who developed their own modules.

INTERNATIONAL CHANGE

Barnes (2005) reported about curriculum changes in technology education in Australia. Forty progressive technology teachers were selected from a pool of 1,150, from which a purposeful sample of five teachers in information-rich schools were selected to be interviewed. The interviews were logged, yielding common factors that were categorized with supporting statements. Factors were defined by Barnes (2005) as "an influence that existed prior to the change and therefore influenced the teacher to initiate the change process" (p. 10).

Based on the five teacher interviews, five factors were determined to facilitate change in the technology education curriculum in Australia. They were flagging student interest in current curriculum, external curriculum development (abroad and in other Australian states), supportive school environments (time, materials, professional development, peer support), personal renewal (personal reflection and development), and the leadership style of the teacher. Teachers who embrace new change regard themselves as "trendsetters" and teachers who encourage other teachers to change were labeled as "promoters".

The Barnes study (2005) concluded that curriculum change was most often initiated by classroom teachers. Teacher attitudes, professional development, and agreement with the underlying philosophy of curriculum had a positive impact on implementation. The social context was determined to be more important than the nuts and bolts of the implementation steps. With only five Queensland, Australia technology education teachers interviewed, the study had serious limitations in its generalizability.

Dow (2005) reported on changes in technology education curricula in sixteen European countries in the early 2000s. European Union ministers met in 2001 to discuss the diminishing recruitment in mathematics, science, and technology education. The result of these discussions was a report on curriculum innovations in the selected countries and the barriers to change. Consensus was reached that technology education should focus less on the study of facts and more on the development of active, autonomous learners.

The most frequently identified barrier to change in Dow's study was a lack of support for the teacher. The dominant model of teaching was the behaviorist approach with the teacher as expert and the student as the passive recipient. Dow (2005) reported that despite curriculum innovations, policy developments, and technological advances, the prevailing instructional method had not changed in the past 50 years (p. 6). Dow found that most countries had organized regional and national teacher resource centers to increase teacher exposure to new pedagogy.

Another identified barrier was the aging of the teaching population. The European ministers postulated that an influx of beginning teachers would alleviate this barrier but subsequent studies (Dow, 2005; Long, 2004) indicated that new teachers met with resistance when trying to implement new curriculum. This resistance resulted in perpetuation of the status quo. Other barriers to change were national examination systems, teacher skepticism of top-down reforms, lack of support in pre-service education, and underlying assumptions held by teachers about the nature of effective teaching and learning (Dow, 2005). Proposed solutions to the barriers included reducing assessment pressure on teachers, increasing teacher collaboration in the development of innovative curriculum, creation of communities of teachers, and giving a sense of control to teachers.

TECHNOLOGICAL LITERACY STANDARDS

The field of industrial arts and technology education has created different sets of curriculum standards over the past thirty years. Dugger (2005) indicated that two predecessors of contemporary national standards are the *Standards for Industrial Arts Programs* developed at Virginia Tech in 1981, and the *Standards for Technology Education* published in 1985 by ITEA. The ITEA released *Standards for Technological Literacy* (2000) with the goal of establishing national standards and benchmarks for all those delivering technology education programs to use in order to promote technological literacy among American students. Modeled after the *National Science Education Standards* (National Research Council, 1996), *Standards for Technological Literacy* (STL) was developed over the latter half of the 1990s. Four groups provided input into the development of STL: an advisory group, standards team, a committee from the National Research Council, and a focus group from the National Academy of Engineering.

Bybee and Loucks-Horsley (2000) stated that the implementation of STL will require a concerted effort by leaders in the field of technology education and an openness to new ideas by classroom teachers. Dugger (2005) reported that,

in order to increase the implementation of STL, the ITEA conducted numerous workshops, hearings, conference presentations, professional development activities, and published articles in the ITEA website and *The Technology Teacher*, the organizations' flagship publication. In the five years after the publication of STL, the standards specialists alone conducted over 70 workshops. This work on dissemination resulted in strong awareness by the states and teachers about the standards in technology education.

Russell (2005) summarized American studies on the awareness, adoption, and implementation of STL by conducting surveys at the 2003, 2004, and 2005 ITEA conferences as well as a survey of teacher education programs. The 2003 ITEA survey recorded responses from 263 of 1195 participants (22%). The 2004 ITEA survey received 125 responses from 1042 participants (12%). During this year, familiarity with STL increased from 57% (2003) to 86% (2004). At the 2005 ITEA conference, 96 of 1548 (6.2%) participants responded to the survey. Eighty-nine point six percent felt that the quality of STL was excellent or very good. Later, Russell conducted a survey of teacher education programs with a response of 15 of 51 respondents (29%). All except one respondent either strongly agreed or agreed that their "faculty work with the state department or local technology education supervisors or teachers in K-12 schools to support implementation of the STL" (p. 36). Russell concluded that based on these studies and a review of several other STL implementation studies, "there has been extensive activity related to the promotion of awareness, adoption, and implementation of STL since publication in 2000" (p. 37).

Daugherty (2003) conducted a survey of teacher educators on the importance of individual standards in *Standards for Technological Literacy*. Sixty-eight technology teacher educators responded to a survey sent out to 123 professors (55% response). Of the twenty standards in STL, the teacher educators either agreed or strongly agreed that 18 of the 20 standards were important to the field. There was not strong support for standards relating to medical technologies and biotechnology.

Meade and Dugger (2004) reported that 40 of the 50 states (80%) use STL at the district or state level. More than half of the states based their course curriculum standards on STL. Three years later, Dugger (2007) reported that the number of states using STL had increased slightly to 42. The number of states using STL for their curriculum guides dropped to 48%. Sixty-three percent of states reported using *Advancing Excellence in Technological Literacy* (ITEA, 2003). Based on these two reports, the content standards may be reaching a saturation point of use in the United States.

Loveland (2003) reported on district-level factors in the implementation of *Standards for Technological Literacy* in Florida. Surveys were mailed to 1083 Florida technology teachers and the 67 county technology education supervisors to determine whether district-level factors increased implementation of STL. Sixty usable district supervisor surveys (89.5%) and 400 teacher responses (37%) were

received. Eight levels of teacher self-perceptions of their STL implementation were determined based on a previous innovation diffusion study (Larsen, 1980). The key findings were that higher school district enrollment and school enrollment density could be statistically linked to higher levels of implementation of STL by technology education teachers in Florida. Larger districts have larger budgets, greater flexibility to direct funding, more professional development opportunities, and more political flexibility. Loveland (2003) concluded that national associations and educational leaders may have to make a concerted effort to increase the use of STL in smaller school districts. Based on strong support in Florida at the state level, it may be difficult to generalize these findings nationally.

SUMMARY

The field of technology education is continually changing due to both internal and external influences. New initiatives in engineering, industry certification, and science, technology, engineering, and mathematics (STEM) integration ensures that change to the content and methods currently used by practitioners will continue. The history of innovation diffusion outside and inside education is clear: adoption of innovative practices takes time. New curricula and ideas will not be adopted overnight nor are they likely to be in a form envisioned by the change agents. There are many factors that affect the change adoption rate and they occur at many different levels: internal, external, national, state, district, and classroom.

External factors include organizational size, wealth, education, social status, contact with change agents, communication channels, infrastructure, economic gain, time, positive feedback, and performance. National and state education factors include continued access to federal seed money, the role and acceptance of change agents, curriculum development by associations and other countries, and support and money from state supervisors. District size, school density, district wealth, superintendent tenure, and district supervisor support and funding are significant factors at the district level. Of course, the nature of the teachers and schools in which they teach is an important factor in the implementation of innovations. School-based factors include cultural beliefs within the school, teacher-student relationships, the motivation of the teachers, the social capital within the school and the targeted departments, the philosophy and leadership style of the teacher, and the school environment issues of time, materials, and professional development.

Future research in the implementation of innovations should consider these factors in the development of dissemination schedules and approaches. Technology education could benefit from more research on the diffusion of innovation within the field. Meta studies that compare the levels of technological literacy in high and low implementing states, districts, and schools would be helpful in focusing efforts in the diffusion of new learning theories and ideas for our field. The innovations may be in the areas of lab facilities, teacher preparation, and professional development. Lewis (1999) discussed the need for empirical

case studies on the implementation of technology education innovations with the units of analysis being the school districts, schools, or specific technology teachers. These studies could provide practical answers about the curriculum change process and under what conditions would effective change occur.

As new curricula and ideas are proposed, it is important that research be conducted about the effectiveness of these innovations to the bottom line, student learning. The age of accountability is here to stay and efforts that show linkages between facilities, programs, and resources on the one hand, and higher student achievement on the other, will likely receive the most support. Research on the change process in education and in technology education specifically can support these efforts. Perhaps more than any other subject in the school, technology education has undergone constant change. However, little application of the principles of the change process has occurred. It is imperative that future professionals and change agents develop an understanding of how change theory can be applied for the benefit of all in the profession and those the profession serves.

REFERENCES

Barnes, R. (2005). Moving towards technology education: Factors that facilitated teachers' implementation of a technology curriculum, *Journal of Technology Education, 17*(1), 6-18.

Bass, F. (1969). A new product growth model for consumer durables. *Management Science, 13*(5), 215-227.

Ben-Ari, G. (2006). Innovation policy in the knowledge-based economy: The Israeli case. In E. Carayannis & D. Campbell (Eds.). *Knowledge creation, diffusion, and use in innovation networks and knowledge clusters: A comparative systems approach across the United States, Europe and Asia*. Westport, CN: Praeger.

Berman, P., & McLaughlin, M. (1976). Implementation of educational innovation. *Educational Forum, 40*(3), 345-370.

Brusic, S., & LaPorte, J. (2000). The status of modular technology education in Virginia. *Journal of Industrial Teacher Education, 38*(1), 5-28.

Bybee, R., & Loucks-Horsley, S. (2000). Standards as a catalyst for change in technology Education. *The Technology Teacher, 59*(5), 14-15.

Cochran, L. (1970). *Innovative programs in industrial education*. Bloomington, IL: McKnight & McKnight.

Daugherty, M. (2003). *A changing role for technology teacher education*. Paper presented at the Mississippi Valley Technology Teacher Conference, Nashville, TN, November 6-7, 2003.

Dow, W. (2005). *The need to change pedagogies in science and technology subjects: A European perspective. Implications for initial teacher education*. Paper presented at the meeting of the Pupils' Attitudes Towards Technology (PATT 15) Conference. Haarlem, The Netherlands.

Dugger, W. (2005). *Twenty years of educational standards for technology education in the United States*. Paper presented at the meeting of the Pupils' Attitudes Towards Technology (PATT 15) Conference. Haarlem, The Netherlands.

Dugger, W. (2007). The status of technology education in the United States: A triennial report of the findings from the states. *The Technology Teacher, 67*(1), 14-21.

Dyrenfurth, M., & Householder, D. (1979). *Industrial arts education: A review and synthesis of the research, 1968 – 1979. Information series 183*. Columbus, OH: The National Center for Research in Vocational Education. (ERIC Document Reproduction Service No. ED 185 239).

Feirer, J. (1969). The future on innovative programs in industrial arts. *Industrial Arts & Vocational Education, 58*(19).

Frank, K., Zhao, Y., & Borman, K. (2004). Social capital and the diffusion of innovations within organizations: The case of computer technology in schools. *Sociology of Education, 77*, 148-171.

Grubler, A. (1997). Time for a change: On the patterns of diffusion of innovation. In J. Ausubel & H.D. Langford (Eds.). *Technological trajectories and the human environment*. Washington, DC: National Academy of Engineering, National Academy Press.

Havelock, R. (1976). *Planning for innovation through dissemination and utilization of knowledge (6th ed.)*. Ann Arbor, MI: Center for Research on Utilization of Scientific Knowledge.

Henderson, C., & Dancy, M. (2006). *Physics faculty and educational researchers: Divergent expectations as barriers to the diffusion of innovations*. Paper presented at the 2005 Physics Education Research Conference. American Institute of Physics, 149-152.

Holloway, R. (1996). Diffusion and adoption of educational technology: A critique of research design. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology,* 1107-1133. New York: Macmillan.

Householder, D. (1972). *Review and evaluation of curriculum development in industrial arts education*. Columbus, OH: ERIC Clearinghouse on Vocational and Technical Education.

International Technology Education Association. (1985). *Directory of curriculum guides and other key resources*. Reston, VA: Author.

International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2003). *Advancing excellence in technological literacy: Student assessment, professional development, and program standards*. Reston, VA: Author.

Koonce, T. (1968). *State prepared industrial arts resource material: Their*

status, preparation, and effectiveness. (ERIC Document Reproduction Service No. ED025621).

Larsen, J. (1980). Information utilization in community mental health centers. Unpublished doctoral dissertation, University of California, Santa Cruz. *Dissertation Abstracts International.*

Larsen, J. (1985). Effect of time on information utilization. *Knowledge: Creation. Diffusion, Utilization, 7*(2), 143-159.

Lewis, T. (1999). Research in technology education: Some areas of need. *Journal of Technology Education, 10*(2), 41-56.

Long, S. (2004). Separating rhetoric from reality: Supporting teachers in negotiating beyond the status quo. *Journal of Teacher Education, 55*(2), 141-153.

Loveland, T. (2003). District level predictors of implementation of the standards for technological literacy in Florida. Unpublished doctoral dissertation, University of South Florida. Dissertation Abstracts International, Accession No. OCLC 53278273.

McCrory, D. (1987). *Technology education: Industrial arts in transition. A review and synthesis of the research, Fourth edition. Information series No. 325.* Columbus, OH: The National Center for Research in Vocational Education. (ERIC Document Reproduction Service No. ED 290 935).

Meade, S., & Dugger, W. (2004). Reporting on the status of technology education in the U.S. *The Technology Teacher, 64*(2), 29-34.

Morehouse, D., & Stockdill, S. (1991). A technology adoption model. (TDC Research Report No. 16) St. Paul, MN: University of Minnesota Extension Service.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

Porter, B. (2005). Colloquium: Time and implementing change. *British Journal of Educational Technology, 36*(6), 1063-1065.

Reed, P.A. (2001). Learning style and laboratory preference: A study of middle school technology education teachers in Virginia. *Journal of Technology Education, 13*(1), 59-71.

Reed, P.A. (2002). Research in technology education: Back to the future. *Journal of Technology Education, 13*(2), 68–72.

Rogers, E. (2003). *Diffusion of innovations*, Fifth Edition. New York: Free Press.

Russell, J. (2005). Evidence related to awareness, adoption, and implementation of the Standards for Technological Literacy: Content for the Study of Technology. *The Journal of Technology Studies, 31*(1), 30-38.

Ryan, B., & Gross, N. (1943). The diffusion of hybrid seen corn in two Iowa communities. *Rural Sociology, 8,* 15-24.

Sanders, M. (2001). New paradigm or old wine: The status of technology education practice in the United States. *Journal of Technology Education, 12*(2), 35-55.

Savage, E., & Sterry, L. (Eds.). (1990). *A conceptual framework for technology education*. Reston, VA: The International Technology Education Association.

Snyder, J., & Hales, J. (1981). *Jackson's mills industrial arts curriculum theory*. Charleston, WV: West Virginia Department of Education.

Zuga, K. (1994). *Implementing technology education: A review and synthesis of the research literature. Information series No. 356.* Columbus, OH: Center on Education and Training for Employment. (ERIC Document Reproduction Service No. ED 372 305).

Chapter
7

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INTRODUCTION

There is little doubt that inventive practices and subsequent innovation in technology have been accompanied by both a wealth of cultural, economic, and environmental changes and a dearth of educational and political changes to regulate these practices. This is not to say that education and politics lag economic changes; rather, technology has to be understood as a cultural and economic force *and* an educational and political product. Recent economic and environmental crises remind us of the urgencies for understanding ingenuity and technology. Hence, throughout the past century it has become increasingly important to study how designers, engineers, and inventors think or process information at hand and what goes through their minds. Arguably, new technologies and production processes along with a return of do-it-yourself (DIY) culture invite or configure everyone to employ inventive practices or "designerly ways of knowing" and thinking (Cross, 1982, 2001a, 2006). Designerly mindsets now mark cognitive interaction with technology. Given new demands and expectations of design and engineering cognition for new responsive or interactive consumer products, it is arguably just as important to study the cognitive processes of everyday users and lay designers of new technologies. Sampling cognitive processes among these distinct groups is important not only for facilitating and regulating inventive practices and innovation, but also for the challenges of learning and teaching technology.

This chapter reviews research into design and engineering cognition beginning with its scope and theoretical frameworks followed by a historical overview and analysis of current trends. What frameworks and samples of design and engineering cognition most productively inform research *and* curriculum and instruction (C&I)? The goal is to outline a significant, yet under-developed, aspect of research in technology education (Jones & de Vries, 2009; Lewis, 2008; Middleton, 2008).

SAMPLING AND FRAMING DESIGN AND ENGINEERING COGNITION

There are two major, interdependent problems that researchers of design and engineering cognition necessarily must resolve. The first problem is one of sampling: Who, or what, demonstrates or exemplifies design and engineering

cognition? The second problem is one of mapping or framing: What is design or engineering? What is cognition? What is design and engineering cognition? More fundamentally, what is the best or proper unit of analysis for researching design and engineering cognition?

Immediately, ageist, elitist, gendered, and racial sampling issues confront researchers of designerly and inventive practices: a) Is there impartiality throughout stages of immature and mature ingenuity or the informal inventive practices of children and formal practices of adults throughout the lifespan? Is it intrinsic and implicit or can it be learned? b) Is there parity between the everyday ingenuity of the working classes and the inventive practices of the R&D laboratories? Is ingenuity native to specific individuals and groups or are favorable conditions established for some but not others? c) Is there equality of domestic and office ingenuity, where women are predominant, and the ingenuity in the construction sites, factories, and R&D labs, where men are predominant? d) Is there symmetry across geographic divides of eastern and western or northern and southern ingenuity, and across what had become temporal divides across so-called premodern and modern ingenuity? Or are distinctions necessarily drawn between the craft cognition and vernacular of the poor and the design and engineering cognition of the affluent?

These issues of sampling bias do not suggest that inventive practices are uniform. Rather, what is at stake is which inventive practitioners are studied and profiled as exemplars and which are neglected (McGee, 1995). Is the process of design and engineering cognition that of gradual development from novice to proficient or expert? If so, is design or engineering expertise the exemplar on which learning and teaching technology ought to be based or patterned? If the answer is yes to both then it makes sense to study how designers and engineers practice and think. However, as constructivists warn, kids simply cannot and do not think like adults. Similarly, critical theorists note that laborers do not think like managers or professionals; feminists caution that girls and boys do not think alike and women do not think like men; postcolonial theorists note that the colonized do not think like the colonizers, avoiding assumptions of uniform cognition across enfranchised and disenfranchised countries; and finally, artificial intelligence specialists note that machines do not think like humans. In which case, it is a good idea to study the inventive practices and thinking of all.

Mapping, framing, and defining design and engineering cognition are similarly challenging. Cross (1982, 2001a, 2004, 2006) effectively distinguished designerly ways of knowing from artistic ways and scientific ways of knowing, yet design and engineering cognition is not so apparently distinguished within developmental models. Dreyfus and Dreyfus' (1986, pp. 16-51) classic developmental model (Table 1) of expertise, for example, may not map neatly onto lifelong learning or lifespan perspectives. Framed differently, are there levels of design and engineering cognition that allow us to distinguish among the "adolescent expert," "teen expert," and "adult expert" or professional designer and engineer? Or ought

researchers limit adolescent expertise to using new technologies while reserving expertise in designing and engineering the new technologies to professionals? Similar questions arise once researchers begin to differentiate among everyday design and engineering activity and outside-the-box, breakthrough inventions, or between incremental, "normal design" and revolutionary "radical design" (Arthur, 2005; Cross, 2004; Vincenti, 1990, pp. 8-9). The point here is that distinctions between novice and expert are often blurred; as Varela (1999) noted, expertise is not a capacity always already waiting to be developed.

Table 1. Stages of Expertise (Adapted from Dreyfus & Dreyfus, 1986)

	Novice	Advanced Beginner	Competent	Proficient	Expert
Aim	Accuracy and Acceptance	Accuracy and Independence	Fluency and Independence	Fluency and Demonstration	Characterization

To delimit this challenge of expertise, one is tempted to narrowly define design and engineering to exclude everyday, vernacular design and lay practitioners. This is the approach taken by the Accreditation Board for Engineering and Technology (ABET), which defines engineering as the "knowledge of the mathematical and natural sciences gained by study, experience, and practice…applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind" and design as "the process of devising a system, component, or process to meet desired needs…. a decision-making process… in which mathematics, basic sciences, and engineering sciences are applied to convert resources optimally to meet a stated objective." Although for the purposes of accreditation, popular textbooks, such as *Engineering Your Future*, employ these definitions for aspiring designers and engineers (Gomez, Oakes & Leon, 2006, pp. 2, 451-452).

Coincidental with specialized definitions, design and engineering are also framed more generally, allowing for a democratization or domestication of these practices (see, e.g., Hubka & Eder, 1996, pp. 3-4; Lawson, 1990, 1990, p. 22-23). Petroski (1982/1992), Schön (1992), and Simon (1969/1981), for instance, stretch definitions of engineering and design to respond to Latin and old English etymologies and accommodate a plurality of practices. In *To Engineer is Human*, Petroski (1982/1992) suggests that engineering simply means "to make something stand that has not stood before, to reassemble Nature into something new, and above all to obviate failure in the effort" (p. 9). As he acknowledges, "we are all engineers of sorts" (p. 11). This echoes Simon's (1971/1981) observation that "the intellectual activity that produces material artifacts is no different fundamentally than the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a welfare policy for a state" (p.

129). As another example, Schön (1992) reasoned that many interactions between students and teachers qualify as design inasmuch as it means "making things out of the materials of a situation under conditions of complexity and uncertainty" (p. 23). Perhaps Simon's (1969/1981) definition of design remains most universal: "devis[ing] courses of action aimed at changing existing situations into preferred ones" (p. 129). Reworded, design means "transforming a given state of affairs into a desired state of affairs" (Zimring & Craig, 2001, p. 127). Comparably, Perkins (1986, p. 2) defined the noun design as "a structure adapted to a particular purpose." However pluralistic, these definitions fall short in accounting for cultural or ecological questions related to who produced what "given state of affairs" and whose definition of what is "desired" is accepted.

Researchers are reminded of forms of individual cognition built into definitions of design and engineering, and of parallel challenges to model and frame cognition. Cognitive psychology and the cognitive turn in education, design, and engineering draw extensively from Neisser's (1967) seminal definition of cognition as "all processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used" (p. 4). Thus, more contemporary specialists define cognition as "the collection of mental processes and activities used in perceiving, learning, remembering, thinking, and understanding, and the act of using those processes" (Ashcraft, 1998, p. 5). For researchers, this basically reduces to how we come to know; in numerous glossaries cognition is a process of knowing and, more precisely, the process of being aware, knowing, thinking, learning and judging. To the consternation of many due to a potential subjugation of affect, learning, thinking, and volition, cognition becomes all encompassing in the most abbreviated, general form: "information processing." This reduction dates to the beginnings of cognitive science in the mid 1950s. To distinguish human from primate cognition, or juvenile from adult cognition, various developmental models account for a wide spectrum of processes. Piaget's (1973) stage model is among the most well known and various popular accounts treat simple cognition or linear processing as grounding complex cognition, which includes creativity, critical thinking, analogical and inferential reasoning, metacognition, and problem solving.

This type of continuum remains a breakthrough, as processes such as creative cognition were once singled out as distinct in degree *and* kind. As Haensly and Reynolds (1989) argue, "creativity is not another 'breed' of mental processing, but is the ultimate expression of that finely honed system of thinking we know of as intelligence" (p. 130). Creative or inventive cognition is "no longer conceived as a single unitary process, but as a product of many types of mental processes" (Finke, Ward & Smith, 1992, p. 2). One implication obligates researchers to sample well beyond 'creative types,' 'great minds,' and the 'gifted and talented' (e.g., Gardner, 1993; Osche, 1990). Arthur (2007) draws this implication for inventive thinking: "By this reasoning, what is common to originators is not 'genius' or special powers. Rather it is the possession of a very large quiver of

functionalities (i.e., 'achievable actions and deliverable effects')" (p. 283). And a second entails recognizing, as Ward, Smith and Finke (1999, p. 189) point out, the "striking generativity" of everyday cognition.

Distinguished from general problem solving, design cognition references a particular domain or instance of cognition. For Eastman (2001), design cognition is simply "human information processing in design" (p. 147). More specifically, Cross (2001b) notes that design cognition refers to information processing in "finding appropriate 'problems', as well as 'solving' them, and includes substantial activity in problem structuring and formulating, rather than merely accepting the 'problem as given'" (p. 81). It involves how designers formulate problems and generate solutions with identifiable strategies for the process. Adding more specificity, Aikin (2001) delineates design cognition as "cognitive skills" used in "representation, strategic behavior (e.g., 'problem restructuring, process management'), and innovation" (p. 109). These reduce to what he identifies as four "cognitive behaviors": "(1) rich representations, (2) indiscriminate use of creative design strategies, (3) non-standard problem composition schemata, and (4) complexity management approaches" (p. 109). Domain independence aside, demarcating cognitive boundaries between design and engineering is futile (Zimring & Craig, 2001, pp. 128-129). Indeed, engineering cognition is often conflated with cognitive engineering in an emphasis on actively designing and manipulating cognitive systems— whereas cognitive science is primarily descriptive, cognitive engineering is primarily normative (Lambie, 2005; Norman, 1987; Simon, 1980).

Whether or not a focus on cognitive systems redefines the ontology of cognition, it certainly modifies how the nature of cognition is conceived and, more pointedly, changes the unit of analysis. Few theoretical frameworks can adequately inform an analysis of dynamic cognition extended from "cognitive skills" or "mental processes," which suggest individual cognition, to a system suggesting distributed cognition. More so than other theories (e.g., constructivism), activity theory, autopoiesis (e.g., enactivism), and distributed cognition were shaped to account for this latter ontology (Petrina, Feng & Kim, 2008, pp. 384-387). Vygotsky's (1934/1962) basic observation that "all the higher psychic functions are mediated processes" (p. 56) laid a foundation for cultural-historical psychology. Working from this Marxist insight that cultural-historical systems mediate thinking, Leont'ev (1978) made the unit of analysis for cognition the "system of human activity" (i.e., activity system) (pp. 67, 80). Cognition in activity theory is artifact-mediated and object-oriented (Andreucci, 2008; Engeström, 1987; Wertsch, 1998). Combining cognitive science, cybernetics, and biology, Maturana and Varela (1980) arrived at a similar conclusion for analysis: "living systems are cognitive systems, and living as a process is a process of cognition" (p. 13). Here, the autopoietic, cognitive system is the defining unit of analysis for cognition *and* life, and cognition means "sense-making" (Thompson, 2004, pp. 388, 392). "Cognition is not the representation of a pregiven world by a pregiven

mind," Varela, Thompson and Rosch (1991) clarified, "but is rather the enactment of a world and a mind on the basis of a history of the variety of actions that a being in the world performs" (i.e., enactivism) (p. 9). Addressing the problem of technology, Hutchins (1995) dispensed with an ontology of cognition and learning that separates people from the technologies they use. Informed by the work of Lave and Wenger's (1991) "situated cognition" and through the work of human-computer interaction (HCI), distributed cognition accounts for technology, giving "new meaning to 'expert system':"

> Clearly a good deal of expertise in the system is in the artifacts (both the external implements and the internal strategies)— not in the sense that artifacts are themselves intelligent or expert agents, or because the act of getting into coordination with the artifacts constitutes an expert performance by the person; rather, the system of person-in-interaction-with-technology exhibits expertise (p. 155).

The proper unit of analysis for design and engineering cognition is neither the individual brain, which is different than the mind, nor consciousness— collective, expansive, or otherwise; rather, the proper unit of analysis is a distributed process or person-in-interaction-with design and engineering problems, solutions, and strategies. Here, the unit of analysis becomes interaction-with-the-designed-and-engineered-world.

HISTORICAL OVERVIEW

Although treatises on thinking and cognition date thousands of years, Locke's *Essay on Human Understanding* (1690) and Kant's *Critique of Pure Reason* (1781/1787) grounded studies until philosophers turn epistemologists turn psychologists began to systematically address mental work in the late 1800s. Paradigmatic of this research, Dewey's (1910) *How We Think* was the standard text through its second edition in 1933. Building on Dewey's methods for problem solving, Wallas (1926, p. 80) isolated four stages in the creative process: preparation, incubation, illumination and verification (Petrina, 2000). However, Rossman's (1931, 1964) *Industrial Creativity: The Psychology of the Inventor* was the first empirical, systematic study of a subset of cognition called inventive thinking. This was among the first to move beyond studies of "eminent men" by addressing practices of a range of professional, independent, and lay inventors, and remains relevant and significant to this day for research into design and engineering cognition. The 1910s and 1920s represent a time in many countries when an era of the lone inventor or designer in the workshop more or less yielded to engineers and specialists in new industrial research and development (R&D) laboratories (Arthur, 2007; McGee, 1995). Surveying 710 inventors and 176 patent attorneys, Rossman explored various characteristics of invention, drawing on a common definition: "arrangement of old materials in new modes of organization" (1964, p. 91). Chapters on "The Mental Processes of the Inventor" and "Psychological Theories of Invention" provide empirical findings

on mental processes such as novel and imaginative thought, and perseverance, albeit within a framework of individual cognition

Industrial Creativity, along with Ogburn's (1922) *Social Change* and Gilfillan's (1935) *Sociology of Invention*, which added sociological dimensions to emphases on mental processes, continued to be standards through the early 1960s (Arthur, 2007; McGee, 1995). Rossman's (1964) introduction to his third edition offers an exhaustive review of literature on inventive thinking through this time. In the mid 1940s, Schumpeter (1947) added an economic dimension to this tradition, distinguishing between the inventor, who "produces ideas," and the entrepreneur, who "gets things done" (p. 152). On this basis he drew distinctions between invention and innovation, and the invention-innovation-diffusion stage model continues to generate currency. At the same time, Guilford (1950, 1967) continued the "habits of mind" or "hypothetical stages" of cognition tradition established by Dewey (1910, 1933) and Wallas (1926), and turned inward to map creativity as a mental process of ideational fluency, flexibility, elaboration, and originality. Popular definitions of creative thinking at the time, such as a "recombination of known elements into something new" (Ciardi, 1956, p. 7), nevertheless suggested mental, cultural, economic, and social processes at work. The nascent cognitive science tradition of the 1950s and 1960s emphasized mental processes, to move beyond hypothetical mental stages, while the sociological tradition emphasized cultural, economic, and social processes, albeit by reiterating socio-historical stages.

Although systematic research into the cognition of end-users or users dates to the early 1900s and the work of industrial psychologists, it was through ergonomics of electronic interfaces in the 1950s that cognitive processes became the most important of human factors. The diffusion of television at this time also prompted researchers to investigate how broadcasts were processed in the minds of audience members. Students' cognitive interaction with new devices for learning in the 1960s helped expand usability studies to user design and development. Nowadays, consumer electronic products proliferate and "user-friendly" refers to both a reduction in cognitive load and customizability or ease of redesign or reconfiguration. Effects range from a democratization of design knowledge to a great triumph for consumerism and instrumentalism. For various reasons and purposes, researchers were left with a wide scope of participants for sampling and studying design and engineering cognition.

National policies across the world through the 1960s and 1970s placed weight on creative or inventive thinking and educators renewed their interests in these processes. Researchers in mathematics and science education focused extensively on problem solving while researchers in technology education focused on designerly thinking. For example, Halfin (1973) analyzed the works of ten notable technologists (designers, engineers, etc.) to identify seventeen key "functional or intellectual skills which are the random or ordered methods, strategies or operations used by a technologist to accumulate knowledge about an artifact or to solve a

technological problem" (p. 205). These processes include: Defining problems or opportunities; Observing; Analyzing; Visualizing; Computing; Communicating; Measuring; Predicting; Questioning or hypothesizing; Interpreting data; Constructing models; Experimenting; Testing; Designing; Modeling; Creating; and Managing. Hill (1997) developed a helpful instrument for assessing these seventeen processes (see Kelly, 2008), which were expanded by Wicklein and Rojewski (1999) to twenty-six in total. Through the 1980s, Lawson's (1980/1990) *How Designers Think*, Cross' (1982) *Designerly Ways of Knowing*, and Schön's (1983) *The Reflective Practitioner* helped popularize cognitive emphases in technology education. By the mid to late 1980s, researchers began to shift focus from delineating or modeling cognitive processes to studying what students actually do and how they think or process information at hand when designing or engineering (Petrina, Feng & Kim, 2008).

British design and technology (D&T) researchers were among the first to conduct large-scale research into school-based learning in design and engineering (Kimbell & Stables, 2008; Kimbell, Stables, Wheeler, Wosniak & Kelley, 1991). Directed by Richard Kimbell and the Assessment of Performance Unit (APU) at Goldsmiths College, the 1988-89 D&T assessment generated 20,000 artifacts— design brief explanations, drawings, portfolio entries, and so on— from about 10,000 students and 700 schools, and required 120 raters to deal with the evidence (Kimbell, 1997, pp. 28-43). Concentrating on the process of learning to design, the APU attempted to provide norms for progression from one level of capability and literacy to another through a time-consuming, nuanced performance component of the assessment (Kimbell, Stables & Green, 1996, pp. 48-86). Although oriented toward an assessment of learning in D&T, this study provided fundamental insights into design and engineering cognition and, more importantly, generated a base of methodology for subsequent researchers (Barlex, 2007; Kimbell & Stables, 2008; Welch, 2008). These types of assessments of learning and surveys of technological literacy were crucial to stabilizing the curriculum of D&T or technology education (i.e., *Standards for Technological Literacy*) (Petrina & Guo, 2007).

In this context, the *Journal of the Learning Sciences* was launched in 1991; "learning sciences" was coined at the time to encompass aspects of various disciplines, including cognitive science, education, instructional design, and neurosciences (Kolodner, 1991, 2004). The International Society of the Learning Sciences (2007, quoted in http://itls.usu.edu/learning-sciences) maintains that this involves studying "learning as it happens in real-world situations and how to better facilitate learning in designed environments— in school, online, in the workplace, at home, and in informal environments." Given a sense that there is something special or urgent about thinking in science, technology, engineering, and mathematics (STEM), learning scientists often focus on cognition in these disciplines (e.g., Kelly, Lesh & Baek, 2008). Specifically, the focus is on understanding cognitive processes in problem solving and design, and evaluating

C&I designs to promote these processes (Kolodner, 2004; Sawyer, 2006). From early studies onward in the learning sciences, design took center stage, primarily through design-based research (DBR), which became the de facto methodology. Brown (1991) described DBR and her "design experiments" as attempts "to engineer innovative educational environments and simultaneously conduct experimental studies of those innovations" (p. 141). In the mid 1990s, Kolodner and her team introduced a series "learning by design™" (LBD) projects, reflecting Perkins' (1986) "knowledge as design" and other C&I efforts to harness D&T for learning (Hmelo, Holton & Kolodner, 2001; Kolodner, 2002). Iterations on these types of efforts have potential to generate insights into design and engineering cognition. In the late 1990s, the National Academy of Sciences synthesized the learning sciences to date in *How People Learn* (Bransford, Brown & Cocking, 2000).

The cognitive turn for studying design and engineering, or science and technology, had been completed, or so it would seem. However, coincident with this turn throughout the 1980s and 1990s in science and technology studies (STS) was a reassessment of how well cognitive theories accounted for the processes and products of science and technology. Like questions that arose over the work of Gilfillan and Rossman, ethnographers and sociologists in STS challenged individual cognition (Fuller, De Mey, Shinn, & Woolgar, 1989; Latour, 1987, 1996). Latour (1987), for example, demonstrated the fallibility of individual cognition and a reliance on contradictions in engineers' and scientists' self-reports of cognitive processes. As indicated at the outset of this chapter, accompanying the cognitive turn are fundamental questions of studying design and engineering cognition (Hollan, Hutchins & Kirsh, 2000; Latour, 1996).

CURRENT TRENDS

At this point, it should be clear that the key question for researchers is not 'what does cognitive science offer D&T or STEM education?' Rather, the question is 'what frameworks and samples of design and engineering cognition most productively inform research *and* C&I in these disciplines?' The challenge is to methodically and systematically work through the research base on this subset of cognition and attend to contemporary framings. In a comprehensive meta-study, our team (Petrina, Feng & Kim, 2008) worked from challenges and shortcomings in *How People Learn* to describe a lifelong learning context and far-ranging agenda for researching design and engineering cognition. We wanted to synthesize empirical research to stabilize key findings specific to cognition and learning in technology. The following summarize a few key findings stabilized through empirical research:

- Young children readily focus attention on tangible objects (computers, buildings, dolls, machines, vehicles, etc.) and perceptions of technology grow more sophisticated toward a range of technological concepts (see Mawson, 2010). Children may not accurately express the facts of

composition, but understand properties such as flexibility and strength.

- Although there is little empirical evidence that learning through technology makes a difference in the academic achievement of students, there is evidence that design and programming has an effect on cognitive development for problem solving (Jarvinen, 1998; Jarvinen & Hilunen, 2000; Jarvinen & Twyford, 2000). Children involved in robotics author more sophisticated programs (i.e., program length, flexibility, modularity and global efficiency) than those not exposed to hands-on robotics.

- . Children generally rely on the authority of their teacher to guide them through ethical decisions, but also learn to reason by engaging with moral dilemmas Eight-year-old or younger children appeal to authority (i.e., teacher) as the arbiter, noting that rules and regulations have to be followed because the students who do not follow rules get into trouble. Older students tend to appeal to the logic of rules, noting that they are there for a good reason.

- A vast majority of inquires into design and engineering cognition necessarily focus on collective interaction rather than lone designers. For researchers, who have different goals than teachers, the development of character values in collaborative work is secondary to the finding that cognition is shared and distributed across groups and things.

- Learning technology at the middle, junior, and high school levels means learning how to cope with dependence on various, and at times ambiguous, resources. What looks like autonomy and independence in students is actually a redistribution of dependence from teacher to handbooks, procedure manuals, drawings, mathematical symbols, and scientific principles, design briefs, models, conventions, norms, new language and expert tutors. At this level, students learn to learn within increasingly complex cognitive systems.

- For the most part, post-secondary students learn design and engineering through the lens of disciplines. Participation in design, engineering, and technology for many people does not require that they become experts; but for those people in technology careers, this requirement is generally expected. In some ways, differences between novice and expert designers reduce to metacognition, or the organization of cognitive functions. Both novice and expert designers manage a range of concurrent cognitive actions, but novices lack strategies for organizing their activity.

- Researchers note that it is often the design problem that forces designers or engineers to work in teams. "Equivocal data," for example, taxes cognitive load and requires social resolution and agreement. Students, like professionals, have difficulties learning to work together; divisions of labour are established, while coordination and collaboration are learned.

- Learning at work is contradictory, increasing demands on employees for

both expression and capability, and occupying time both on and off the job. Inherent in the discourse of lifelong learning is an assumption that learning technology has its own reward; motivation is invested in the technology. Innocent as it seems, technology does not always empower cognition.

- Older (i.e., ages 65+) adults feel anxious or threatened by technological changes. A majority identify health as a primary need but also place a high value on learning about new technologies. Many connect the process of learning technology with a healthy mind and body— with youth— or active aging and the "use-it-or-lose-it" syndrome.

- Older adults learn to moderate their cognition and skills, and make changes to their everyday routines and tasks. A question that arises for many older adults is whether cognitive tasks can be redesigned and learned without a change in environments. They learn to simplify their behavior within familiar environments and are highly dependent on routine arrangements, structure, and order.

These types of findings have direct bearing on *how* children, adolescents, teens, and adults become technologically literate (e.g., Dakers, 2006; Eisenkraft, 2009; Williams, 2009). Is accounting for design and engineering cognition across the lifespan an equivalent of accounting for technological literacy across the lifespan? To what degree ought we transform stages of expertise (Dreyfus & Dreyfus, 1986) into taxonomies of technological literacy (Table 2)? To what degree does know-how permeate cognition and technological literacy across the lifespan? *How* does one become technologically literate or develop and transform from technological perception to sensibility (Compton & Harwood, 2005)? By asking these questions, researchers across a broad range of disciplines are reconnected; research into design and engineering cognition of children may be coordinated with gerontechnology. Indeed, understanding design and engineering cognition across the lifespan challenges us to rethink some of our most basic assumptions about cognition, learning, literacy, and technology.

Table 2. Taxonomy of Technological Literacy (Adapted from Todd, 1991, p. 24)

Level of Technological…	Action & Knowing…	Level of Cognition
Perception	What	Attention
Expression	What, That	Expression
Capability	What, That, and How	Application
Ingenuity	What, That, How, When, and Why	Invention
Sensibility	What, That, How, When, Why, and Why not	Judgment

Trends in D&T and STEM research are promising in the sophistication of studies addressing design and engineering cognition (e.g., Kelly, 2008; Ginestié, 2008; Welch, 2008), including longitudinal studies (e.g., Mawson, 2010). Maybe

too easy of an epistemological divide, problems addressing *how* people learn or know in conjunction with *what* they learn or know define these trends. If researchers are to understand what enables intelligent or creative interaction-with-the-designed-and-engineered-world, they will have to give up convictions that this is dependent on a deployment of *what* a person knows. Varela, Thompson, and Rosch (1991, p. 148) remind us that this interaction is much more so a matter of know-how or, increasingly, ethical know-how (Varela, 1999). Research into design and engineering cognition makes this point a priority.

REFERENCES

Aikin, O. (2001). Variants in design cognition. In C. M. Eastman, W. M. McCracken & W. C. Newstetter (Eds.), *Design knowing and learning: Cognition in design education* (pp. 105-124). New York: Elsevier.

Andreucci, C. (2008). The structuring role of artifacts in thought development. In J. Ginesié (Ed.), *The cultural transmission of artifacts, skills, and knowledge* (pp. 21-41). Rotterdam: Sense Publishers.

Arthur, W. B. (2007). The structure of invention. *Research Policy, 36*, 247-287.

Ashcraft, M. H. (1998). *Fundamentals of cognition*. New York: Addison-Wesley.

Barlex, D. (2007). Creativity in school design & technology in England: A discussion of influences. *International Journal of Technology and Design Education*, *17*(2), 149-162.

Bransford, J. D., Brown, A. L. & Cocking, R. (Eds.). (2000). *How people learn: Brain, mind, experience and school*. Washington D.C.: National Research Council.

Bown, A. L. (1992). Design experiments. *Journal of the Learning Sciences 2*(2), 141-178.

Ciardi, J. (1956, December 15). What every writer must learn. *Saturday Review*, 7-8, 37-39.

Compton, V. & Harwood, G. (2005). Progression in technology education in New Zealand: Components of practice and a way forward. *International Journal of Technology and Design Education*, *15*(3), 253-287.

Cross, N. (1982). Designerly ways of knowing. *Design Studies, 3*(4), 221-227.

Cross, N. (2001a). Designerly ways of knowing: Design discipline versus design science. *Design Issues, 17*(3), 49-55).

Cross, N. (2001b). Design cognition: Results from protocol and other studies of design activity. In C. M. Eastman, W. M. McCracken & W. C. Newstetter (Eds.), *Design knowing and learning: Cognition in design education* (pp. 79-104). New York: Elsevier.

Cross, N. (2004). Expertise in design: An overview. *Design Studies*, *25*(5), 427-441.

Cross, N. (2006). *Designerly ways of knowing*. London: Springer.

Dakers, J. (2006). *Defining technological literacy: Toward an epistemological framework*. New York: Palgrave MacMillan.

Dewey, J. (1910). *How we think*. Boston: Heath.

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. Boston: Heath.

Dreyfus, H. & Dreyfus, S. E. with Athanasiou, T. (1986). *Mind over machine: The power of human intuition and expertise in the era of the computer*. New York: Free Press.

Eastman, C. (2001). New studies in design cognition: Studies of representation and recall. In C. M. Eastman, W. M. McCracken & W. C. Newstetter (Eds.), *Design knowing and learning: Cognition in design education* (pp. 147-198). New York: Elsevier.

Eisenkraft, A. (2009). Retrospective analysis of technological literacy of K-12 students in the USA. *International Journal of Technology and Design Education*, online first.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. Cambridge, MA: MIT Press.

Fuller, S., De Mey, M., Shinn, T. & Woolgar, S. (Eds.). (1989). *The cognitive turn*: *Sociological and psychological perspectives on science*. New York: Kluwer.

Gardner, H. (1993). *Creating minds: An anatomy of creativity seen through the lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi*. New York: Basic Books.

Gilfillan, S. C. (1935). *The sociology of invention*. Chicago: Follett Publishing Company.

Ginestié, J. (Ed.). (2008). *The cultural transmission of artifacts, skills, and knowledge* (trans. J. Watson). Rotterdam: Sense Publishers.

Gomez, A. G., Oakes, W. C. & Leon, L. L. (2006). *Engineering your future: A project-based introduction to engineering*. St Louis: Great Lakes Press, Inc.

Guilford, J. P. (1950). Creativity. *American Psychologist*, *5*(6), 444-454.

Guilford, J. P. (1967). Creativity: Yesterday, today, and tomorrow. *Journal of Creative Behavior*, *7*(1), 3-14.

Haensly, P. A. & Reynolds, C. R. (1989). Creativity and intelligence. In J. A. Glover, R. R. Ronning R C. R. Reynolds (Eds.), *Handbook of creativity* (pp. 111-134). New York: Plenum Press.

Halfin, H. (1973). *Technology— A process approach*. Unpublished doctoral dissertation, West Virginia University.

Hill, R. (1997). The design of an instrument to assess problem solving activities in technology education. Journal of Technology Education, 9(1), 31-46.

Hmelo, C., Holton, D. & Kolodner, J. (2000). Designing to learn about complex systems. *Journal of the Learning Sciences*, 9(3), 247-298.

Hollan, J., Hutchins, E. & Kirsh, D. (2000). Distributed cognition: Toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction, 7*(2), 174-196.

Hubka, V. & Eder, W. E. (1996). *Design science*. Amsterdam: Springer-Verlag.

International Society of the Learning Sciences. (2007). About ISLS. Retrieved October 20, 2007 from http://www.isls.org/about.html and February 22, 2010 from http://itls.usu.edu/learning-sciences.

Jarvinen, E. -M. (1998). The Lego/Logo learning environment in technology education: An experiment in a Finnish context. *Journal of Technology Education, 9*(2), 47-59.

Jarvinen, E. -M. & Hiltunen, J. (2001). Automation technology in elementary education. *Journal of Industrial Teacher Education, 37*(4), 51-76.

Jarvinen, E. –M. & Twyford, J. (2000). The influences of socio-cultural interaction upon children's thinking and actions in prescribed and open-ended problem solving situations. *International Journal of Technology and Design Education, 10*(1), 21-41.

Jones, A. & de Vries, M. J. (Eds.). (2009). *International handbook of research and development in technology education*. Rotterdam: Sense Publishers.

Kelly, T. R. (2008). Cognitive processes of students participating in engineering-focused design instruction. *Journal of Technology Education, 19*(2), 50-64.

Kelly, A. E., Lesh, R. A. & Baek, J. Y. (Eds.). (2008). *Handbook of design research methods in education*. New York: Routledge.

Kimbell, R. (1997). *Assessing technology: International trends in curriculum and assessment*. Buckingham: Open University Press.

Kimbell, R. & Stables, K., (2008). *Researching design learning: Issues and findings from two decades of research and development*. Dordrecht: Springer.

Kimbell, R., Stables, K., & Green, R. (1996). *Understanding practice in design and technology*. Buckingham: Open University Press.

Kimbell, R., Stables, K., Wheeler, T., Wosniak, A., & Kelley, V. (1991). *The assessment of performance in design and technology*. London: Schools Examination and Assessment Authority.

Kolodner, J. (1991). The *Journal of the Learning Sciences*: Effecting changes in education. *Journal of the Learning Sciences, 1*(1), 1-6.

Kolodner, J. (2002). Learning by design™: Iterations of design challenges for better learning of science skills. *Cognitive Studies 9*(3), 338-350.

Kolodner, J. (2004). The learning sciences: Past, present and future. *Educational Technology, 44*(3), 37-42.

Lambie, T. (2005). Cognitive engineering. In W. Karwowski (Ed.), *International encyclopedia of ergonomics and human factors, volume III* (pp. 22-24). New York: Taylor & Francis.

Latour, B. (1987). *Science in action: How to follow engineers and scientists through society*. Cambridge, MA: Harvard University Press.

Latour, B. (1996). Cogito Ergo Sumus! Or psychology swept inside out by the fresh air of the upper deck. *Mind, Culture and Activity, 3*(1), 54-63.

Lave, J. & Wenger, E. (1991). *Situated Learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lawson, B. (1980/1990). *How designers think: The design process demystified* (2nd ed.). London: Butterworth Architecture.

Leont'ev, A. N. (1978) *Activity, consciousness, and personality* (trans. M. J. Hall). Englewood Cliffs, NJ: Prentice Hall.

Lewis, T. (2007) Engineering education in the schools. *International Journal of Engineering Education, 23*(5), 843-852.

Maturana, F. & Varela, F. (1980). Autopoiesis and cognition: The realization of the living. *Boston Studies in the Philosophy of Science*, *42*, 1-92.

Mawson, B. (2010). Children's developing understanding of technology. *International Journal of Technology and Design Education*, *20*(1), 1-13.

McGee, D. (1995). Making up mind: The early sociology of invention. *Technology and Culture,* 36(4), 773-801.

Middleton, H. (Ed.). (2008). *Researching technology education: Methods and techniques*. Rotterdam: Sense Publishers.

Neisser, U. (1967). *Cognitive psychology*. New York: Prentice-Hall.

Norman, D. A. (1987). Cognitive engineering—Cognitive science. In J. M. Carroll (Ed.), *Interfacing thought: Cognitive aspects of human-computer interaction* (pp. 325-336). Cambridge, MA: MIT Press.

Osche, R. (1990). *Before the gates of excellence: The determinants of creative genius*. Cambridge: Cambridge University Press.

Perkins, D. (1986). *Knowledge as design*. Hillsdale, NJ: Lawrence Erlbaum.

Petrina, S. (2000). The political ecology of design and technology education: An inquiry into methods. *International Journal of Technology and Design Education*, *10*(3), 207-237.

Petrina, S. & Guo, R. (2007). Developing a large-scale assessment of technological literacy. In M. Hoepfl & M. Lindstrom (Eds.), *Assessment in technology education* (pp. 157-180). New York: Glencoe-McGraw Hill.

Petrina, S., Feng, F. & Kim, J. (2008). Researching cognition and technology: How we learn across the lifespan. *International Journal of Technology and Design Education*, *18*(4), 375-396.

Petroski, H. (1982/1992). *To engineer is human: The role of failure in successful design.* New York: Vintage Books.

Piaget, J. (1973). *The child & reality: Problems in genetic epistemology* (trans. A. Rosin). New York: Viking.

Rossman, R. (1931). *Industrial creativity: The psychology of the inventor*. Washington, D.C.: Inventors Publishing Company.

Rossman, R. (1964). *Industrial creativity: The psychology of the inventor* (3rd ed.) New Hyde Park, NY: University Books.

Sawyer, R. K. (2006). The new science of learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 1-16). Cambridge: Cambridge University Press.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Schön, D. A. (1992). Teaching and learning as a design transaction. In N. Cross, K. Dorst & N. Rozenberg (Eds.), *Research in design thinking* (pp. 21-36).

Delft: Delft University Press.

Schumpeter, J. A. (1947). The creative response in economic history. *Journal of Economic History, 7*(2), 149-159.

Simon, H. A. (1969/1981). *The sciences of the artificial*. Cambridge, MA: MIT Press.

Simon, H. A. (1980). Cognitive science: The newest of science of the artificial. *Cognitive Science, 4*(1), 33-46.

Simon, H. A. & Newell, A. (1962). Computer simulation of human thinking and problem solving. *Monographs of the Society for Research in Child Development, 27*(2), 137-150.

Thompson, E. (2004). Life and mind: From autopoiesis to neurophenomenology. A tribute to Francisco Varela. *Phenomenology and the Cognitive Sciences, 3*, 381-398.

Todd, R. (1991). The nature and challenges of technological literacy. In M. Dyrenfurth & M. Kozak (Eds.), *Technological literacy* (pp. 10-27). Peoria, IL: Glencoe.

Varela, F. (1999). *Ethical know-how: Action, wisdom, cognition*. Stanford: Stanford University Press.

Varela, F. J., Thompson, E. & Rosch, E. (1991). The *embodied mind: Cognitive science and human experience*. Cambridge: MIT Press.

Vincenti, W. G. (1990). *What engineers know and how they know it*. Baltimore: Johns Hopkins University Press.

Wallas, G. (1926). *The art of thought*. New York: Harcourt, Brace and Company.

Ward, T. B., Smith, S. M. & Finke, R. A. (1999). Creative cognition. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 189-212). Cambridge: Cambridge University Press.

Welch, M. (2008). Learning to design: Investigating the 'inner activity' of the pupil. *Design and Technology Education, 12*(3), 17-32.

Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

Wicklein, R. C., & Rojewski, J. W. (1999). Toward a "unified curriculum framework" for technology education. *Journal of Industrial Teacher Education, 36*(4), 38-56.

Williams, P. J. (2009). Technological literacy: A multiliteracies approach for democracy. *International Journal of Technology and Design Education*, *19*(3), 237-254.

Zimring, C. & Craig, D. L. (2001). Defining design between domains: An argument for design á la carte. In C. M. Eastman, W. M. McCracken & W. C. Newstetter (Eds.), *Design knowing and learning: Cognition in design education* (pp. 125-146). New York: Elsevier.

Engineering Education Research: Implications for Technology Education

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Chapter
8
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INTRODUCTION

Engineering is a vast field, divided into dozens of sub-disciplines—mechanical, civil, electrical, biomedical, etc. Engineering research typically focuses on technical issues and problems within those sub-disciplines, little of which has implications for technology education. Engineering *education* research represents an extremely small percentage of *engineering* research because the field of engineering education is only now emerging as a new engineering sub-discipline. However, because of the rapid growth and development of the engineering education discipline and research culture, engineering educators' research findings will be of increasing importance and utility to technology educators at all levels.

In describing the nature of their research engineering educators have recently and repeatedly cited Ernest Boyer's (1990) broad reconceptualization of educational scholarship in the 21st century (e.g., Fortenberry, 2009; Jones, 2005; Lohmann, 2005; Whitin & Sheppard, 2004). Boyer captured the essence of his vision of scholarship as follows:

> What we urgently need today is a more inclusive view of what it means to be a scholar—*a* recognition that knowledge is acquired through research, through synthesis, through practice, and through teaching. We acknowledge that these four categories—the scholarship of discovery, of integration, of application, and of teaching—divide intellectual functions that are tied inseparably to each other (Boyer, 1990, pp. 24-25).

Because engineering educators are using Boyer's redefinition of scholarship to define their new research paradigm, this chapter addresses the results of literature associated with the scholarship of integration, application, and teachingas well as that of the more traditional research component, discovery. Engineering journals and conference proceedings were the source for most of the discovery-related scholarship reviewed for this chapter, while much of the scholarship of engineering teaching, application, and integration was found in an array of relatively new Web-based sources of engineering education scholarship.

20TH CENTURY ENGINEERING EDUCATION RESEARCH & SCHOLARSHIP

Although the *American Society for Engineering Education* was established in 1893 and began publishing the *Journal of Engineering Education* (*JEE*) in 1925[1], throughout the 20th century, the *JEE* focused on "dissemination of society communications as well as… ideas and innovations on engineering education" (Lohmann, 2005, p. 2). Buoyed by the "rapidly expanding support for engineering education by the National Science Foundation (NSF) following the 1986 National Science Board report," interest in engineering education research and scholarship began to increase (Lohmann, 2005, p. 2). The January 2005 "Special Issue" of the *Journal of Engineering Education* signaled a new and unprecedented emphasis on "rigorous" engineering education research and scholarship. To date, nearly all engineering education research has been conducted by university engineering faculty trained to conduct *engineering* research, rather than *educational* research. A very small percentage of engineering faculty have investigated education-related issues in the past, but have had to do so as a secondary interest rather than as their primary research focus. Moreover, they did so without formal preparation for conducting educational research. By all accounts and measures, anecdotal/descriptive narratives of engineering teaching practice dominated engineering education scholarship throughout the 20th century.

EARLY VISIBILITY FOR ENGINEERING EDUCATION RESEARCH: *FRONTIERS IN EDUCATION*

In 1971, when the *IEE Transactions on Education* was the only refereed journal for engineering education, about 100 engineering educators from academia and industry gathered in Atlanta for the inaugural *Frontiers in Education* (*FIE*) conference (Jones, 2005). In 1972, many members of the ASEE Educational Research and Methods Division attended and presented papers at the *FIE* conference, which grew steadily in size and stature and became recognized for the high standards it set for conference papers and proceedings (Jones, 2005). When the *Engineering Education Coalitions* gained momentum in the early 1990s, FIE conference organizers worked with the NSF to include the work of the Coalitions, making FIE an important venue for dissemination to the broader audience of engineering educators.[2] Jones (2005, p. S3E-2) identified the following topics as "issues that have been a part of nearly every [FIE] conference… over the past 3 decades:" appropriate uses of computers; continuing education; distance education; laboratory education; the future of the university; engineering college structures and organization; evaluation of teaching/learning and the faculty reward structure; learning theories, techniques, and motivation; student issues—

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1   The *JEE* was re-titled *Engineering Education* (1969-1991) and reverted to *Journal of Engineering Education* in 1993 (Lohmann, 2005).

2   The annual Conference of the ASEE has also been a place for dissemination, but the FIE is focused on educational research, while the Educational Research & Methods Division is just one of about 50 ASEE Divisions.

quality, grading and evaluation, recruiting and retention, underrepresented groups; curricular issues; teaching of engineering design; accreditation; resources; and educational technology. These topics might be thought of as the early engineering education research agenda.

LAYING THE FOUNDATION: ENGINEERING EDUCATION COALITIONS

In 1990, the National Science Foundation (NSF) began funding eight large Engineering Education Coalitions comprised of about 40 different university engineering programs. The purpose of these Coalitions, which continued through 2005, was to promote widespread change and improvement in engineering education "by developing and demonstrating the efficacy of new curricular models (Froyd, 2002, as cited in Borrego, 2007)." In an effort to assess their impact, Borrego (2007) analyzed abstracts of 700 publications produced by four of these engineering education coalitions between 1990 and 2004 and interviewed Coalition leaders and authors. She found that 74% of all Coalition publications described *the authors' experiences* and 20% reported on the *development of objects or procedures*, while only 4% reported *research* meeting her criteria: the authors mentioned theory, described experiments with control groups, and/or reported analysis of quantitative data. Moreover, only 7% of the 700 Coalition publications were published in refereed journals. Borrego did, however, note a gradual increase between 1994-2002 in the percentage of *research* publications, and a significant increase in *research* publications from the Coalitions in 2004[3]. She concluded, "the assessment efforts throughout the 1990s advanced engineering education to its current point where standards of rigor can be discussed, defined, and enforced" (p. 16). In effect, the Engineering Education Coalitions built a foundation for engineering education *discovery* research, an emerging research paradigm in this century.

ENGINEERING EDUCATION SCHOLARSHIP IN THE *JOURNAL OF ENGINEERING EDUCATION*

Two literature reviews published in the 2004 volume of the *JEE* describe the changing emphasis of the *Journal* and the profession, and offer advice for future authors consistent with the new research paradigm. Wankat (2004) reviewed all articles appearing between 1998-2002 in the *JEE*—"the most important venue for disseminating engineering education research in the United States" (p. 13)—thus extending his earlier review of *JEE* articles appearing between 1993-1997 (Wankat, 1999). To begin to describe the content being investigated, Wankat categorized the keywords associated with each *JEE* article, which resulted in the following rank order of content addressed in the 1998-2002 *JEE* articles: 1) Teaching (25.6%); 2)

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3   Only 3% of Coalition publications were grounded in K-12 education (outreach), underscoring the postsecondary focus of nearly all engineering education research.

Computers (18.0%); 3) Design (13.6%); 4) Assessment (9.8%); 5) Groups/Teams (8.2%); 6) Internet/Web (7.6%); 7) ABET (6.5%); 7) Learning (6.5%); 9) First Year (5.7%); 10) Curriculum (5.4%); 11) Laboratory (5.2%); 12) Gender/Women (3.5%); 13) Distance Education (3.3%); 14) Communication/Writing (3.0%); 15) Ethics (2.7%); 16) Experiential/Hands-on (2.5%); 17) Four topics accounted for 2.2%: Entrepreneurship; International/Global; Retention; and Programming (Wankat, 2004). This list provides a sense of the engineering education research priorities during that era.

Wankat drew a number of conclusions, including: 1) *JEE* content coverage was very broad, yet relevant to engineering educators; 2) the 1998-2002 articles revealed a decreasing proportion of articles requiring discipline-specific knowledge (thus appealing to a broader readership); 3) an increasing proportion of papers applied quantitative analytical methods; 4) increasing external support for engineering education research; and 5) authors from "all engineering disciplines" were contributing, with no one discipline dominating. Wankat also noted a "disappointing lack and use of educational theories and learning styles" and offered his opinion that "the very low median number of times *JEE* papers are cited later in the *JEE* remains disturbing". He recommended *JEE* authors "be encouraged to do more thorough literature reviews" and thought that survey and student assessments were "probably over used" while "other assessment techniques are probably under utilized" (p. 19).

Similarly, Whitin and Sheppard (2004) reviewed articles appearing in the *JEE* from 1996 through 2001 and also noted the breadth of topics investigated by *JEE* authors and identified several new topics that had begun to appear: integrated curricula; ethics and design; and increased use of technology in classrooms. They described the *JEE* as "growing in size, in the complexity of the work it is undertaking, and in its ability to present this work in a reflective and convincing manner" and concluded, "the *Journal* appears to be successfully supporting what Boyer calls the scholarship of teaching" (p. 10). In addition, they provided a list of nine characteristics of a scholarly paper, which they encouraged future *JEE* authors to consider.

Johnson, Burghardt, and Daugherty (2008) reviewed 151 *JEE* articles published between 1997-2006 that they determined to be "based on empirical data that was collected through either quantitative or qualitative methods" (p. 243). They categorized those articles according to the primary research method employed as follows: 1) Descriptive (28.8%); 2) Correlation (23.3%); 3) Quasi-experimental (22.7%); 4) Causal Comparative (12.3%); 5) Interpretive (7.4%); 6) Case Study (3.1%); 7) Evaluation (1.2%); 8) Delphi (.6%) and Ethnography (.6%). Looking back, there were a total of 526 *JEE* articles (excluding editorials and other non-articles) published during that 10-year span of issues. Therefore, only about one fourth (28.7%) of those 526 *JEE* articles were deemed by Johnson, Burghardt, and Daugherty to be data-based publications.

HEYWOOD'S ENGINEERING EDUCATION TEXTBOOK

Another indicator of the evolving engineering education landscape was the publication of *Engineering Education: Research & Development in Curriculum and Instruction* (Heywood, 2005). Smith (2008) characterized this work, which received an award from the ASEE's Educational Research & Methods Division, as an "extraordinary synthesis of work in engineering education" (p. 5). With the exception of the chapters on "Design" and "Attrition and Retention," the chapter topics parallel those found in most other education curriculum and instruction texts. Though this may be the first such book published for engineering education, teacher education programs have used texts of this nature throughout the 20th century. Heywood drew liberally from previous work in education, adding findings from engineering education research wherever available and appropriate. The citation patterns provide some insight in this regard. For example, about half of the sources cited in the opening chapter titled "Curriculum," were from education disciplines other than engineering education. For the "Design" chapter, arguably the most engineering-centric in the book, Heywood drew 49 articles from 15 different engineering journals, nine of which included "Education" in their title (Tables 1 & 2), providing an indication of the range of journals publishing engineering design-related articles. Approximately 26% of all publications cited in the "Design" chapter were non-engineering publications, while about 22% were from the *FIE* conference proceedings. The *JEE* /*Engineering Education*[4] was the most frequently cited journal. The ASEE conference proceedings were not cited, though an online search indicates that "design" appeared in the titles of 931 ASEE conference papers between 1996-2009.

Table1. Publications Cited in Heywood's (2005) Chapter on Design

Sources / Publications Cited	# of Citations
Sources cited from engineering journals	49
Sources cited from *Proceedings: Frontiers in Engineering*	32
Proceedings: World Conf on Engineering Education for Advancing Tech	4
Engineering sources cited other than journals and conference proceedings	23
Total of all engineering sources cited (books, journals, proceedings, etc.)	109
Total non-engineering sources (journals, books, conf proceedings, etc.)	38

4 What is now the *Journal of Engineering Education* was titled *Engineering Education* from 1969-1991

Table 2. Engineering Journals Cited in Heywood's (2005) Chapter on Design

Engineering Journals Cited	# of Citations
Journal of Engineering Education	11
Engineering Education	8
International Journal of Mechanical Engineering Education	6
IEEE Transactions on Education	6
Design Studies	3
International Journal of Applied Engineering Education	3
Research in Engineering Design	2
European Journal of Engineering Education	2
International Journal of Engineering Education	2
Designing Engineers	1
Design Theory & Methodology	1
Journal of Professional Issues in Engineering Education and Practice	1
Journal of Man-Machine Studies	1
Journal of Electrical Engineering Education	1
Artificial Intelligence for Engineering Design, Analysis, and Mfg	1

TRANSITIONING TO THE NEW DISCIPLINE OF ENGINEERING EDUCATION RESEARCH

In many ways, 2005 was a defining year for engineering education. It was a year in which a slew of new engineering education research initiatives and infrastructure components were rolled out. Collectively, they conspired to "raise the bar" on engineering education research, increase visibility, and signal the arrival of the emerging new engineering discipline.

The January 2005 special issue of the *JEE* was carefully designed to herald the new era of engineering education research and scholarship. The headline on the editor's page read "Building a Community of Scholars: The Role of the *JEE* as a Research Journal" followed by the first section heading: "The Emerging Discipline of Engineering Education." Editor Lohmann used that space to describe the historical backdrop to the repositioning of the *JEE* with its new mission "to serve as an archival record of scholarly research in engineering education" and to remind readers of the new manuscript review criteria (both introduced in January 2003). These two changes, he wrote, made the *JEE* "the first journal in the engineering community dedicated solely to the publication of research in engineering education" (Lohmann, 2005, pp. 1-2). Additionally, the guest-editors titled their lead-in editorial "A New Journal for a Field in Transition" and selected topics for the invited articles they "judged to be currently important… and likely to remain important in the next decade and beyond" (Felder, Sheppard, and Smith, p. 8). As Lohmann (2005) recounted six months later, "the January 2005 special issue celebrated a major transformation…. We hope this new focus will have a catalytic effect in the creation of a community of scholars and practitioners

dedicated to the advancement of scholarship in engineering education" (p. 281). One of the effects of these changes was a drastic reduction, by half, in the average number of *JEE* articles published each year, which dropped from 65.3/year (1997-2002) to 33.1/year (2003-2008), perhaps an indication of a growing emphasis on rigor and quality.

ENGINEERING EDUCATION PROGRAMS

While the *JEE* was rewriting its mission and priorities for scholarship, Purdue University and Virginia Tech University were announcing intentions to reposition their first-year engineering departments as the first "Engineering Education" programs to appear in the U.S. They began hiring the first engineering faculty for whom tenure decisions would be based largely on engineering *education* research. Their inaugural doctoral students—the first formally prepared to conduct engineering *education* research—would begin defending their doctoral dissertations as the decade rolled over. In addition to the several new *departments* of engineering education that began in the middle of the decade, an increasing number of faculty in the other engineering disciplines began focusing their research on engineering *education*, rounding out the cadre of new engineering education researchers.

NATIONAL ACADEMY OF ENGINEERING

Charged with the responsibility for advising the federal government, the National Academy of Engineering (NAE) is in a position to influence national, state, and ultimately, local educational policy and funding. It is, therefore, significant that the NAE has impacted the engineering education research trajectory over the past decade through a series of initiatives and projects. Their standing Committee on Engineering Education (CEE), comprised of invited thought leaders and experts from the business, academic, and public sectors is charged with 1) identifying and examining significant engineering education issues; 2) organizing studies and developing long-term strategies for engineering education; and 3) recommending specific policies to appropriate national and state government agencies and academic administrations (NAE, 2009). Recent publications include: *The Engineer of 2020; Educating the Engineer of 2020;* and *Developing Metrics for Assessing Engineering Instruction: What Gets Measured is What Gets Improved*. In addition, NAE's CEE was instrumental in establishing the Center for the Advancement of Scholarship in Engineering Education (CASEE, described below).

Many technology educators are familiar with the NAE's Technological Literacy/K-12 Engineering Education Program, which was responsible for their review and recommendations relating to the *Standards for Technological Literacy* (ITEA, 2000) and the publication of *Technically Speaking: Why All Americans Need to Know More About Technology* (Pearson &Young, 2002); *Tech Tally:*

Approaches to Assessing Technological Literacy (Garmire & Pearson, 2006); and *Engineering in K-12 education: Understanding the status and improving the prospects* (NAE & NRC, 2009) and is currently operating its Exploring Content Standards for K-12 Engineering Education Committee.

These NAE initiatives, including CASEE and related online strategies described below, are consistent with Boyer's broad vision of the scholarship of application, integration, and teaching. Viewed together, they reflect a substantive federal interest in K-16 engineering education. Their work has focused new resources and human capital on creating greater visibility, new opportunities, broader networks, and comprehensive syntheses of data and ideas beneficial to those engaged in K-16 engineering education and research. Their agenda for K-12 education, revealed in part by the publications cited above, could have much greater impact on K-12 engineering/technology education in the long run than we might now imagine.

CASEE was created in 2002 by the NAE "as a mechanism to foster a climate of continuous improvement in engineering education" with many perceiving a need for a new research agenda. CASEE responded by identifying and promoting six research themes, outlined in detail on the center's Web site: 1) Teaching, Learning, and Assessment Processes; 2) Teachers and Learners; 3) Courses, Laboratories, Curricula, Instructional Materials, and Learning Technologies; 4) Educational Management and Goal Systems; 5) Political, Economic, and Social Influences on Engineering Education; and 6) Diffusion of Educational Innovations (CASEE, 2009). Consistent with its mission, CASEE strives to: 1) promote and facilitate rigorous quantitative and qualitative approaches to education research; and 2) disseminate education research results and aid in their transition into practical use. Accordingly, CASEE offers the following range of information and services.

Billed as "an experiment in collaborative scholarship," the Annals of Research in Engineering Education (AREE) is a "community-developed collection of resources on education research." Thus, the AREE Web site, posts and categorizes by CASEE's six research themes, summaries of selected articles culled from about a dozen journals. To facilitate scholarly dialogue, AREE solicits and posts reflective essays and comments from journal authors and other scholars. To encourage rigorous research and scholarship, AREE provides access to educational research standards developed by the National Research Council and by the American Educational Research Association. AREE also publishes an e-newsletter to further disseminate these resources (AREE, 2009).

Peer Reviewed Research Offering Validation of Effective and Innovative Teaching (PR^{2}OVE-IT) offers online summaries of selected research conducted on instructional practices employed in undergraduate STEM education settings. These studies have been shown to enhance student learning, retention, and/or professional success in post-secondary engineering and allied sciences (PR^{2}OVE-IT, 2009).

Established in 2005, DISTILATE is an e-newsletter that points researchers to

publications and articles that address issues relating to the six CASEE research themes. Additioanlly, DISTILATE spotlights effective educational strategies, lists recent reports published by the National Academies and other ortanizations; and identifies relevant meetings, conferences, funding sources, etc.

CASEE develops and offers the following theory-into-practice briefs for a nominal fee:

- Data-driven Engineering Education Practice (DEEP): a series of briefs discussing the classroom implications of recent engineering education research;
- Teachers Integrating Prior Scholarship (TIPS): a series of briefs discussing the classroom implications of recent social science research; and
- Responding to Administrative Priorities (RAP): a series of briefs similar to DEEP & TIPS, but written for academic unit leaders,

ENGINEERING EDUCATION RESEARCH CENTERS

With only a few formal engineering education programs in the U.S., engineering education research centers have surfaced at universities over the past fifteen years. CASEE maintains a list of engineering education centers and related organizations on its Web site. Two such centers under the direction of Cynthia Atman at the University of Washington are emblematic. Operating continuously since 1993, the *Center for Education Learning and Teaching* (CELT, 2009) focuses its research on: 1) engineering student learning, particularly with regard to design instruction and knowledge integration; and 2) improving engineering teaching. CELT also participates in, and provides administrative leadership to the *Center for the Advancement of Engineering Education* (CAEE, 2009). Initially funded by NSF in 2003, CAEE is a collaboration of scholars at the Colorado School of Mines, Howard University, Stanford University, the University of Minnesota and the University of Washington. CAEE scholarship is focused on 1) learning engineering; 2) teaching engineering, and 3) engineering education. Collectively, the various engineering education research centers across the U.S. have been responsible for a large body of research and scholarship over the past fifteen years, most of which is accessible from and/or identified on the individual Center Web sites.

ENGINEERING EDUCATION STANDARDS

Post-secondary engineering education programs are accredited, in part, according to the following [abridged] ABET, Inc. criteria: a) apply knowledge of mathematics, science, and engineering; (b) design and conduct experiments and analyze/interpret data; (c) design a system, component, or process; (d) function on multi-disciplinary teams; (e) identify and solve engineering problems; (f) understand professional and ethical responsibility; (g) communicate effectively; (h) understand

the impact of engineering solutions in a global and societal context; (i) engage in life-long learning; (j) understand contemporary issues; and (k) use necessary techniques and modern engineering tools (ABET, Inc., 2000). There are currently no nationally validated K-12 engineering education content standards, though NAE President William Wulf authored the Foreword to *Standards for Technological Literacy,* in which he wrote: "Thankfully, in *Standards for Technological Literacy…* the ITEA has successfully distilled an essential core of technological knowledge we might wish all boys and girls to acquire" (ITEA, 2000, p. v). Increasing interest in K-12 engineering education and "STEMmania" (Sanders, 2008) have led some to suggest the development of new engineering education content standards for grades K-12. In 2006, the Corporate Members Council (CMC) of the ASEE partnered with Project Lead the Way (PLTW) with that very purpose in mind. Following a two-day working meeting comprised largely of engineers and postsecondary engineering faculty, the CMC released *K-12 Engineering/Engineering Technology Standards* (ASEE Corporate Members Council, 2007) for public review. That review led the CMC to distribute, for further review, a revised version of the document under the title *K-12 Engineering/Engineering Technology Guidelines* (ASEE Corporate Members Council, 2008). Subsequently, the NAE initiated its Exploring Content Standards for K-12 Engineering Education Committee to study this issue, with work currently underway.

THE ENGINEERING EDUCATION RESEARCH AGENDA

Not surprisingly, the new discipline of engineering education thought it worthwhile to identify a "research agenda" that might provide guidance to the emerging discipline. With support from the NSF, more than 70 engineers, scientists, mathematicians, and learning scientists were invited to a series of three "National Engineering Research Colloquies," held between September 2005 and February 2006 to develop "a national research framework and agenda to conduct rigorous engineering education research" (Special Report, 2006a, p. 257). Through this iterative discussion process, they distilled more than 55 initial engineering education outcomes into five research areas, which they published as "The Research Agenda for the New Discipline of Engineering Education" (Special Report 2006b). The five research areas, described in their report, were 1) Engineering Epistemologies; 2) Engineering Learning Mechanisms; 3) Engineering Learning Systems; 4) Engineering Diversity and Inclusiveness; and 5) Engineering Assessment.

The notion of a research agenda is amorphous. It is dependent upon the variety of independent variables controlling its fate, including: the intellects, interests, and personalities of those assembled to produce the agenda; external social, political, and economic variables; and so forth. For that reason there have been, and will continue to be, other efforts to identify the engineering education research agenda, some of which have been cited elsewhere in this chapter.

ENGINEERING EDUCATION RESEARCH IN THE NEW MILLENNIUM

As Wankat (2004) concluded, much of the engineering education research and scholarship of the 20th century was not grounded in educational theory. It was more likely to be anecdotal in nature than "data-based," and rarely focused on student learning (Sheppard, Pellegrino, & Olds, 2008; Wankat, 2004). But the landscape was, indeed, in transition, and the unprecedented level of support for the transition to a new research paradigm has resulted in marked changes in engineering education research and scholarship.

Smith (2008) described the nature of this change in a talk in which he spoke almost entirely about engineering educators who had drawn from or built upon the work of celebrated educational researchers and theorists, including Ralph Tyler (curriculum theory); Robert Mager and Norman Grondlund (instructional objectives); Benjamin Bloom (taxonomies); John Dewey (inquiry and student engagement); Jerome Bruner and Joseph Schwab (problem-based / project-based learning); Wiggins and McTighe (backward design); John Bransford, James Pellegrino (constructivism and cognitive science); and Ernest Boyer (scholarship). Each of Smith's examples were of engineering educators who had begun to use and/or build upon existing educational theory/research, a pattern that seems to define the new engineering education research paradigm.

The trajectory of research and scholarship associated with the use of design pedagogy is illustrative of this transformation. Though design instruction has long been the most prevalent topic in engineering education literature, the scholarship has historically been more dialogue than "rigorous, scientific investigation." Heywood found "a paucity of research" regarding the rationale for including design instruction in the engineering curriculum (2005, p. 284). Evans, McNeill, and Beakley described the issue this way: "The subject [of design] seems to occupy the top drawer of Pandora's box of controversial curriculum matters…"(1990, p. 517). Much of the ongoing debate has focused on the appropriate balance between traditional engineering *content*, and design *process* (Dym, Agogino, Eris, Frey & Leifer, 2005; Heywood 2005). Arguments include: the lack of a theoretical basis for design in engineering education; design learning/knowledge cannot be accurately assessed; and design *process* instruction robs valuable time away from the more defensible engineering science content.

Regardless, design pedagogy is now more prominent in the engineering curriculum than ever, which Dym, et al. (2005) attributed to four trends: 1) increased industry interest in engineering education; 2) increased interest of academic administrators and many faculty members in improving retention and learning outcomes; 3) the effect of ABET's new engineering accreditation standards; and 4) the emergence of a vibrant and strong community of design researchers" (p. 112).

In 1955, the ASEE Committee on Evaluation of Engineering Education (as cited in Journal of Engineering Education Round Table: Reflections on the

Grinter Report, 1995, p. 74) recommended "an integrated study of engineering analysis, design, and engineering systems for professional background… to stimulate creative and imaginative thinking, and making full use of the basic and engineering sciences." Jones (2005) identified design as a perennial topic for papers and discussions at the *Frontiers in Education* conference since 1971. In place of a *theoretical* basis for design pedagogy, engineers justify first year engineering design instruction for its ability to attract students (Ahlgren 2001), motivate interest, and thus retain students (Dym, et al., 2005; Marra & Wheeler, 2000), and justify fourth year design pedagogy as preparation for the engineering workplace (Dutson, Todd, Magleby, & Sorensen, 1997).

Though Heywood (2005) concluded that evaluations of engineering design courses were rare, evaluation models, frameworks, and assessments of engineering design instruction have been increasingly developed and employed. To wit, there are indicative examples of the increasing use of thoughtful research questions and increasingly sophisticated research designs and methods to investigate design pedagogy in engineering education. For example, there is the work of Sheppard and Jenison (1997), Atman and colleagues in the *Center for Engineering Learning and Teaching* (e.g., Atman, Chimka, Bursic, & Nachtmann, 1999; Atman & Nair, 1996; Besterfield-Sacre, Atman, & Shuman, 1997; and Besterfield-Sacre, Atman, & Shuman, 1998), the five university research teams comprising the *Center for the Advancement of Engineering Education,* and the recently completed study of engineering teaching by Sheppard, Macatangay, Colby, Sullivan and Shulman (2008).

Moreover, recently published *JEE* articles (2003-2009) on engineering design seem to increasingly reflect the new research paradigm (e.g., Atman, Adams, Cardella, Turns, Mosborg, and Saleem, 2007; Atman, Kilgore, & McKenna, 2008; Charyton & Merrill, 2009; Mehalik, Doppelt, & Schunn, 2008; and Paretti, 2008). To explore that idea for this Yearbook, the author reviewed each of the articles published in the *JEE* between 2000-2009 that included "design" in their titles. Each of these articles was assigned to one of four ordinal categories defined as follows: 1) descriptive narratives of teaching practice; 2) descriptive narratives of teaching practice with an assessment added; 3) studies that drew conclusions from quantitative and/or qualitative data; and 4) studies that addressed explicitly stated research questions using quantitative and/or qualitative data and appropriate research designs/methods (Table 3). These data suggest a substantive shift, occurring around 2003, in the sophistication of research conducted/reported by engineering educators. Engineering educators appeared to be acting on the call for "more rigorous" research.

Related to these findings, there were, on average, 10 design-related articles/year published in the *JEE* between 2000-2002, but an average of only two design-related articles/year published between 2003-2009. This reduction is even more dramatic than the 50% reduction, noted earlier, in the overall number of *JEE* articles published after the introduction of the new manuscript review guidelines.

Table 3.*Research Methods Employed in Design Articles Published in JEE, 2000-2009*

Publication Date	n	Teaching Practice Narratives	Narrative with Assessment	Data-Based Studies	Rigorous Research	*M*
2000-2002	30	15 (50%)	9 (30%)	4 (13%)	2 (7%)	1.8
2003-2009	14	1 (7%)	3 (21%)	0	10 (71%)	3.4

ONLINE SCHOLARSHIP

Over the past decade, the engineering community has made a concerted effort to enable K-16 engineering educators to benefit from their scholarship of teaching, application, integration, and discovery. Though most would agree that this is the primary purpose of educational research, it has always been a challenge to make the connection between theory and practice. The strategies and dissemination practices outlined below and described earlier (CASEE, AREE, PR^{2}OVE-IT, DISTILATE, and Theory Into Practice Briefs) and similar strategies should be duly recognized for what they are—examples, and in some cases exemplars, of the scholarship of integration, application, and teaching that Boyer proposed, and which engineering education has openly embraced and appropriately supported. If and when scholarship of this sort becomes more widely recognized and rewarded in higher education, we might *then* expect to see more widespread benefit from the application of educational research across the board in PK-PhD education.

The National Science Digital Library (NSDL) was established to provide STEM educators at all levels with access to high quality instructional materials. Since 2000, the NSF has funded more than 200 projects to create such collections, services, and tools, post those materials on Web portals, and conduct research regarding their use (NSDL, 2009). Collectively, these Web portals, which may also be accessed individually, comprise the NSDL network, the entirety of which may be searched from the NSDL Web site. For example, the *TeachEngineering* and *Engineering Pathway* Web portals (described below) were developed by engineering educators with funding from the NSF, and each comprises a small part of the NSDL information network. A search engine at http://nsdl.org/ provides access to the whole. For example, a search of the term "engineering" using the he NSDL search engine yielded 2,286 *pages* of links to high quality engineering education-related information developed and/or assembled by scholars in the field. In contrast, a Google search on "engineering" yielded about 478,000,000 links to engineering content of radically varying quality, a very small percentage of which would be of use to PK-PhD engineering educators.

TeachEngineering (http://www.teachengineering.com/) is a Web portal providing educators with access to a large number of K-12 engineering-related lesson plans and instructional materials, which should be of significant benefit to technology teachers and technology teacher educators alike. Similarly, the *Engineering Pathway Web* portal (http://www.engineeringpathway.com/ep/)

provides access to "high-quality teaching and learning resources in applied science, mathematics, engineering, computer science/information technology, and engineering technology. This portal has an "Engineering Education Research" section that offers links to resources under the following categories: Active Learning, Assessment, Concept Inventories, Cooperative Learning, Education Research Centers, Educational Technologies, Engineer 2020 Reports & Initiatives, Engineering Education Research, Funding Opportunities, Learning Styles, Project & Inquiry-Based Learning, Service Learning, Student Retention, and Team Skills.

DISCUSSION AND IMPLICATIONS

Over just two decades, the field of Engineering Education has rallied to emerge as a new discipline and has begun to make its mark in engineering. Because engineers and engineering faculty place a high value on research, engineering educators have identified and embraced a culture of research as a central component of the new discipline. Buoyed by unprecedented support for engineering education research and an expanding cadre of engineering education researchers, the field is in a position to impact engineering teaching and learning in the decades ahead. With little or no formal preparation for this new undertaking, many engineering educators have begun navigating a postdoctoral crash course—a self-imposed professional development program focused on the study of educational theory, the review of educational literature, and the development of new behavioral research skills. The new engineering education discipline, comprised largely of new-age educational researchers, has successfully ramped up its research expectations and scholarship, and is motoring ahead to tackle an evolving research agenda.

There is much that technology education might learn from their journey, as well as from the research findings they generate. First and foremost, technology educators might learn from the strategies engineering education has pursued over the past two decades to *create* the infrastructure, *mobilize* a new cadre of researchers, and begin to *address* their new research agenda, for they have made great strides toward the high standards they have set.

Technology educators at all levels, especially those who seek to play a leadership role in PK-12 engineering/technology education, should familiarize themselves with the research findings engineering educators have begun to generate. While it may be too early to point to seminal engineering education studies of learning—with much of their work thus far focused at the course, program, and curriculum levels—their work will be increasingly relevant to technology educators as it shifts toward studies of cognition and student learning (Turns, Atman, Adams, & Barker, 2005).

Moreover, technology educators at all levels should take full advantage of the remarkable body of new online scholarship generated by the engineering education research community. In particular, the NSDL—created by STEM education researchers—provides an enormous and unprecedented library of free,

high quality engineering/STEM instructional materials within a few keystrokes of all PK-PhD technology educators. New online tools such as CASEE, AREE, PR²OVE-IT, DISTILATE, and Theory Into Practice Briefs offer immediate, free access to engineering education research findings. In addition, membership in the ASEE provides immediate access to all, fully searchable articles published in the *JEE* since 1993 and to thousands of papers published in the annual *ASEE Conference Proceedings* since 1996.

At the same time, technology educators should recognize that nearly all engineering education research has been focused at the postsecondary level, which is all the more reason technology educators must take responsibility for investigating PK-12 engineering/technology teaching and learning. Specifically, technology teacher educators should seek to investigate the learning outcomes associated with the signature pedagogy of the profession—design-based learning. This research should be informed by the research on engineering design teaching, discussed earlier in this chapter, as well as related engineering education research on integrated teaching, which generally refers to the use of engineering design activities to facilitate the learning of engineering science content (Froyd & Ohland, 2005). Their review of the research on integrated teaching in engineering describes many findings with direct implications for PK-12 technology educators seeking to integrate science and or mathematics content into design-based learning activities. The research questions associated with this instructional approach are arguably the most important confronting technology educators—for without growing evidence of tangible benefit in this regard, technology education will continue to be marginalized in education. Alternatively, a growing body of evidence regarding learning outcomes resulting from the integration of mathematics and/or science concepts and processes with PK-12 engineering design activities could create unprecedented interest in engineering/technology education for all, and could conceivably alter the general approach to PK-12 STEM education.

In many ways, technology teacher educators are ideally situated to conduct this research. Nearly all hold doctoral degrees in education and were, therefore, prepared to conduct educational research. The courses they teach often employ design-based learning activities, and they work closely with secondary technology education programs where design-based learning is being (or should be) practiced; two good venues for investigating learning outcomes associated with design-based pedagogy.

Given the level of investigation of PK-12 mathematics and science pedagogy over the past three decades, why haven't technology teacher educators been aggressively studying their unique design-based pedagogy? First, the field has never been successful in developing a culture of research (Sanders, 1999). Second, the now-dominant technology teacher education model, which over the past three decades has replaced most teacher educators with industrial technology faculty, has decimated the number of teacher educators in the profession (Sanders, 2006; Volk, 1997). In other words, technology teacher educators in the U.S. are not

generally driven to conduct research on teaching and learning. And, despite the unremitting call for such research, the field now lacks the horses to pull the load.

Concurrent with the sharp decline in the number of technology teacher educators, the new discipline of engineering education has identified and embraced a culture of research that is earning them widespread respect and will benefit engineering in the decades ahead. The rapid growth of the new K-12 Engineering Division of the ASEE is evidence of a significant and growing number of engineering faculty interested in PK-12 engineering education… a group motivated by their new research culture. And, because educational research is new to most engineering educators, one of their most effective research strategies has been collaboration with *educational* researchers.

These parallel circumstances, coupled with the fact that the engineering community continues to actively promote and encourage widespread PK-12 engineering education, provides new impetus for engineering education and technology education scholars to come together for the purpose of investigating PK-12 engineering/design pedagogy. Both of these stakeholders—and public education—stand to benefit from the establishment of new PK-12 engineering/ technology education research collaborations. It's time to get on with it.

REFERENCES

ABET, Inc. (2000). *Criteria for accrediting engineering programs.* Baltimore, MD: Author.

Ahlgren, D. J. (2001). Fire-fighting robots and fist year engineering design: Trinity College experience. *Proceedings: Frontiers in Education conference*. Reno, NV.

AREE. (2009). Annals of research on engineering education. Retrieved from http://www.areeonline.org/

ASEE Corporate Members Council (2007). *K-12 engineering/engineering technology standards.* Washington, DC: Author.

ASEE Corporate Members Council (2008). *K-12 engineering/engineering technology guidelines.* Washington, DC: Author.

Atman, C. J., & Nair, I. (1996). Engineering in context: An empirical study of freshmen students' conceptual frameworks. *Journal of Engineering Education, 85*(4), 317-326.

Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J. Mosborg, S., Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of Engineering Education, 96*(4), 359-379.

Atman, C. J., Chimka, J. R., Bursic, K. M., & Nachtmann, H. L. (1999). A comparison of freshman and senior engineering design processes. *Design Studies, 20*(2)2, 131–152.

Atman, C. J., Kilgore, D., & McKenna, A. (2008) Characterizing design learning: A mixed methods study of engineering designers' use of language. *Journal of Engineering Education, 97*(3), 309-325.

Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1997, November). A cross-institutional comparison of freshman engineering Attitudes. *Proceedings: Frontiers in Education Conference*, Pittsburgh, PA.

Besterfield-Sacre, M., Shuman, L. J., & Atman, C. J. (1998, June). Implications of statistical process monitoring for ABET 2000 program evaluation: An example using freshman engineering attitudes. In *Proceedings: American Society of Engineering Education Annual conference*, Seattle, WA.

Borrego (2007). Development of engineering education as a rigorous discipline: A Study of the publication patterns of four coalitions. *Journal of Engineering Education, 96*(1), 5-18.

Boyer, E. L. (1993). *Scholarship reconsidered*: *Priorities of the professoriate.* San Francisco, CA: Jossey-Bass Publishing.

Brophy, Klein, Portsmore, & Rogers (2008). Advancing Engineering Ed in PK12 Classrooms. *Journal of Engineering Education, 97*(3), 369-387.

CAEE. (2009) Center for the Advancement of Engineering Education: CAEE overview. Retrieved from http://www.engr.washington.edu/caee/overview.html.

CASEE. (2009). CASEE: Engineering education researchers. Retrieved from http://www.nae.edu/Programs/CASEE/Projects12300/EntryPortals/Researchers.aspx

CELT. (2009). Center for Engineering Learning and Teaching. Retrieved from http://depts.washington.edu/celtweb/index.html.

Charyton, C., & Merrill, J. A. (2009). Assessing general creativity and creative engineering design in first year engineering students. *Journal of Engineering Education, 98*(2), 145-156.

Dutson, A. J., Todd, R. H., Magleby, S. P., Sorensen, C. D. (2005). A review of literature on teaching engineering design through project-oriented capstone courses. *Journal of Engineering Education, 94*(1), 17-28.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103-120.

Evans, D. L., McNeill, B. W., & Beakley, G. C. (1990). Design in engineering education: Past views of future directions. *Engineering Education, 79*(4), 517-522.

Felder, R. M., Sheppard, S. D., & Smith, K. A. (2005). A new journal for a field in transition. *Journal of Engineering Education, 94*(1), 7-10.

Fortenberry, N. L. (2009, April). Engineering education research: What it is, is not, and why it matters. Powerpoint presented at the Virginia Tech Engineering Education Seminar, Blacksburg, Virginia.

Froyd, J. E. & Ohland, M. W. (2005). Integrated engineering curricula. *Journal of Engineering Education, 94*(1), 147-164.

Garmire, E. & Pearson, G. (2006). *Tech tally: Approaches to assessing technological literacy*. Washington, DC: National Academy Press.

Heywood, J. H. (2005). *Engineering education: Research & development in curriculum and instruction.* IEEE Press / John Wiley & Sons, Inc.

International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

Johnson, S. D., Burghardt, M. D., & Daugherty, J. (2008). Research frontiers— an emerging research agenda. In Custer, R. & Erekson, T. (Eds.). *Engineering and technology education. Yearbook #57 of the Council on Technology Teacher Education.* Peoria, IL: Glencoe/McGraw-Hill.

Jones, E. C. (2005, October). Continuing the journey through the FIE bookshelf. *Proceedings: Frontiers in Education Conference*, Indianapolis, IN, S3E-1-6.

Journal of engineering education round table: Reflections on the Grinter Report. (1995). *Journal of Engineering Education, 83*(1), 69-94.

Lohmann, J. (2005). Editor's Page: The path forward: 2005-2010. *Journal of Engineering Education, 93*(1), 281.

Lohmann, J. (2005). Building a community of scholars: The role of the Journal of Engineering Education as a research journal. *Journal of Engineering Education, 94*(1), 1-3.

Marra, R.M., & Wheeler, T. (2000). The impact of an authentic, student-centered engineering project on student motivation. *Proceedings of the Frontiers in Education conference*, F2C/8-F2C13.

Mehalik, M. M., Doppelt, Y., & Schunn, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education, 97*(1), 71-85.

National Academy of Engineering and National Research Council. (2009). Katehi, L. Pearson, G., & Feder, M (Eds.). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington, D.C.: The National Academies Press.

National Academy of Engineering. (2008). Developing metrics for assessing engineering instruction: What gets measured is what gets improved. Washington, DC: Author.

National Academy of Engineering. (2009). National Academy of Engineering: Engineering education. Retrieved from http://www.nae.edu/Programs/Education.aspx.

NSDL. (2009). National science digital library. Retrieved from http://www.nsdl.org/

Paretti, M. C. (2008). Teaching communication in capstone design: The role of the instructor in situated learning. *Journal of Engineering Education, 97*(4), 491-503.

Pearson, G. & Young, A. T. (2002). *Technically speaking.* Washington, DC: National Academy Press.

PR²OVE-IT. (2009). Peer Reviewed research offering validation of effective and

innovative teaching. Retrieved from http://www.nae.edu/Programs/CASEE/
Projects12300.aspx.

Sanders, M. E. (1999, December). *Cultivating research in technology education.
Proceedings: First AAAS Technology Education Research Conference*.
Retrieved from http://www.project2061.org/events/meetings/technology/
papers/Sanders.htm

Sanders, M. E. (2006). Technology teacher education in the United States.
In Williams, P. J. (Ed.). *International Technology Teacher Education.*
Yearbook #55 of the Council on Technology Teacher Education. Peoria, IL:
Glencoe/McGraw-Hill.

Sanders, M. E. (2008). STEM, STEM education, STEMmania. *The Technology
Teacher, 68*(4), 20-26.

Sheppard, S. D., & Jenison, R. (1997). Freshmen engineering design
experiences: An organizational framework. *International Journal of
Engineering Education, 13*(3), 190-197.

Sheppard, S. D., Macatangay, K., Colby, A., Sullivan, W.M. & Shulman, L. S.
(2008). *Educating engineers: Designing for the future of the field*. New
York: Jossey-Bass.

Sheppard, S. D., Pellegrino, J. W. & Olds, B. M. (2008). On becoming a 21st
century engineer. *Journal of Engineering Education, 97*(3), 231-234.

Smith, K. A. (2008, October). Implications of research in engineering education
for practice in engineering education. Paper presented at the 7th ASEE
Global Colloquium on Engineering Education. Capetown, South Africa.
Retrieved from http://www.asee.org/conferences/international/2008/upload/
Smith-EngEdResearch-GCEE2008-v8.doc

Special Report. (2006a). The national engineering education research colloquies.
Journal of Engineering Education, 95(4), 257-258.

Special Report. (2006b). The research agenda for the new discipline of
engineering education. *Journal of Engineering Education, 95*(4), 259-261.

Turns, J., Atman, C. J., Adams, R. S., & Barker, T. (2005). Research on
engineering student knowing: Trends and opportunities. *Journal of
Engineering Education, 94*(1), 27-40.

Volk, K. S. (1997). Going, going, gone? Recent trends in technology teacher
education programs. *Journal of Technology Education, (8)*2, 67-71.

Wankat, P. (2004) Analysis of the first ten Years of the Journal of Engineering
Education. *Journal of Engineering Education, 93*(1), 13-21.

Wankat, P. C. (1999). An analysis of the articles in the Journal of Engineering
Education. *Journal of Engineering Education, 88*(1), 37-42.

Whitin, K. & Sheppard, S. (2004). Taking stock: An analysis of the publishing
record as represented by the Journal of Engineering Education. *Journal of
Engineering Education, 93*(1), 5-12.

Mathematics Education

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Chapter
9

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INTRODUCTION

If one were to examine the learning standards developed by professional associations of mathematics and technology education, one may conclude that there exists a relationship between the two disciplines. For example, either the subject of mathematics or the word itself is used or stated thirty times in *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000/2002) and technology is cited over twenty times in the National Council of Teachers of Mathematics *Principles and Standards for School Mathematics* (2000). More importantly, within the twenty kindergarten through twelfth grade *Standards for Technological Literacy*, one standard (standard three) states that "students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study" (ITEA, p. 44). Within this standard, several benchmarks that span several grade levels and directly relate to mathematics and technology education are utilized. For example, the study of technology uses many of the same ideas and skills as other subjects; various relationships exist between technology and other fields of study; knowledge gained from other fields of study has a direct effect on the development of technological products and systems; technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields; and technological progress promotes the advancement of science and mathematics.

Within the National Council of Teachers of Mathematics *Principles and Standards for School Mathematics* (2000) pre-kindergarten through twelfth grade standards, the *Connections* standard reads that students will recognize and apply mathematics in contexts outside of mathematics, and the *Problem Solving* standard reads that students will solve problems that arise in mathematics and in other

contexts. After a critical analysis of both standards documents, it is clear that both disciplines identify one another and with one another, but the scope or purpose of technology in mathematics is that of use. Mathematics education is primarily concerned about using technology to aid in instruction (instructional technology, e.g., computers, calculators, software) and student learning. Technology education is more focused on how to use mathematics to solve technological problems.

This chapter highlights the historical trajectories that exist between mathematics and technology education. Within these historical trajectories, the evolution of mathematics is highlighted, including the apparent and disproportional connection between mathematics and technology, research in both educational fields, applications of technology and mathematics in the form of problem solving, curricular and instructional efforts in both mathematics and technology education, and the integration between and among these disciplines.

HISTORICAL TRAJECTORIES

A brief examination and comparison of the historical trajectories of mathematics and technology education provides the background for a discussion of integration. In particular, each field has responded to the increasing pressures to better prepare students for the technologically rich, globally-competitive future. Approaches based within each discipline are varied across curriculum and instructional strategies. However, when examining the disciplines' historical paths, there are important similarities to consider in determining how to best impact student learning in both mathematics and technology education.

MATHEMATICS AND INSTRUCTIONAL TECHNOLOGY

From the perspective of the mathematics community, mathematics education and technology per se (not necessarily technology education) have had a close, but often contentious relationship. Many reports have called for better preparation in mathematics and science, and for increased skills for the technology-rich workplace of the 21st century (see, American Association of University Women (AAUW), 2000; Borgman, Abelson, Dirks, Johnson, Koedinger, Linn, Lynch, Oblinger, Pea, Salen, Smith, & Szalay, 2008; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Mathematics Advisory Panel, 2008). Yet, many parents and teachers see mathematics as a very traditional process of technology-independent practice. They see mathematics education learning as algorithms, facts, and procedures. The history of technology integration into mathematics is embedded in the developments and debates about mathematics education in general.

Herrera and Owens (2001) pointed to two distinct reform movements within mathematics: (a) the "new mathematics movement", and (b) the National Council of Teachers of Mathematics' (NCTM) standards-based reform; with an era of "back to basics" between the two movements. During the 1960s, the

new mathematics movement developed in response to the launch of Sputnik and concerns over the nation's technical and mathematical skills. The College Entrance Examination Board appointed a Commission on Mathematics, which developed a nine-point program that "called for preparation in concepts and skills to prepare for calculus and analytic geometry at college entry" (Herrera & Owens, 2001, p. 85). Hallmarks of the new mathematics included the precise language of sets, logic, algebraic structures, and pedagogical approaches of discovery.

Criticism of the new mathematics movement grew (Kline, 1973), however, and the "back to the basics" era began in the 1970s. The release of *A Nation at Risk* (National Commission on Excellence in Education, 1983) in the early 1980s and the results of the Second International Mathematics Study (McKnight, Crosswhite, Dossey, Kifer, Swafford, Travers, & Cooney, 1987), attention was again focused on curricular changes to improve the mathematical standing of American students. Growing concerns of the "back to basics" mathematics centered on the belief that the field of mathematics was not responsive to changes in society. It was the National Council of Teachers of Mathematics that came forward with an attempt to "create a coherent vision of what it means to be mathematically literate" in the *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics, 1989). The standards made explicit that technology should be used in teaching, stating that, "appropriate calculators should be available to all students at all times," (p. 8) and

> Technology, including calculators, computers, and videos, should be used when appropriate. These devices and formats free students from tedious computations and allow them to concentrate on problem solving and other important content. They also give them new means to explore content. As paper-and-pencil computation becomes less important, the skills and understanding required to make proficient use of calculators and computers become more important. (NCTM, 1989, p. 67)

Recommendations at the high school level also called for the use of technology. The integration of ideas from algebra and geometry has been particularly strong, with graphical representation playing an important connecting role. The standards also called for increased use of "computer-based explorations of 2-D and 3-D figures" and "real-world applications and modeling" as well as decreased attention to "paper-and-pencil graphing of equations by point plotting" and "paper-and-pencil solutions to trigonometric equations." Instructional technologies for the mathematics classroom were being developed and refined. The most dominant is the graphing calculator. Today, Texas Instruments sells over a hundred thousand calculators a year in Illinois alone (Texas Instruments, 2009). Software for doing mathematics with computers has also developed. Examples include dynamic geometry (Scher, 2000), computer-based algebra (Texas Instruments, 1997), and data analysis (Finzer, 2005).

This is not to imply that digital technologies have been readily adapted in

education. Professor Chris Dede said to the U.S. Congress that "If all computers and telecommunications were to disappear tomorrow, education would be the least affected of society's institutions" (Dede, 1995). In addition, during the 1990s, the advocated standards and technology were a cause of controversy, the so-called "math wars" in which technologies in the classroom were a part of the arguments.

The *Handbook of Research on Mathematics Teaching and Learning* (Grouws, 1992) appeared in 1992. It included a chapter by Kaput discussing technology and mathematics education (Kaput, 1992). Kaput noted that technology was changing so rapidly that it is difficult to know what the fundamental questions are with regard to mathematics education. Drawing analogies with the printing press and the automobile, he was reluctant to make predictions regarding the future of technology's impact on school mathematics.

If technology development itself was revolutionary, the research on its use in mathematics education has been focused on traditional outcomes. That is, most research assumes that digital technologies are a tool in the service of learning traditional mathematics rather than a revolutionary medium around which the goals of school mathematics might be rearranged. Typically, the burden is on a new technology to prove its utility in traditional mathematics instruction, rather than on a particular school mathematics topic to prove its utility in a digital age.

Research on the use of technology in mathematics classrooms was also limited. In the 25th Anniversary issue of the *Journal for Research in Mathematics Education*, Kaput (1994) noted that even though the first quarter century of *JRME* coincided with the electronic revolution, "perhaps two-thirds of all issues of *JRME* have no technology-related articles (p.680)."

In 2000, NCTM revised the standards, seeking to simplify and clarify their vision with the *Principles and Standards for School Mathematics* (*PSSM*). The *PSSM* are the basis for most of the discussion and development in the mathematics education community today. The *PSSM* contain six principles (Equity, Curriculum, Teaching, Learning, Assessment, and Technology), five content standards (Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability) and five process standards (Problem Solving, Reasoning and Proof, Communication, Connections, and Representation). The standards are broken down by grade level and are expanded upon in the Navigations Series (e.g., Pugalee, Frykholm, Johnson, Slovin, Malloy, & Preston, 2002) and with online resources and articles in NCTM journals.

Despite the controversies associated with the mathematics standards, the *PSSM* will almost certainly continue to be the focal point for discussion and development in mathematics education; technology is a crucial component of the *PSSM*. The "Vision for School Mathematics" described in the standards is still one in which "Technology is an essential part of the environment" (National Council of Teachers of Mathematics, 2000, p.3). Many of the exemplary lessons in the Navigations series include uses of spreadsheets, graphing calculators, and dynamic geometry programs. The *PSSM* are bolstered by online activities that

include Java applets and other technologies. Graphing calculators are permitted on the SAT, ACT, and Advanced Placement mathematics examinations. The proper use of technology in mathematics teaching and learning is still a source of debate even as development continues rapidly.

TECHNOLOGY EDUCATION AND PROBLEM SOLVING

In response to the changing needs of our technology-based society, technology education has emerged as a field of study in its own right. Technology education's roots are located in the manual/industrial arts education movement of the late 1800s. Whether or not technology education can be considered distinct from these earlier iterations is debatable (Foster, 1994). However, the current definition of technology education offered by the discipline's professional association, the International Technology Education Association (ITEA), shifts the focus of the discipline to the education and preparation of all students for a technological world through the development of technological literacy. With the development of *Standards for Technological Literacy* (*STL*) (ITEA, 2000/2002), the ITEA outlined what students should know and be able to do related to technology.

The curriculum of the early 1900s reflected the manual training and industrial arts movement of the time period with its primary focus on tool usage and design within the graphic, mechanical, plastic, textile, and bookmaking arts (Kirkwood, Foster, & Bartow, 1994). By the 1950s, manual/industrial arts or vocational education was an established aspect of the curriculum. During the 1960s, however dissention within the field began to develop. Three seminal documents were published that led to the development of three fractions or camps within industrial arts that lasted through the 1980s (DeVore's *Technology: An Intellectual Discipline* (1964); Towers, Lux, & Ray's *A Rationale and Structure for Industrial Arts Subject Matter* (1966); and Maley's *Maryland Plan* (1973)).

Throughout the greater part of the 20th century, schools offered a variety of classes that fell under the umbrella of manual/industrial arts, including industrial education, industrial technology education, and technology education. However, by the 1980s these programs began to suffer a decline due to incoherence in the field, a loss in credibility, and changing demands of high school graduation requirements (Hansen & Reynolds, 2003). Spurred by reports such as *A Nation at Risk*, the educational system responded in ways that largely excluded technology education. In an attempt to reach a consensus on the direction of the field and respond to its decline, the *Jackson's Mill Industrial Arts Curriculum Theory* was developed in 1981. The Jackson's Mill Project has been referred to as the "starting point of the modern era of technology education" (Wicklein, 2006, p. 25). The Jackson's Mill Project initiated a set of events that moved the field toward technology education. The *Standards for Industrial Arts Programs* (*SAIP*) were developed during this time period to: (a) create a database of industrial arts programs, (b) develop a set of standards for quality programs, and (b)

publicize the standards (Dugger, 2002). The *SAIP* were revised by the American Industrial Arts Association in 1985, resulting in the *Standards for Technology Education Programs*. During this same time period, the American Industrial Arts Association, which was founded in 1939 by William E. Warner, changed its name to the International Technology Education Association in 1985. In the late 1980s, Savage and Sterry convened 25 leaders to "create a product that would provide a framework for the study of technology in the 1990s" (Savage, 2002, p. 98). This framework, titled *A Conceptual Framework for Technology Education*, endorsed the domains of knowledge of the Jackson's Mill Theory and added a dimension of problem solving.

By the late 1990s and into the present, the field has largely transitioned into technology education. The expanded mission of the field was articulated in the *Technology for All Americans Project* (ITEA, 1996). This project was funded by the National Science Foundation and the National Aeronautics and Space Administration in 1994 with the first of three phases focused on articulating a rationale for technology education. The phases resulted in: (a) *Technology for All: A Rationale and Structure for the Study of Technology* (1996/2004), (b) *Standards for Technological Literacy: Content for the Study of Technology* (*STL*), and (c) *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* (ITEA, 2003).

The expanded mission and philosophy of technology education, however, have not been universally adopted in the United States (Sanders, 2001) and, according to Spencer and Rogers (2006), have led to widespread confusion both within the discipline and amongst the public. Perhaps in response, the ITEA and teacher preparation institutions have undergone "extensive activity related to the promotion of awareness, adoption, and implementation of *STL* since its publication in 2000" (Russell, 2005, p. 37). This effort has seemed to pay off with *STL* "being used by a majority (over 91%) of states as a model for developing state technology education standards" (Dugger, 2007, p. 20). However, as Dugger pointed out, the "bottom line is that technology education is still an elective in most states" (p. 20). Any substantive change to embrace a philosophy of technology education by schools is voluntary. For example, in 2007, Dugger researched the status of technology education in the U.S. by surveying state technology education supervisors, with 46 states represented in the sample. The data indicated that 40 of those states included technology education in their frameworks, with only 12 requiring coursework. As Wicklein (2006) argued, "with all of the efforts, documentation, and developmental work supporting the national need for a technologically literate citizenry, it seems that there has been little practical and comprehensive advancement of technology in most public schools" (p. 25).

As technology education has evolved, little emphasis has been explicitly placed on mathematics. The roots of technology education in the manual arts and the current status of technology education in schools, often shifts the curricular focus away from "core" academics to an emphasis on more "practical" knowledge

and skills. In targeting sustainable enrollment numbers, technology education programs often emphasize the hands-on and "fun" aspects of their courses, deemphasizing specific learning outcomes in mathematics and other disciplines. However, implicit in technology education's emphasis on authentic problem solving is the incorporation of both mathematical and scientific principles in solving technological problems. It has been argued that the major program goals of technology education include "adaptive, critical thinking, problem-solving skills and development in all domains of learning" (Zargari & MacDonald, 1994, p. 10).

INTEGRATION

Given the historical trajectories of mathematics and technology education, there appears to be room for both disciplines to collaborate on developing effective practices. In particular, the mathematics community has increasingly embraced the use of different instructional technologies as tools and contexts for learning mathematical principles. Within technology education, mathematical principles are increasingly emphasized in authentic problem solving contexts. The *PSSM*, as does *STL*, emphasizes the development of students' problem solving skills in both abstract and applied contexts. It seems likely that both communities would benefit from collaborative activities and research. It appears that both disciplines' trajectories are aligning to make those efforts more feasible and necessary. There are well-established standards in both fields and new programs have been developed to implement those standards. In addition, both mathematics and technology education have had major curricular development in recent years.

MATHEMATICS EDUCATION CURRICULA

A flurry of mathematics curricula development began after the release of the NCTM Standards in 1989. The National Science Foundation funded the development of many of these programs. The research basis for these programs included the cognitive science developments of previous decades laid out in the research publications of NCTM, such as the 1992 handbook and the articles published in *JRME* and other peer-reviewed journals. These new curricula emphasized conceptual learning and many had a modular, thematic approach that integrated the content strands. For example, in a module of the Interactive Mathematics Program (Fendel, Resek, Alper, & Fraser, 2004), the "Game of Pig" (a dice game) is a theme. Students work on probability, averaging, recognizing patterns, and making predictions through learning the rules of a simple game and exploring the expected value. "Frogs, Fleas, and Painted Cubes" (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1998) explores quadratic relationships through area and perimeter problems. In general, the new curricula had more hands-on activities and fewer drill and practice exercises. They also appeared at a time when instructional technology in mathematics was becoming more powerful

and inexpensive enough to start appearing in classrooms. Java applets, dynamic geometry software, and computer algebra systems are a few of the other tools that were rapidly developed in the 1990s.

Today, the revised curricula that are based on the *PSSM* contain frequent technology applications. For example, the high school curricula College Preparatory Mathematics (Sallee & Hoey, 2002) and Core-Plus (Coxford, Fey, Hirsch, Schoen, Burrill, Hart, Watkins, Messenger, & Ritsema, 1998) both have graphing calculators as important components of typical lessons. Programs such as the Cognitive Tutor (Hadley, 1998-2001) make extensive use of the computer. Even at the university level there are technology-rich options for learning mathematics. The Calculus & *Mathematica* course (Uhl, 2002), for example, has all lectures and homework assignments in the form of *Mathematica* notebooks. However, there is still very little data on how widely the reform curricula have been adopted and which curricula are most effective (National Research Council, 2004).

The need for impact data is heightened by the fact that the new mathematics curricula have been the subject of the "math wars" debates (Colvin, 1999; Ralston, 2003; Schoen, Fey, Hirsch, & Coxford, 1999; Schoenfeld, 2004). What started as disagreements about the implications of the 1989 Standards and the curricula they spawned was elevated with the release of a report in 1999 listing of "exemplary and promising" curricula in mathematics education (U.S. Department of Education's Mathematics and Science Expert Panel, 1999). It turned out that all the exemplary and promising curricula were based on the NCTM Standards. A group of concerned parents and mathematicians, calling themselves the "Mathematically Correct," called on then Secretary of Education, Richard Riley, to retract the recommendations in the report (Mathematically Correct, 1999). As an example of the disputes, consider the following: the popular middle school program Connect Mathematics was "exemplary" according to the Department of Education's report but received a grade of "F" according to the Mathematically Correct group (Stein, Remillard, & Smith, 2007).

The controversy continues to this day with debates on which curricula are best and how to measure their impact. Evaluating the curricula is a complex task, and rigorous comparisons are very hard to do. The so-called "gold standard," randomized trials with experimental and control groupings, is difficult and expensive, and not enough studies have been done to draw definitive conclusions (see, National Research Council, 2004, p. 3). Nonetheless, the standards continued to influence curriculum development and professional development for mathematics teachers.

The role of technology in mathematics curricula and in mathematics teaching and learning is also uncertain and contentious. A study by Wenglinsky (1998) looked at NAEP data and found that using computers, especially for drill and practice, had a negative correlation with student achievement in mathematics at the fourth and eighth grades. Yet, ten years later, the report of the National

Mathematics Advisory Panel recommended that "Use of technology shows promise when: Computer-assisted instruction supports drill and practice" (Faulkner, 2008). And of course, clarity is hindered by the reality that digital technologies are a moving target for impact studies. As growing numbers of students have cell phones, computers, mp3 players, and sophisticated video games, computer literacy can be assumed by mathematics teachers. Yet, many teachers remain unsure if technology is a ladder or a crutch for students (Brown, Karp, Petrosko, Jones, Beswick, Howe, & Zwanizig, 2007), and best practices must be constantly evolving as the tools change.

MATHEMATICS INSTRUCTION

The standards-based curricula include more opportunities for hands-on activities, collaborative problem solving, and multiple types of assessment both of and for learning. They also expect that technology will be "an essential component" (National Council of Teachers of Mathematics, 2000, p. 3) of the standards-based classroom. Teachers will be using technology to help students "make, refine, and explore conjectures on the basis of evidence and use a variety of reasoning and proof techniques" as they work.

However, simply because the standards and supporting technologies are available does not mean those standards are implemented. While some teachers embrace the new curricula and actively promote the learning environment, other times the curricula are only partially implemented. Implementation may also be subverted by lack of teacher buy-in, lack of professional development, or by established classroom routines that conflict with new approaches (Lambdin & Preston, 1995). Finally, teachers have differing views on the role of textbooks as sources for day-to-day curricular activities. Some teachers view them as templates to be followed strictly, but others see them as only one type of resource among the many needed for day-to-day teaching (Remillard, 2005).

The new curricula seem to have improved conceptual understanding while doing no harm to procedural knowledge (Senk & Thompson, 2003), especially if implemented in a "standards-based learning environment" (Tarr, Reys, Reys, Chavez, Shih, & Osterlind, 2008). However, it is not currently known how widely the reform-based materials have been adopted or how faithfully they have been implemented, especially at the high school level. With nearly 100,000 active members, it is fair to say that the NCTM represents the most influential professional organization for mathematics teachers, the standards, the *PSSM*, and the curricula created from them have had a significant impact on the dialogue regarding what mathematics should be taught and how. The impact of NCTM is further reinforced with the Second *Handbook of Research on Mathematics Teaching and Learning* (Lester, 2007), which now includes a chapter on "How curriculum Influences Student Learning" (Stein, Remillard, & Smith, 2007) that examines the philosophies reform curricula, their approach to instruction, and the controversy surrounding them.

Adding to the already complex situation is the No Child Left Behind Act, which requires testing in reading, science, and mathematics. This puts additional performance pressures on mathematics students, but also on teachers and school administrators. The standardized tests are now high stakes for an entire school district. Meanwhile, as American students continue to be faced with higher expectations for learning, the public continues to get reports that indicate American education is inferior to the education in Asian countries. So there is great pressure on the education community to improve mathematics achievement. There is also a growing market of educational technology that is being incorporated into mathematics curricula. However, the terrain of curricula and technology remains contested and the connection of mathematics education to technology education has only begun.

Technology Education Curriculum

Although technology education does not have a uniform curriculum, as a field there have been general trends. During the move toward technology education, programs began to change "from traditional wood and metal shops to more advanced technological concepts" (Spencer & Rogers, 2006, p. 95). In 1987, two middle school teachers in Pittsburg, Kansas redesigned and reconfigured their teaching laboratory to reflect modular learning experiences. This model of classroom design "started a nationwide redesign in both physical characteristics of technology education laboratory and the curricular format in the delivery of technology" (Wicklein, 2006, p. 25). Although modular technology education continues to exist throughout technology classrooms, many programs have shifted to a technological problem-solving approach to instruction. As Sanders (2001) discovered in his survey of technology programs in the United States, "roughly three programs in four are using either the modular technology education or technological problem-solving approach to instruction, while one program in four prefers the project-from-plans method" (p. 52).

More recently, technology education has increasingly embraced an engineering-oriented perspective with the hope that engineering will "not narrow the choices" (Salinger, 2005, p. 3) for technology education but broaden them. For example, Warner and Morford (2004) found in their study that 57 technology education programs were offering coursework on the study of design. In addition, different initiatives such as curriculum development projects and National Science Foundation funded projects such as the National Center for Engineering and Technology Education (NCETE) have been developed to infuse engineering into primary and secondary education. For example, one key goal of the Technology Teacher Education component of NCETE was to impact the focus and content of the technology education field at the secondary level (Hailey, Erekson, Becker, & Thomas, 2005). The discourse about the implementation of engineering design into technology education has largely centered on "problem solving and the application of scientific understanding to a given task" (Hill & Anning, 2001, p. 118).

In particular, numerous curriculum projects have been initiated to incorporate various elements of technology education, from technological problem solving to engineering design. A few of these projects include *Project Lead the Way*™ (PLTW), *Engineering byDesign*, and *Engineering the Future: Science, Technology, and the Design Process*™ (EtF). PLTW is a 501(c)(3) not-for-profit corporation that, according to its website, "works with schools to implement an instructional program to prepare students to be successful in post secondary engineering and engineering technology programs." PLTW is the organization that provides leadership and financial support, teacher training and curriculum development, and consultant services (Blais & Adelson, 1998). The PLTW middle school program called *Gateway to Technology* contains six nine-week courses. The high school program called *Pathway to Engineering* is divided into three tiers: (a) foundation courses; (b) specialization courses; and (c) capstone courses.

Engineering byDesign is operated from the Center to Advance the Teaching of Technology and Science (CATTS), which is the professional development arm of the International Technology Education Association (ITEA). CATTS' efforts are directed toward four goals: (1) development of standards-based curricula; (2) teacher enhancement; (3) research concerning teaching and learning; and (4) curriculum implementation and diffusion. One of those efforts is the *Engineering byDesign* curriculum, which is a standards-based national model for grades K-12 that delivers technological literacy. A network of teachers (EbD™ Network) has been selected to collaborate and conduct action research in order to better understand the complexities of student learning.

Spurred by a desire to develop an engineering course that delivers technological literacy for all first or second year high school students, the National Center for Technological Literacy at the Museum of Science in Boston published Engineering the Future (EtF) in 2007. EtF is a one year course designed to meet technology education standards; foster inquiry, critical thinking, and hands-on problem solving; and utilize a variety of assessments. A central goal of the EtF course is to "communicate how everyone is influenced by technology, and in turn influences future technological development by the choices they make as workers, consumers, and citizens" (Sneider & Brenninkmeyer, 2007, p. 6).

Technology Instruction

A point of contention surrounding the incorporation of engineering design is how it is implemented within technology education and the knowledge base it requires for teaching and learning. Lewis (2005) characterized two approaches to engineering design: (a) conceptual and (b) analytic. Conceptual design is the point where engineering science, practical knowledge, production knowledge and methods, and commercial aspects are brought together. Lewis argued that this type of design is "within the normal purview of technology education" (p. 48). Analytic design, however, relies upon mathematics and scientific principles to make decisions and "poses a challenge" (p. 48) for technology education.

This issue relates directly to another point of contention, the "inauthentic" approach of teaching technological problem solving and design. Many instructors have taught problem solving and design with a prescriptive, step-by-step, model or a trial-and-error approach. Wicklein and Thompson stated that this approach has common features including: (a) the identification of a problem, (b) the development of a proposal, (c) the creation of a model or product, and (d) the evaluation of the model or product. Engineers, however, design in an iterative, non-predetermined manner and typically "predict the behavior of the design and the success of a solution before it is implemented" (Wicklein & Thompson, p. 57). In addition, design is context-specific, in that it is "shaped by the tools and resources available and adapts to the specific, and changing, situation" (McCormick, Murphy, & Hennessy, 1994, p. 6), further complicating its implementation into the K-12 classroom.

Many teachers have structured the learning experiences around a general problem-solving process. However, as McCormick, Murphy, and Hennessy (1994) have pointed out, the research does not support a general process and warned that technology educators should re-examine this approach. They argued that teachers need to be aware of the cognitive demands placed on students and select problems carefully. Middleton (2005) concurred, arguing that the problems selected should be meaningful to the students. The ideas and processes involved in the problem-solving process with which students engage needs to be "connected to the lived world rather than being abstracted from it" (Middleton, p. 67). Engineering design has emerged in the literature and within the technology education field as an avenue to develop meaningful and authentic problem solving capabilities in students (Burghardt & Hacker, 2004).

Engineering design can be viewed as a form of problem solving, "where there is the requirement that, in addition to solving the problem, the solution be creative" (Middleton, 2005, p. 65). Design problems, however, are usually among the most complex and ill-structured kinds of problems that individuals encounter (Jonassen, 2000). Amongst engineers and other professional designers, "a certain degree of consensus exists regarding the overall definition and stages of the design process: identification of problems and diagnosis of needs, through a series of loops at which solutions are conceived, explored and evaluated until a suitable answer is found and then instantiated" (Mioduser, 1998, p. 177). However, beyond that general consensus, the process is open and flexible, allowing space for a variety of possible problem definitions and solution paths. Expert designers often cycle through the design process, "expanding creative thinking, generating ideas, analyzing them and making a selection" (Court, 1998, p. 145), in an iterative, not predetermined manner.

Within the classroom, Burghardt and Hacker (2004), in a synthesis of the related literature, found that "pedagogically solid design projects involve authentic, hands-on tasks; use familiar and easy-to-work materials; possess clearly defined outcomes that allow for multiple solutions; promote student-centered, collaborative

work and higher order thinking; allow for multiple design iterations to improve the product; and have clear links to a limited number of science and engineering concepts" (p. 6). With general problem-solving, many instructors, however, have taught engineering design by implementing a prescriptive, step-by-step approach, typically through a design process model. The prescriptive approach to teaching design has been increasingly criticized because it contradicts both expert and novice designers' approaches to problem solving and design processes (Mawson, 2003; Welch, 1999; Williams, 2000) The prescriptive approach also runs the risk of overly simplifying the complex process of design and stifling student creativity (Lewis, Petrina, & Hill, 1998).

Conclusion

There are several similarities between and among technology and mathematics education: (a) both disciplines have developed learning standards; (b) both make use of instructional technologies; (c) both have a call for further study to discover more effective curricular and instructional approaches; (d) both have contention within the ranks as to the purpose of the subjects; (e) both have teachers and schools that see no reason to change from prior practices; (f) both disciplines call for an applied/integrative/authentic approach; and (g) both disciplines have evolved based on the needs of society.

Mathematics education has been the object of research and development for decades longer than technology education and has typically viewed technology as just another tool among the others for learning the traditional content of mathematics. A key component in the future of mathematics education, technology education, and their synergies, is the character of the research questions that are asked and how those questions are operationalized.

> From the onset of a study, the questions that one chooses to ask and the data that one chooses to gather have a fundamental impact on the conclusions that can be drawn. Lurking behind the framing of any study is the question of what is valued by the investigators, and what is privileged in the inquiry (Schoenfeld, 2007, p.70).

If the research focus is on whether a particular technology (or technology in general, whatever that might mean) improves test scores, we may miss the opportunity to bridge two essential domains for student success in the modern world.

We assert that there is, or at least should be, a growing symbiosis between technology education and mathematics education. Mathematics educators are seeking both rigor and relevance in curriculum and instruction at the same time that technology education is determining its role in general education, career and technical education, and pre-engineering. The overlap of interests is obvious and will be solidified by research and development on the mechanisms that best prepare students to be simultaneously technologically and mathematically literate.

It is a premise of both disciplines that the ways in which the subjects are

taught is an essential component to how well students learn. Key to this notion is the authenticity of the task. That is, how closely do the problem situations in a classroom setting resemble those that are confronted by a mathematician, an engineer, or a mathematically and technologically literate citizen? It is clear that a connection between the two disciplines exists, but further collaboration, authentic learning activities, research-based findings, and above all, communication between the disciplines, needs to continue and flourish.

References

American Association of University Women (AAUW). (2000). *Tech-savvy: Educating girls in the new computer age* (Executive Summary). Washington, DC: American Association of University Women. Available at http://www.aauw.org/research/girls_education/techsavvy.cfm.

Blais, R. R., & Adelson, G. I. (1998). Partnerships in education: Project Lead the Way...Models a program for changing technology. *Tech Directions*, *58*(4), 40-43.

Borgman, C. L.*, et al.* (2008). *Fostering learning in the networked world: The cyberlearning opportunity and challenge, A 21st Century agenda for the National Science Foundation* (Repot of the NSF Task Force on Cyberlearning). Washington, D.C.: National Science Foundation.

Bottoms, G., & Uhn, J. (2007). *Project Lead The Way works: A new type of career and technical program* (Research Brief). Atlanta, GA: Southern Regional Education Board.

Burghardt, M. D., & Hacker, M. (2004). Informed design: A contemporary approach to design pedagogy as the core process in technology. *The Technology Teacher*, *64*(1), 6-8.

Brown, E. T., Karp, K., Petrosko, J. M., Jones, J., Beswick, G., Howe, C., & Zwanizig, K. (2007). Crutch or catalyst: Teachers' beliefs and practices regarding calculator use in mathematics instruction. *School Science and Mathematics*, *107*(3), 102-116.

Colvin, R. L. (1999, November 18). Experts attack math teaching programs. *Los Angeles Times*.

Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

Court, A. W. (1998). Improving creativity in engineering design education. *European Journal of Engineering Education*, 23(2), 141-154.

Coxford, A. F., Fey, J. T., Hirsch, C. R., Schoen, H. L., Burrill, G., Hart, E. W., Watkins, A. E., Messenger, M. J., & Ritsema, B. (1998). *Contemporary mathematics in context: A unified approach, Course 1A, Part A*. New York, NY: Glencoe McGraw-Hill.

Dede, C. (1995). Testimony to the U.S. Congress, House of Representatives.

Joint Hearing on Educational Technology in the 21st Century, Committee on Science and Committee on Economic and Educational Opportunities. *New Horizons for Learning*. Retrieved March 13, 2004, from the World Wide Web: http://www.virtual.gmu.edu/ss_pdf/congress.pdf

DeVore, P. (1964). *Technology: An intellectual discipline*. Bulletin No. 5. Washington, DC: American Industrial Arts Association.

Dugger Jr., W. E. (2002). Roots of technology education: Standards project. *Journal of Technology Studies*, *28*(2), 96-98.

Dugger, W. E. (2007). The status of technology education in the United States: A triennial report of the findings from the states. *The Technology Teacher*, *67*(1), 14-21.

Faulkner, L. R. (2008). *Foundations for success: National Mathematics Advisory Panel (Final Report Briefing)*. Washington, D.C.: U. S. Department of Education.

Finzer, W. (2005). Fathom: Dynamic Data Software (Version 2.0): Key Curriculum Press.

Fendel, D., Resek, D., Alper, L., & Fraser, S. (2004). *Interactive mathematics program: Integrated high school mathematics, Year 1*. Emeryville, CA: Key Curriculum Press.

Foster, P. (1994). Technology education: AKA industrial arts. *Journal of Technology Education*, *5*(2), 15-30.

Hadley, W. S. (1998-2001). *Cognitive Tutor: Algebra 1*. Pittsburgh, PA: Carnegie Learning, Inc.

Hansen, L. S., & Reynolds, C. J. (2003). The future of industrial technology education at the K-12 level. *Journal of Industrial Teacher Education*, *40*(4), 36-46.

Hailey, C. E., Erekson, T., Becker, K., & Thomas, M. (2005). National Center for Engineering and technology education. *Technology Teacher*, *64*(5), 23-26.

Hill, A. M., & Anning, A. (2001). Primary teachers' and students' understanding of school situated design in Canada and England. *Research in Science Education*, *31*(1), 117-135.

Herrera, T. A., & Owens, D. T. (2001). The "new new mathematics"? Two reform movements in mathematics education. *Theory into Practice*, *40*(2), 84-92.

International Technology Education Association. (1996/2004). *Technology for all: A rationale and structure for the study of technology*. Reston, VA.

International Technology Education Association. (2000/2002). *Standards for Technological Literacy: Content for the Study of Technology*. Reston, VA.

International Technology Education Association. (2003). *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards.* Reston, VA.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *ETR&D*,

48(4), 63-85.

Kaput, J. J. (1992). Technology and mathematics education. In D. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 515-555). New York, NY: Macmillan Publishing Company.

Kaput, J. J., & Thompson, P. W. (1994). Technology in mathematics education research: The first 25 years in the JRME. *Journal for Research in Mathematics Education, 25*(6), 676-684.

Kirkwood, J. J., Foster, P. N., & Bartow, S. M. (1994). Historical leaders in technology education philosophy. *Journal of Industrial Teacher Education*, *32*(1), Retrieved March 3, 2008, from http://scholar.lib.vt.edu/ejournals/JITE/v32n1/Kirkwood.html

Kline, M. (1973). *Why Johnny can't add: the failure of the new math*. New York,: St. Martin's Press.

Lambdin, D. V., & Preston, R. V. (1995). Caricatures in innovation: Teacher adaptation to an investigation-oriented middle school mathematics curriculum. *Journal of Teacher education*, *46*, 130-140.

Lappan, G., Fey, J. T., Fitzgerald, W. M., Friel, S. N., & Phillips, E. D. (1998). *Frogs, fleas, and painted cubes: Quadratic relationships*. White Plains, NY: Dale Seymour.

Lester, F. K., Jr., (Ed.). (2007). *Second Handbook of Research on Mathematics Teaching and Learning*. Charlotte, NC: Information Age Publishing.

Lewis, T. (2005). Coming to terms with engineering design as content. *Journal of Technology Education*, *16*(2), 37-54.

Lewis, T., Petrina, S. & Hill, A. M. (1998). Problem posing: Adding a creative increment to technological problem solving. *Journal of Industrial Teacher Education*, *36*(1), 5-35.

Mathematically Correct. (1999). An open letter to United States Secretary of Education, Richard Riley. Available at http://mathematicallycorrect.com/riley.htm.

Maley, D. (1973). *The Maryland plan*. New York: Benzinger, Bruce & Glencoe.

Mawson, B. (2003). Beyond 'the design process': An alternative pedagogy for technology education. *International Journal of Design Education*, *13*(2), 117-128.

McKnight, C. C., Crosswhite, F. J., Dossey, J. A., Kifer, E., Swafford, J. O., Travers, K. J., & Cooney, T. J. (1987). *The underachieving curriculum: Assessing U.S. school mathematics from an international perspective*. Champaign, IL: Stipes Publishing Company.

Middleton, H. (2005). Creative thinking, values and design and technology education. *International Journal of Technology and Design Education*, *15*(1), 61-71.

Mioduser, D. (1998). Framework for the study of cognitive and curricular issues of technological problem solving. *International Journal of Technology and Design Education*, *8*(2), 84-167.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: U.S. Department of Education.

National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before it's too late: A report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*. Washington, DC: U.S. Department of Education.

National Council Teachers of Mathematics. (1980). *An agenda for action: Recommendations for school mathematics of the 1980s.* Reston, VA: NCTM.

National Council Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: NCTM.

National Council Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA: NCTM.

National Council Teachers of Mathematics. (1995). *Assessment standards for school mathematics*. Reston, VA: NCTM.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel*. Jessup, MD: U.S. Department of Education.

National Research Council. (2004). *On evaluating curricular effectiveness: Judging the quality of K-12 mathematics evaluations*. Washington, D.C.: The National Academies Press.

Pugalee, D. K., Frykholm, J., Johnson, A., Slovin, H., Malloy, C., & Preston, R. (2002). *Navigating through geometry in grades 6-8*. Reston, VA: National Council of Teachers of Mathematics.

Ralston, A. (2003). California dreaming: Reforming mathematics education (book review). *Notices of the American Mathematical Society (AMS)*, 1245-1249.

Remillard, J. T. (2005). Examining Key Concepts in Research on Teachers' Use of Mathematics Curricula. *Review of Educational Research*, *75*(2), 211-246.

Russell, J. F. (2005). Evidence related to awareness, adoption, and implementation of the Standards for Technological Literacy: Content for the study of technology. *Journal of Technology Studies, 31*(1), 30-38.

Salinger, G. L. (2005). The Engineering of Technology Education. *Journal of Technology Studies, 31*(1), 2-6. Available at http://search.ebscohost.com/login.aspx?direct=true&db=tfh&AN=21888088&site=ehost-live.

Sallee, T., & Hoey, B. (2002). *College Preparatory Mathematics 1: (Algebra 1)*. Sacramento, CA: CPM Education Program.

Sanders, M. (2001). New paradigm or old wine? The status of technology education practice in the United States. *Journal of Technology Education*,

12(2), 35-55.

Savage, E. N. (2002). A conceptual framework for technology education: A historical perspective. *The Journal of Technology Studies*, *28*, 98-100.

Scher, D. (2000). Lifting the curtain: The evolution of Geometer's Sketchpad. *The Mathematics Educator*, *10*(1), 42-48.

Schoen, H. L., Fey, J. T., Hirsch, C. R., & Coxford, A. F. (1999). Issues and Options In the Math Wars. *Phi Delta Kappan, 80*(6), 444. Available at http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=1515997&site=ehost-live.

Schoenfeld, A. H. (2004). The Math Wars. *Educational Policy, 18*(1), 253-286. Available at http://epx.sagepub.com/cgi/content/abstract/18/1/253.

Schoenfeld, A. H. (2007). Method. In F. K. Lester, Jr. (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning* (Vol. 1, pp. 69-107). Charlotte, NC: Information Age Publishing.

Senk, S. L., & Thompson, D. R. (2003). *Standards-based school mathematics curriculs: What are they? What do students learn?* Mahwah, NJ: Lawrence Erlbaum Associates.

Sneider, C., & Brenninkmeyer, J. (2007). *Achieving technological literacy at the secondary level: A case study from Massachusetts.* Paper presented at the Professional development for engineering and technology: A national symposium, Dallas, TX.

Spencer, B. R., & Rogers, G. E. (2006). The nomenclature dilemma facing technology education. *Journal of Industrial Teacher Education*, *43*(1), 91-99.

SREB. (not dated). *High Schools That Work: An Enhanced Design to Get All Students to Standards: Southern Regional Education Board,*. Available at http://www.sreb.org/programs/hstw/publications/2005Pubs/05V07_enhanced_design.pdf.

Stein, M. K., Remillard, J. T., & Smith, M. (2007). How curriculum influences student learning. In F. K. Lester, Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (Vol. 1, pp. 319-369). Charlotte, NC: Information Age Publishing.

Tarr, J. E., Reys, R. E., Reys, B. J., Chavez, O., Shih, J., & Osterlind, S. J. (2008). The impact of middle-grades mathematics curricula and the classroom learning environment on student achievement. *Journal for Research in Mathematics Education*, *39*(3), 247-280.

Texas Instruments. (1997). Cabri Geometry II. Austin, TX: Texas Instruments. Available at www.ti.com/calc.

Texas Instruments. (personal communication, 2009).

Towers, E., Lux, D., & Ray, W. (1996). *A rationale and structure for industrial arts subject matter*, ERIC Document Reproduction Service no. ED 013 955.

Uhl, J. (2002). Calculus & *Mathematica* [World Wide Web]. Retrieved April 21, 2002, from the World Wide Web: http://www-cm.math.uiuc.edu/

U.S. Department of Education's Mathematics and Science Expert Panel. (1999). *Exemplary & promising mathematics programs*. Washington, D.C.: United States Department of Education. Available at http://www.eric.ed.gov/ ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/15/de/f1.pdf

Warner, S. A., & Morford, L. L. (2004). The status of design in technology teacher education in the United States. *Journal of Technology Education*, *15*(2), 33-45.

Welch, M. (1999). Analyzing the tacit strategies of novice designers. *Research in Science & Technological Education*, *17*(1), 19-34.

Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Princeton, NJ: Educational Testing Service (ETS).

Wicklein, R. C. (2006). Five good reasons for engineering design as the focus for technology education. *The Technology Teacher*, *65*(7), 25-29.

Williams, P. J. (2000). Design: The only methodology of technology? *Journal of Technology Education*, *11*(2), 48-60.

Zargari, A., & MacDonald, K. (1994). A history and philosophy of technology education. *The Technology Teacher*, *52*(8), 7-11.

Research on Teaching and Learning in Science Education: Potentials in Technology Education

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Chapter
10

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Learning is personal, contextualized, and takes time. To be successful, teaching must attend to each of these criteria and be grounded in the knowledge of practice, the learner, and the learning process.

INTRODUCTION

This chapter presents a discussion around contemporary teaching and learning research in science education that holds promise for informing the educational research efforts on classroom practices in technology education. Ultimately, the goal of this chapter is to highlight select genre of science education research that are compatible with, and parallel to, areas of needed research on the teaching/learning practices in technology education. The approach begins by first presenting the framework around which science education research has been organized, followed by highlighting strategic areas of pedagogical crossover, and concluding with attention to select research efforts in science education regarding the linkages between the teaching/learning (pedagogical) process and teacher knowledge. The intent is to draw on various aspects of science education research as a means of encouraging new perspectives on organizing the investigation of educational practices in technology education.

Historically speaking the connection between science and technology has long been established with broad acceptance of the reciprocal impact of developments in one field on advancements in the other. In education, the potential for using those connections to improve students' science and technology literacy and to instill a deeper functional understanding of content in both areas is today well recognized. Yet of these two school subjects, science is a nationally established core content area, while technology is typically relegated to an elective. There is a deep societal discrepancy in perceived value of the teaching and learning outcomes afforded students by these two school disciplines, which to some degree is empirically supported. In science the connection between value and empirical

evidence is clearly conveyed in the science assessment framework: "Science is a way of knowing about the natural world that is based on tested explanations supported by accumulated empirical evidence" (NAGB, 2008 p. 10). Educational research is one of the primary vehicles through which school disciplines establish the credibility of their programs for promoting student learning of core knowledge and skills at the PK-12 level. In science education one cannot but be impressed by the scope of research on teaching and learning published by those in the field for nearly a century. The shear number of science education researchers makes possible a breadth and depth of empirical investigation not afforded the emergent field of technology education.

Cognizant of the important relationship between empirical evidence and valued pedagogical practice, researchers in technology education have repeatedly sought to document an empirical framework for the field. Prior analyses of published research in technology education over the past several decades (McCrory, 1987; Waetjen, 1992; Foster, 1992, 1996; Zuga, 1994, 1995, 1997; Petrina, 1998; Lewis, 1999; Hoepfl, 2002, 2007) revealed significant gaps in the research needed to establish the viability of pedagogical practices in technology education. The most recent analyses and summary assessments (Johnson & Daugherty, 2008; Wells, et al, 2008, 2009) of published technology education studies further verified previous findings regarding those gaps in technology education research. This chapter focuses on three of the identified gaps in technology education research – design-based teaching/learning, integrative practices, teacher knowledge – that have particular relevance to areas of teaching and learning research conducted in science education. These gaps align well with analogous topics addressed within the genre of learning theory and pedagogical practice around which science education research has been organized, and serve as the framework for discussions in this chapter.

In a field not accustomed, or perhaps even prepared to conduct such challenging research along the lines and at the level called for (Zuga, 2001), technology education researchers would benefit from better understanding the approach to educational research in other school disciplines having similar/corollary practices, related educational standards, and close historical connections to the field of technology education (Lewis, 1999). Science education represents a school discipline that has long historical ties with technology education and strong parallels in both content and pedagogical practices. Drawing on the structure of teaching and learning research in science education has potential for providing direction for the types of research in technology education necessary for developing its credibility as a school subject. For these reasons science education is ideally suited to providing insights for developing the necessary framework of research needed in technology education to empirically document its viability as a school subject that contributes substantively to learning of core concepts/content at the PK-12 level.

The current framework used to organize research on science education is logically aligned with the National Science Education Standards (NSES)

(NRC, 1996) and the science assessment framework for 2009-2021 developed by the National Assessment Governing Board (NAGP, 2008). To understand the alignment of frameworks calls for some discussion that will provide a basis for envisioning similar alignments to frame the educational research agenda in technology education.

SCIENCE EDUCATION: ASSESSMENT, STANDARDS, AND RESEARCH FRAMEWORK

"…we will only be effective if we begin with the end in mind." — *S. Covey*

To achieve a learning goal, one structures the instructional process by beginning with the end in mind; i.e. what is to be learned and how will achievement of that learning be assessed? Assessment seeks to measure the degree to which the learner achieves a stated outcome (end) (Linn & Gronlund, 2000). The "ends" identified in the 2009-2021 framework for the national assessment of science education progress (NAGB, 2008) are structured around two broad dimensions - content and practice - both of which were based on the 1996 NSES and benchmarks. The 2009 NAEP science framework defines the content dimension through a series of content statements that describe the key principles, concepts, and facts which are organized according to three content areas: physical science, life science, and earth and space science. Likewise, four practices define the practice dimension: identifying science principles, using science principles, conducting science inquiry, and using technological design (p. 21-22). Dividing the assessment across only the dimensions of content and practice both simplifies and clarifies the main "ends" of the educational process – what students should know and be able to demonstrate.

In science education the content dimension is defined by the following three broad areas: physical science, life science, and earth and space science. To assess student learning in these areas proposition statements were developed by the NAGB (2008) to reflect the key principles, concepts, and facts for each content area. The proposition statements alone do not describe the learner's performance in observable terms. To do this they must be crossed with science practices so as to generate performance expectations, which ultimately allow for inferences to be made about what the learner knows and can do in science. Crossing content areas with practices allows for both to be assessed concurrently, with comparisons made between expected performances and observed performances (Figure 1). As a result, assessment of performance outcomes can then be used to gauge student achievement across three levels: basic, proficient, and advanced (NAGB, 2008). These become the three primary levels used for data collection and reporting of findings on student achievement to the various stakeholders about what students know and are able to do in science.

		Science Content		
		Physical Science content statements	**Life Science** content statements	**Earth and Space Science** content statements
Science Practices	**Identifying Science Principles**	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*
	Using Science Principles	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*
	Conducting Scientific Inquiry	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*
	Using Technological Design	*Performance Expectations*	*Performance Expectations*	*Performance Expectations*

Figure 1. Crossing Content and Practices to Generate Performance Expectations

By design, this assessment structure provides the basis for researching connections between pedagogical practices (science teaching) and student achievement (learning science). Technology education, because it is nationally assessed to such a limited extent, lacks this type of data and assessment structure. As a result, this is one main reason the profession has been unsuccessful in developing its own unified framework for research into the impact of teaching practices on the technology content and practice outcomes (learning) that students should be expected to demonstrate across grade spans. However, a critical change regarding the practice of employing technological design in the NAEP 2009 Science Framework presents technology education with a significant research opportunity. The NAGB clarified its position regarding technological design as an assessment practice by stating "Because NAEP addresses the subject area of science, the use of technological design components in the 2009 NAEP Science Assessment will be limited to those that reveal students' ability to apply science principles in the context of technological design." (NAGB, 2008, p. 76). The Framework views technological design as a vehicle for learning science content and concepts, with no attention to learning or assessing concepts of technological design. This realm of assessment can and should be championed by researchers in technology education.

Predicated on the National Science Education Standards and benchmarks (NRC, 1996), the NAEP 2009 science framework provides a mechanism for assessing the targeted performance and learning expectations within the content and practice dimensions across grade spans. The structure around which research on science education has been organized aligns with the NAEP 2009 science framework and is designed to assess the capacity of science education for achieving the outcomes expressed in the standards and benchmarks; i.e. research

into the science teaching and learning processes to better understand how well the "educational ends" are being achieved. Clarity of assessment affords an equal clarity of pedagogical practices necessary for achieving the educational ends, and around which research on science education (teaching and learning) has been logically organized.

FRAMEWORK OF RESEARCH ON SCIENCE EDUCATION

Reviews of science education research have been available to the science community since the late 1920s and were regularly summarized in research digests up until 1957 and then republished in 1971 as a six-volume set by the Teachers College Press. Summaries of the science education research after 1957 continued to be published as chapters of the *Handbook of Research on Teaching* as well as various reports supported through the National Association for Research and Science Teaching (NARST) published by the ERIC Science, Mathematics, and Environmental Clearing House. However, a comprehensive analysis of research on science education did not occur until 1994 when the first *Handbook of Research on Science Teaching and Learning* was published (Gabel, 1994). This single volume was the first attempt to synthesize research over an extended period of time and provide the science education research community with a clearer picture of the content addressed and methods used. As reflected in the title, science teaching and learning were the guiding themes of the handbook and addressed in two sections with three chapters each. Significant attention was also placed on problem solving, with an entire section, six chapters, devoted to this topic. Two additional sections were developed around curricular and contextual issues relating to the instructional environment. The purpose of the handbook was to synthesize past research as a means of better understanding the teaching and learning practices of science education and to set the course for continued science education research. In 2007 the *Handbook of Research on Science Education* (Abell & Lederman, 2007) was presented as a comprehensive synthesis of empirical and theoretical research concerning teaching and learning in science education, and with an expressed purpose of providing a foundation upon which future science education research could be built.

Research on science education is presented in the 2007 handbook as a progression that begins with learning theory and proceeds toward pedagogical practices as instilled through teacher preparation. This was an intentional effort to provide more coherence of purpose and unify future directions among investigations conducted by science education researchers. This progression is framed by three themes – Learning Theory, Research Methods, and Pedagogical Practices – that together provide the agenda and priorities for research in science education. Throughout the past century the main learning theories of the time can be shown to strongly influence science education research and knowledge of the teaching/learning process. In a reciprocal fashion, gains in knowledge

lead to changes and improvements in research methods, which in turn improved understandings regarding how learning science occurs. For example, one key realization affecting science pedagogy is that the teaching and learning of science is found to be "discipline specific," and indicates that effective instructional practices used in teaching biology, for example, are not the same as those used to teach physics. For this reason research on teaching specific science subjects is organized and presented in separate chapters, with the exception of elementary science teaching where the goal for that age group is the learning of general science concepts. That pedagogical practices in science education are viewed as discipline specific begs the question of whether practices in technology education could or should be viewed similarly. For example, what benefit might there be in researching distinct pedagogical practices associated with content (disciplines) organized around physical, informational, and biological technologies (ITEA, 1996); or perhaps as organized in the *Standards for Technological Literacy* (ITEA, 2000) by Energy and Power, Information and Communication, Transportation, Manufacturing, and Construction, and Agricultural and Related Biotechnology?

In addition to thematic organizers, further research structure was provided in the form of guidelines for asking and investigating questions regarding science education. Briefly, these guidelines specified that improving science teaching/ learning worldwide must be the overall goal, that all research must be grounded in the real world of educational practice, that the profession as a whole must remain open to new research theories and methods, and that results must be presented in a manner that allows for practical interpretation by the various stakeholders, from teachers to policymakers. Directed by a thematic progression and based on a clear set of guidelines, the resulting 2007 *Handbook of Research on Science Education* (Abell & Lederman) presents to the profession a theoretically based, well articulated research agenda organized around five research priority categories as briefly summarized in Table 1 below.

Table 1 Summary of research foci within five science education research priority categories

Priority Category	Summary of Research Focus
Science Learning	Research to improve understandings regarding learner/teacher perspectives on science learning, the role of language and classroom discourse in science learning, recognizing interest is an important requisite for learning science and therefore a need to investigate linkages between attitude and motivation, and assessing the influence/impact of the instructional environment, both formal and informal, on the learning of science
Culture, Gender, and Society and Science Learning	Set within the overarching issue of context when learning science, priorities address recent research trends on the relationship between "context" and understanding learners in ways that specifically focus on the *learners'* gender, culture, and special needs
Science Teaching	Grounded in the perspective that the teaching of science is discipline specific, this category includes research that relates to the methods and strategies unique to the major science disciplines, with the one exception being that of elementary science teaching since it is general science and not typically discipline specific
Curriculum and Assessment in Science	Broad spectrum of curriculum and assessment research spanning topics from science literacy, inquiry, and the nature of science to program evaluation, and both large and small scale assessments of science learning
Science Teacher Education	Focus is on research that investigates the science teacher's learning, reflective of the recent ground swell of attention and new understandings related to teacher knowledge, pre/in-service professional development, the teacher learner, and the teacher researcher (as distinct from action research); particular attention given to content and pedagogical preparation issues, inclusive of practices necessary for integrative approaches to teach content from multiple fields

Constrained by chapter length limitations, this brevity of coverage does not do justice to the information offered through these categories of science education research. However, it provides the conceptual organization presented in the 2007 *Handbook* for research conducted on science education, as well as indications of possible avenues for research crossover within technology education. Specifically, the research addressed in the categories of Science Learning, Science Teaching, and Science Teacher Education hold particular relevance to the research gaps identified in technology education.

A COMMONS FOR TEACHING AND LEARNING RESEARCH

The *commons* is a centuries old concept referring to a resource, such as land, that is commonly owned and used by members of a community. Today the term seems equally applicable for envisioning a STEM education research collaboratory focused on the growing body of educational research questions, methods, and strategies used among these disciplines, and in particular for science and technology education considering their longstanding parallels in content and pedagogical practices. A model well suited for this is found in the PK-12/University *collaboratory* (Wells, 1999; Wells, Webb-Dempsey, & Khun-Van Zant, 2001) established through professional development schools that provides stakeholders the common ground necessary for *reformed education* (Wells, 2008). However, as previously discussed, technology education lacks an accepted assessment structure, and without that structure the extent to which such research can be used to establish technology education as a viable contributor to the core curriculum is limited. Paralleling science education, this issue could be addressed by similarly developing structures for assessing student learning in technology education. As presented in the NAEP 2009 science assessment framework (NAGP, 2008), student learning of content and practices in science education is assessed by correlating performance expectations as observed across each of the four science practices (Figure 2). Furthermore, to indicate the various ways of knowing and thinking that students should be able to demonstrate, each of the four practices is underpinned by a set of four cognitive demands: *knowing that* (declarative knowledge), *knowing how* (procedural knowledge), *knowing why* (schematic knowledge), and *knowing when and where to apply knowledge* (strategic knowledge). A student's ability to respond to the cognitive demands allows for assessment of expectations at the basic, proficient, and advanced levels with respect to learning both content and practices. The cognitive demands provide a mechanism for assessing knowledge gained along a continuum from declarative, to procedural, to schematic, and finally to strategic knowledge.

Figure 2.General Performance Expectations for Science Practices

Identifying Science Principles	Using Science Principles	Conducting Scientific Inquiry	Using Technological Design
Describe, measure, or classify observations	Explain observations of phenomena	Design and critique aspects of scientific investigations	Propose or critique solutions to problems given criteria and scientific constraints
State or recognize correct science principles	Predict observations of phenomena	Conduct science investigations using appropriate tools and techniques	Identify scientific tradeoffs in design decisions and choose among alternative solutions
Demonstrate relationships among closely related science principles	Propose, analyze, and evaluate alternative explanations or predictions	Identify patterns in data and/or relate patterns of data to theoretical models	Apply science principles or data to anticipate effects of technological design decisions
Demonstrate relationships among different representations of principles	Suggest examples of observations that illustrate a science principle	Use empirical evidence to validate or criticize conclusions about explanations and predictions	
← Communicate accurately and effectively →			

NAEP 2009 Science Framework (NAGB, 2008, p. 80)

Most educators are familiar with the concepts of declarative and procedural knowledge. Schematic and strategic knowledge are less familiar concepts, and need further explanation to articulate their potential for facilitating research on the pedagogical crossovers inherent within the design-based learning approaches used by both technology and science education.

RESEARCH ON DESIGN-BASED LEARNING

In science education, schematic knowledge refers to a student's ability to explain and predict natural phenomena, and to use reasoning in their evaluation of scientific claims regarding those phenomena. Strategic knowledge is the highest order learning stage among the cognitive demands and reflects the student's ability to transfer knowledge in solving novel tasks or problems. Knowledge transfer is an advanced thinking process that underpins practices used in technological design, scientific inquiry, and the integration of both. The capacity technological design has for assessing these higher order cognitive demands is explicitly stated in the NAEP 2009 Science Framework: "In terms of cognitive demand, both declarative knowledge (knowing that) and schematic knowledge (knowing why) come into play for the three components of Using Technological Design, as does strategic knowledge, (knowing when and where to apply knowledge)." (NAGP, 2008, p. 77). These are areas of cognitive demand integral to design-based learning and integrative practices in both technology and science education, and serve as the basis for replication and collaborations to research how students adapt prior science and/or technology knowledge to authentic, novel problem scenarios.

Replicating research in science education surrounding these parallels in cognitive demands is one approach for addressing the identified gaps in technology education research. National encouragement to build on such research in other fields as a means of assessing technological literacy came in a set of recommendations from the Committee on Assessing Technological Literacy in their 2006 publication *Tech Tally* (NAE, 2006), and specifically in Recommendation 7 calling for research on learning by funding studies that would draw from research in other disciplines such as "…learning in science and mathematics, spatial reasoning, design thinking, and problem solving" (p. 11). In recent years a growing number of technology education researchers have promoted design-based learning (DBL) and integrative practices as points of content/practice crossover with strong potential for establishing a teaching and learning research commons.

Lewis in 1999, building from his shifting beliefs regarding disciplinary border crossings (Lewis, 1996), broached the idea of conducting research on parallels in conceptual frameworks for teaching and learning held by technology education that would unite it with other school disciplines. Couched in a set of eight questions, he proposed points of research crossover that would help technology education achieve new paradigms for investigating teaching and learning. His idea of research along disciplinary borders crystallized in 2006 with specific attention to design and inquiry as conceptual parallels (Lewis, 2006). The use of design and inquiry in science, engineering, and technology education was shown to exhibit close resemblances in both processes and integration of content. Implications for accommodating border crossings through design and inquiry extends to the assessment of schematic and strategic cognitive demands in all three fields as a platform for investigating the commonalities of what students should know and be able to do.

Similarly, Petrina, Feng, and Kim (2008) echoed the potential for design and inquiry as crossover points based on the potential of design-based research to provide the experimental control necessary for assessing schematic knowledge, and for using cognitive ethnography to investigate distributed cognition, cognitive psychology, and human factors as could be revealed through assessment of strategic knowledge. The educational benefits of design-based learning were also presented by Daugherty and Mentzer (2008) as a method for promoting analogical reasoning; a cognitive tool fundamental to the design process (p. 9). Theoretically similar to cognitive apprenticeship, pattern recognition, schema, and concept or structure mapping, recognizing analogical reasoning as a cognitive outcome could help shape methods of assessing student learning (schematic and strategic knowledge) in a way that would inform design-based teaching practices in both science and technology education.

In each of the above arguments the goal for encouraging technology education to replicate the research conducted in other disciplines, and specifically science education, was to demonstrate the viability of student learning through the pedagogical practices of the field. Design-based learning is a pedagogical approach that presents core concepts in a way that concretely demonstrates to students the relevance and utility of content knowledge through an authentic context of need and application. The increasing attention by science education researchers for investigating the use of design-based approaches in the teaching of science is due in part to the inclusion of the Science and Technology Standard within the NSES (NRC, 1996). These standards are not to be confused with those of technology education, and are intended to "emphasize abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology" (p. 106). Specifically, the goal of Content Standard E: Science and Technology is for students to develop abilities of technological design ("identify and state a problem, design a solution – including a cost and risk-and-benefit analysis – implement a solution, and evaluate the solution", p. 107), and broaden their understandings about the relationship between technology and science (p. 135). However, it is important to recognize that Science Content Standard E impacts the science teacher's pedagogical practices by requiring them to incorporate, albeit to a limited extent (p. 192), the technological design process within their science courses, which in turn presents opportunities to research the impact on the teaching and learning process.

Recognizing the growing need for research on this impact, the editors of the *Journal of Research in Science Teaching* (Anderson & Hogan, 1999) called for papers reporting research on design in science education. In response to this and many similar requests, the capacity for improving student learning of science using this pedagogical approach has been repeatedly documented by a sizeable number of science education researchers (Barak, Wak, & Doppelt, 2000; Cajas, 2001; Crismond, 2001; Doppelt, 2004, 2006, 2007, 2009; Doppelt & Barak, 2002; Doppelt, Mehalic, & Schunn, 2005; Doppelt & Schunn, 2008; Fortus, et

al., 2004, 2005; Seiler, Tobin, & Sokolic, 2001; Mehalic, Doppelt, & Schunn, 2005, 2008; Krajjick, et al., 1998; Roth, 2001; Roth, Tobin, & Simmerman, 2002). Learning core science and technology concepts in this way provides flexibility in using knowledge gained in novel contexts and enables students to use and/or reinforce prior learning of concepts in both science and technology classrooms. This natural incorporation of concepts from different disciplines mirrors the actual processes and approaches practicing scientists and technologists follow in solving or designing solutions to problems in the field (Bauer, 1992; McComas, 1996; Ledermann, 1998).

Traditionally, scientific inquiry has been presented as a linear sequence of events based on the scientific method, and as such did not mirror the actual practices of scientists in the field (Reiff, Harwood, & Phillipson, 2002). When solving real world problems in the field, scientists and technologists seamlessly transfer and draw on core knowledge from several different disciplines to arrive at solutions and answers. As practiced, authentic scientific inquiry is more fluid and conceptual, and when taught this way gives students a more pragmatic approach to testing their hypotheses (Fortus, et al., 2005; Harwood, 2004; Reiff, Harwood, & Phillipson, 2002).

Design-based learning combines both practical and theoretical knowledge in a blend of technological design and science inquiry. As a result, students are challenged to employ both vertical and horizontal thinking to synthesize information within learning environments that most closely resemble the authentic context of ill-structured design-based problems. In this way design-based learning creates the need for acquiring integrative understandings in a manner reflective of knowledge requirements in actual practice.

RESEARCH ON INTEGRATIVE PRACTICES

Discipline and content integration has been underscored in the educational reform and standards movements of both science and technology for more than a decade (NRC, 1996; NSTA, 1996; ITEA, 2000). Research in science education has recently suggested that technology is an appropriate vehicle for enhancing the integration of science with other subjects because it provides an authentic context for problem solving that assists students' transfer of knowledge while working toward solutions to real-world problems (Pang & Good, 2000). Research in cognitive science supports the belief that integrative practices using hands-on/minds-on methods creates a learning environment where students make connections in a manner that suits how the brain organizes information and constructs knowledge (Bruning, et al., 2004; Shoemaker, 1991). The brain continually seeks meaning within the patterns of information (pattern recognition) it receives and organizes that new knowledge by associating it with meaning and understanding (schema) developed through prior experiences (Cromwell, 1989). Regardless of the discipline or content, students will learn what their teachers teach them, and if the instructional approach used is one where content is fragmented

and presented in isolation from other content then it will be learned that way (Humphreys, Post, & Ellis, 1981).

As previously mentioned, promoting knowledge transfer underpins integrative teaching practices (Sanders, 2006; Sanders & Wells, 2005; Wells, 2008), and supports the argument that such practices avoids the presentation of fragmented, isolated content typical of traditional methods (Lipson, Valencia, Wixson, & Peters,1993). Preparing today's students with tomorrow's skills begins by developing a knowledge base that reflects understandings of the relationships among disciplinary content required for solving complex problems involving interrelated variables (Benjamin, 1989).

To affect students' abilities to transform knowledge into personally useful strategies for learning new content and concepts requires that teaching be improved in a way that promotes integrative learning strategies. The need for such teaching abilities is emphasized in the National Science Education Standards (NRC, 1996) that state "Integrated and thematic approaches to curriculum can be powerful; however they require skill and understanding in their design and implementation" (p. 213). Though school subjects are still being taught using predominantly silo approaches, efforts continue in science education research to document the benefits of integrative approaches for improving student performance (Beane, 1995; Hartzler, 2000; Furger, 2002; Drake & Burns, 2004).

Empirical studies in science education investigating integrative methods have steadily increased over the past decade. Evidence of the positive impact integrative practices have on variables such as increased student achievement, improved interest, attitudes, and motivation, enhanced problem-solving abilities, and increases in content knowledge is being reported by a growing number of science education researchers (Vars, 1991; Greene, 1991; Westbrook, 1998; Isaacs & Gartzman, 1997). Though a considerable number of studies conducted in science education have begun to document the benefits of integrative approaches to science learning, the majority continue to do so by fostering students' conceptual understandings of science. In contrast, technological design as the signature pedagogy of technology education is an instructional strategy intended to make abstract concepts more concrete (ITEA, 2000). This pedagogical framework supports the integration of science (and other) content by intentionally coupling design-based learning to scientific inquiry with the expressed intent of facilitating knowledge transfer.

Though there is no disciplinary claim for integrative approaches, technology education is unique in that it affords the curricular flexibility and instructional environment necessary for facilitating design-based learning. The potential for demonstrating the value of technology education practices could be realized by analyzing how the curriculum it delivers promotes students' understanding of science and technology concepts. Clearly, by paralleling studies in science education, research conducted on integrative practices within the technology education classroom can document the effects of integration on students'

conceptual development and identify just what the implementation of integrative practices really means at the classroom level.

RESEARCH ON TEACHER KNOWLEDGE

Design-based learning strategies employed in science or technology education serve as the contextual bridge for integrative learning of content in both fields. However, instructional design and classroom practices of this caliber will challenge even the most seasoned and knowledgeable educators. Successful incorporation of integrative practices is directly related to the breadth of teacher knowledge essential for this method of teaching. The scope of that knowledge was presented in Shulman's (1986) theoretical model where teacher knowledge was said to be comprised of seven categories: content knowledge, general pedagogical knowledge, pedagogical content knowledge, curricular knowledge, learner knowledge, educational context knowledge, and knowledge of educational ends. The majority of educators have not, nor are they currently being adequately prepared in these seven categories Shulman suggests, all of which are needed to integrate and teach multiple subject areas simultaneously (Warner, 2003; Zubrowski, 2002). To achieve this level of preparation calls for a process of both formal and informal preparation that develops an educator with knowledge of teaching well beyond that of the subject matter expert.

Research in the area of science teacher education has increased significantly in the past ten years. Specifically, research into the relationship between teacher knowledge and practice has been one of the main foci in the science education literature. Its significance to science education is clearly evident in the *Handbook of Research on Science Education* (2007) which devoted six chapters, an entire section, to teacher education issues. The significance of teacher knowledge (e.g. Shulman, 1986) in the teaching/learning process has been consistently and repeatedly supported through empirical research, and continues to substantiate the teacher as the single most important factor in facilitating student learning (Darling-Hammond, 2000, 2002; Darling-Hammond & Youngs, 2002; U.S. DOE, 2007; Committee on Science and Mathematics Teacher Preparation, 2001).

Though the evidence regarding the centrality of teacher quality in the educational process is overwhelming, science (and technology education) teacher preparation programs are still inadequate in developing teachers with the knowledge requisite of design-based and integrative teaching/learning. Beyond subject matter expertise, there remain many unanswered questions regarding what science/technology teachers should know and in what ways should they come to know it. The current research trends surrounding teacher knowledge are a necessary precursor to any substantive dialogue regarding relationships among teacher variables (teacher knowledge, beliefs, etc.) and integrative instructional practices.

The historical perseveration of the notion that increasing teachers' content knowledge improves instruction has not been supported (Fennema & Franke,

1992). Likewise, this was the conclusion Abell (2007) reached in her review of science teacher knowledge. Instead, research has shown that those teachers with more discipline specific teaching methods courses in which they acquire the necessary pedagogical content knowledge (PCK) are more successful in promoting student engagement and improving learning (Darling-Hammond, 2007; Malcom, 2008). Furthermore, these methods were not traditional didactic strategies, but those inclusive of hands-on/minds-on experiential learning integral to design-based learning approaches. However, Kennedy (1998) argued there was not yet sufficient evidence documenting the ways in which teacher knowledge actually contributes to teaching practices, and that further research was needed. Still, Wenglinsky (2002, 2000), using data from the National Assessment of Educational Progress (NAEP), found that student achievement goes up in both mathematics and science when teachers have specific professional development (pre/in-service) in hands-on teaching methods that target higher-order thinking skills.

Lehman (1994) and Stevens and Wenner (1996) researched perceptions held by pre/in-service teachers on integrative science and mathematics instruction. Their findings indicated that in-service teachers, in part due to their tradition-steeped, discipline-specific preparation, had negative attitudes toward integrative approaches, while pre-service teachers had a more positive perception. Collectively the research on instructional practices has not supported approaches that are either entirely "student-centered" or "teacher-centered." What the research actually indicates is that student learning is best facilitated using a blend of strategies when and where they are most likely to have a positive impact under specified conditions (National Mathematics Advisory Panel, 2008). This speaks to one of the basic tenants of technology education, that "technology is a way to apply and integrate knowledge from many other subject areas" (ITEA, 2000, p. 6), which is accomplished through design-based learning and integrative practices. However, unlike our colleagues in science education, technology education lacks the research evidence necessary to substantiate the contribution of those practices for promoting student learning of knowledge and skills in core subjects at the PK-12 level. Obstacles to developing this evidence have been pointed out in prior reviews of technology education research (Lewis, 1996; Zuga, 2001; Hoepfl, 2002). Many, however, could be overcome through a *teaching and learning research commons* established among the STEM disciplines where a shared body of research questions, designs, methods, instruments, and strategies is used to coordinate research collaborations along points of content and pedagogical crossovers.

SUMMARY

Science education has been synthesizing their research on teaching and learning since the late 1920s, generating a sizeable number of reviews and summaries published through sponsorship by various professional organizations.

It was not until 1994 however, that a significant compilation of science education research conducted over a broad period of time was synthesized into a single *Handbook of Research on Science Teaching and Learning* (Gabel, 1994). The most recent effort to compile science education research was contained in the 2007 *Handbook of Research on Science Education* (Abell & Lederman, 2007), which was distinct from earlier handbooks in that it included international scholars and was intentionally designed to be comprehensive in its coverage of research. The overarching structure of the science education discipline was presented in the 2007 *Handbook* and organized around five categories of research: Science Learning; Culture, Gender, and Society and Science Learning; Science Teaching; Curriculum Assessment; and Science Teacher Education. The topics addressed within these categories represent the research priorities and future research directions for the field. Though the 2007 *Handbook of Research on Science Education* contains many areas of research relevant to technology education, space constraints for this yearbook chapter allowed for discussion of only three research categories: Science Learning, Science Teaching, and Science Teacher Knowledge. These categories provided the structure for selecting, reviewing, and synthesizing the literature surrounding science education research that holds particular promise for informing research in technology education used in preparing this chapter.

The chapter began by establishing the existence of a relationship between the current framework that organizes research in the science education discipline and the Science Framework (NAGB, 2008) used for the 2009 National Assessment of Education Progress. This relationship provides the foundation to guide the conduct of empirical research science education needs to demonstrate its impact on student learning of science at the PK-12 level. Specifically, it affords science education a mechanism for researchers to investigate and document how well the profession is achieving the goals of science education. Technology education has in place many of the same standards and benchmark structures used in science education, but lacks the national assessment structure necessary to connect research with PK-12 teaching/learning impact.

The science education research framework was used to align known gaps in technology education research with analogous research topics addressed within the categories of Science Learning, Teaching, and Teacher Education. These alignments served as the platform for discussing points of pedagogical crossover revealed within design-based learning and integrative practices employed by both science and technology education. There are clear implications for accommodating border crossings through design-based learning that particularly lend themselves to investigations of the schematic and strategic cognitive demands on student learning in both fields. These points of crossover are avenues where those in technology education might replicate or collaborate on previously conducted research in science education as a means for demonstrating the viability of their own pedagogical practices to promote student learning of core content. Empirical studies in science education investigating integrative methods have also provided

evidence of the positive impact such practices have on many of the variables associated with student learning. For example, the effective implementation of integrative instruction has been shown to assist students in understanding the relationships among disciplinary content and to transfer prior knowledge in solving complex real-world problems. Technology education is unique in that it affords an authentic context for problem solving that assists students' transfer of knowledge while working toward solutions to authentic problems. Technology education would clearly benefit from paralleling studies in science education to demonstrate the value of its own practices for promoting students' conceptual development. Doing so would also present the opportunity to investigate the types of teacher knowledge required for integrative practices.

The significance of teacher knowledge in the teaching/learning process has been consistently and repeatedly supported through empirical research. This research continues to confirm the centrality of the teacher and recognizing that the teacher remains the single most important factor in facilitating student learning. Content knowledge alone has been found to be insufficient for teaching even a single subject, let alone design-based learning using integrative practices. The ability of the educator to help others learn is directly linked to the level and breadth of teacher knowledge they possess. The seven categories of teacher knowledge proposed in Shulman's (1986) theoretical model of teacher knowledge were recognized by the science education community as useful for structuring science teacher preparation programs. As a result these programs will be well positioned for developing educators with the range of teacher knowledge needed to employ not only science inquiry pedagogy, but design-based and integrative practices as well. It is conceivable then that this approach to the preparation of science teachers may better prepare them to implement technology and design-based learning methods than technology education teachers.

The challenges faced by the technology education profession in presenting a body of research to empirically demonstrate the contributions of its pedagogical practices to the educational enterprise have been pointed out multiple times over the years (McCrory, Foster, Hoepfl, Lewis, Waetjen, Zuga, etc.). In fact Zuga (1994) made this challenge explicit in her statement that research was needed to "demonstrate the inherent value of technology education" (p. 64), a point echoed by Lewis a few years later who stated "To take its place squarely in school curricula, technology education must establish itself not only in its own right, but crucially in relation to other subjects" (1999, p. 49). In contrast, science education has effectively used research to establish the credibility of its pedagogical practices for promoting student learning. Aligning national science education standards with national science assessment standards provides a framework and inherent strategy for investigating linkages between student learning and teacher practice. Design-based learning, as an instructional approach employed by both technology and science educators, presents a research focus of mutual interest. Moreover, because this teaching approach necessitates integrative practices

and unique teacher knowledge, it presents these as additional areas of common research. With established lines of research in science education currently addressing these topics, researchers in technology education have the opportunity to replicate or collaborate on research that links practice with student learning. In so doing, they will address those key research gaps identified in technology education and generate the empirical evidence needed to demonstrate the value of its pedagogical practices and its legitimacy as a school subject.

REFERENCES

Abell, S. K. (2007). Research on Science Teacher Knowledge. In Abell, S. & Lederman, N. (Eds.) *Handbook of Research on Science Education* (pp. 1105-1149). Lawrence Erlbaum Associates, Inc.

Abell, S.K. & Lederman, N.G. (Eds.). (2007). *Handbook of research on science education.* New Jersey: Lawrence Erlbaum Associates, Inc.

American Association for the Advancement of Science (1990). *Project 2061.* New York: Oxford University Press.

American Association for the Advancement of Science (1989). *Science for All Americans*. New York: Oxford University Press.

American Association for the Advancement of Science (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Anderson, C. & Hogan, K. (1999). Editorial and Call for Papers. *Journal of Research in Science Teaching, 26*(9), 975-976.

Barak, M., Waks, S., & Doppelt, Y. (2000, January 1). Majoring in Technology Studies at High School and Fostering Learning. *Learning Environments Research*, *3*(2), 135-58.

Bassok, M., & Holyoak, K. J. (1993). Pragmatic knowledge and conceptual structure: Determinants of transfer between quantitative domains. In D. K. Detterman & R. J. Sternberg (Eds.), *Transfer on trial: Intelligence, cognition, and instruction* (pp. 68-98). Norwood, NJ: Ablex.

Bauer, H. (1992). *Scientific literacy and the myth of the scientific method*. University of Illinois: Urban, IL.

Beane, J. A. (1995). Curriculum integration and the disciplines of knowledge. *Phi Delta Kappan, 76*(8), 616-622.

Benjamin, S. (1989, September). An ideascape for education: What futurists recommend. *Educational Leadership, 47*(1), 8-16.

Bjork, R. A., & Richardson-Klavhen, A. (1989). On the puzzling relationship between environment context and human memory. In C. Izawa (Ed.), *Current issues in cognitive processes: The Tulane Flowerree Symposium on Cognition*. Hillsdale, NJ: Erlbaum.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (editors) (July 2004). How people learn. Washington, D.C.: National Academy Press.

Bransford, J. D., Brown, A. L., Cocking, R. R., Donovan, M. S., & Pellegrino, J. W. (2000). *How people learn: Brain, mind, experience, and school*.

Washington, D.C.: National Academy Press.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*, 61-100.

Bransford, J. D., & Stein, B. S. (1984). *The ideal problem solver: A guider for improving thinking, learning, and creativity.* New York: Freeman.

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Bruning, R. H., Schraw, J. G., Norby, M.M., & Ronning, R. R. (2004). *Cognitive Psychology and Instruction.* Columbus, OH: Pearson.

Bybee, R. (2001). Achieving scientific literacy: Strategies for insuring that free choice science education complements national formal science education efforts. In J. H. Falk (Ed.), *Free choice education: How we learn science outside of school* (pp. 44-63). New York: Teachers College Press.

Carlsen, L. (2007). Language and science learning. In Abell, S. & Lederman, N. (Eds.)*Handbook of Research on Science Education* (pp. 57-74). Lawrence Erlbaum Associates, Inc.

Cajas, F. (2001). The science/technology interaction: Implications for science literacy. *Journal of Research in Science Teaching*, 38(7), 715-729.

Committee on Science and Mathematics Teacher Preparation (2001). *Educating teachers of science, mathematics, and technology: New practices for the new millennium.* Washington, DC: National Academy Press.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13-20.

Crismond, D. (2001). Learning and using science ideas when doing investigate-and-redesign tasks: A study of naïve, novice, and expert designers doing constrained and scaffolded design work. *Journal of Research in Science Teaching, 38*(7), 791-820.

Cromwell, S. (1989). A new way of thinking: The challenge of the future. *Educational Leadership, 49*(1), 60-64.

Daugherty, J. & Mentzer, N. (2008). Analogical reasoning in the engineering design process and technology education applications. *Journal of Technology Education 19*(2), 7-21.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Educational Policy Analysis Archives, 8*(1). Retrieved October 7, 2008 from http://epaa.asu.edu/epaa/v8n1

Darling-Hammond, L. (2002). The research and rhetoric on teacher certification: A response to "Teacher certification reconsidered." *Educational Policy Analysis Archives, 10*(36). Retrieved October 7, 2008 from http://epaa.asu.edu/epaa/v10n36

Darling-Hammond, L. (2007). *Improving the Nation's STEM Capacity: Creating a Systemic Approach.* Testimony at American Association of Colleges for

Teacher Education Congressional Briefing July 21 on Preparing STEM Teachers: The Key to Global Competitiveness. Retrieved September 16, 2008 from http://www.aacte.org/Governmental_Relations/hammond_ STEM_testimony.pdf

Darling-Hammond, L. & Youngs, P. (2002, December). Highly qualified teachers: What does scientifically-based research actually tell us? *Educational Researcher*, 31(9), 13-25.

Doppelt, Y. (2004). The impact of the characteristics of science-technology learning environment: Pupils perceptions and gender differences. *Learning Environment Research, 7*(3), 271-293.

Doppelt, Y. (2006). Teachers' and pupils' perceptions of science-technology learning environments. *Learning Environment Research, 9*(2), 163-178.

Doppelt, Y. (2007, On-Line First). Assessing creative thinking in design-based learning. *International Journal of Technology and Design Education.*

Doppelt, Y. (2009). Assessing creative thinking in design-based learning. *International Journal of Technology and Design Education, 19*(1), 55-65.

Doppelt, Y. & Barak, M. (2002). Pupils identify key aspects and outcomes of a technological learning environment. *Journal of Technology Studies, 28*(1), 22-28.

Doppelt, Y., Mehalik, M. M., & Schunn, D. C. (2005, April). *A Close-Knit Collaboration Between Researchers and Teachers for Developing and Implementing a Design-Based Module.* Paper presented at the National Association of Research in Science Teaching, Dallas, TX.

Doppelt, Y. & Schunn, D. C. (2008). Identifying students' perceptions of the important classroom features affecting learning aspects of a design-based learning environment. *Learning Environment Research, 11*(3), 195-209.

Drake, S. & Burns, R. (2004). *Meeting Standards Through Integrated Curriculum.* Association for Supervision and Curriculum Development. Alexandria, VA.

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science*. Philadelphia, PA: Open University Press.

Fennema, E. & Franke, M. (1992). Teachers' knowledge and its impact. *Handbook of Research on Mathematics Teaching and Learning*, Grouws, D. (Ed), 147-164. National Council of Teachers of Mathematics

Fortus, D., Dershimer, R. C., Marx, R. W., Krajcik, J., & Mamlok-Naaman, R. (2004). Design-based science (DBS) and student learning. *Journal of Research in Science Teaching, 41*(10), 1081-1110.

Fortus, D., Krajcik, J., Dershimer, R. C., Marx, R. W., & Naaman, R. M. (2005, June). Design based science and real-world problem-solving. *International Journal of Science Education*, 27(7), 855-879.

Foster, W.T. (1992). Topics and methods of recent graduate student research in industrial education and related fields. *Journal of Industrial Teacher Education. 30*(1), 59-72.

Foster, W.T. (1996). A research agenda for technology education. *The Technology Teacher, 56*(1), 31-33.

Furger, R. (2002). *Assessment for Understanding: Taking a Deeper Look.* The George Lukas Educational Foundation. Retrieved September 12, 2008 from http://www.edutopia.org/assessment-for-understanding-taking-deeper-look

Gabel, D. L. (Ed.). (1994). *Handbook of research on science teaching and learning.* New York: Macmillan.

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology, 15*, 1-38.

Goldschmidt, G. (2001). Visual analogy: A strategy for design reasoning and learning. In C. Eastman, M. McCracker, & W. Newstetter (Eds.), *Design knowing and learning: Cognition in design education* (pp. 199-218). Amsterdam: Elsevier Science.

Greene, L. C. (1991). Science-centered curriculum in elementary school. *Educational Leadership, 49*, 42-51.

Gregory, K. (2007). Discourse in science classrooms. In Abell, S. & Lederman, N. (Ed.) *Handbook of Research on Science Education* (pp. 443-469). Lawrence Erlbaum Associates, Inc.

Hales, J., & Snyder, J. (1982, March 1). Jackson's Mill Industrial Arts Curriculum Theory: A Base for Curriculum Conceptualization. Part 2 of a Two-Part Series. *Man/Society/Technology*, *41*(6), 6-8.

Hales, J., & Snyder, J. (1982, February 1). Jackson's Mill Industrial Arts Curriculum Theory: A Base for Curriculum Derivation. Part 1 of a Two-Part Series. *Man/Society/Technology*, *41*(5), 6-10.

Harwood, W. (2004). An activity model for scientific inquiry. *The Science Teacher, 71*(1), 44-46.

Hartzler, D. S. (2000). *A Meta-Analysis of Studies Conducted on Integrated Curriculum Programs and their Effects on Student Achievement.* Unpublished doctoral dissertation, Indiana University, Bloomington, IN.

Hoepfl, M. (2002). A strategic framework for research in technology education. In Middleton, H., Pavlova, M., & Roebuck, D. (Eds.), *Learning in Technology Education: Challenges for the 21st Century* (pp. 190-210). Brisbane, Australia: Griffith University Centre for Technology Education Research.

Hoepfl, M. (2007). *Research in Technology Education: Identifying a Strategic Agenda.* Paper presented at the 94th Meeting of the Mississippi Valley Technology Teacher Educaiton Conference, Rosemont, Illinois.

Hurley, M. M. (2003). *The presence, value, and reasoning behind integrated science and mathematics methods courses.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia.

International Technology Education Association (1996). *Technology for all*

Americans: A Rationale and Structure for the study of technology. Reston, VA: ITEA.

International Technology Education Association (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: ITEA.

Isaacs, A., Wagreigh, P., & Gartzman, M. (1997). The quest for integration: School mathematics and science. *American Journal of Education, 106*, 179206.

James, W. (1890). *The principles of psychology (vol. 2)*. New York, NY: Dover.

Johnson, S. & Daugherty, J. (2008). Quality and characteristics of recent research in technology education. *Journal of Technology Education, 20*(1), 16-31.

Katona, G. (1940). *Organizing and memorizing.* New York: Columbia University Press.

Kennedy, M. M. (1998). Education reform and subject matter knowledge. *Journal of Research in Science Teaching, 35*, 249-263.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences, 7*(3&4), 313-350.

Lazarowitz, R. (2007). High school biology curricula development: Implementation, teaching and evaluation from the 20th to 21st century. In Abell, S. & Lederman, N. (Ed.) *Handbook of Research on Science Education* (pp. 561-598). Lawrence Erlbaum Associates, Inc.

Lederman, N. (1998). The state of science education: Subject matter without context. Electronic *Journal of Science Education, 3*(2), 1-11.

Lehman, J. R. (1994). Integrating science and mathematics: Perceptions of preservice and practicing elementary teachers. *School Science and Mathematics, 94*(2), 58-64.

Lewis, T. (1996). Accommodating border crossings. *Journal of Industrial Teacher Education*, 33(2), 7-28.

Lewis, T. (1999). Research in technology education – Some areas of need. *Journal of Technology Education, 10*(2), 41-56.

Lewis, T. (2006). Design and inquiry: Basis for accommodation between science and technology education in the curriculum? *Journal of Research in Science Teaching, 43*(3), 255-281.

Linn, J. & Gronlund, M. (2000). Measurement and Assessment in Teaching (8th Ed.). Prentic-Hall, Inc. Upper Saddle River, NJ.

Lipson, M. Valencia, S. Wixson, K., & Peters, C. (1993). Integration and thematic teaching: Integration to improve teaching and learning. *Language Arts, 70*(4), 252-264.

Malcom, S. (2008, April). *Chat Transcript* on STEM: The Push to Improve Science, Technology, Engineering, and Mathematics Education. Retrieved

August 29, 2008 from http://www.edweek.org/chat/transcript_04_02_08. html

Mason, T. C. (1996). Integrated curricula: Potential and problems. *Journal of Teacher Education, 47*(4), 263-270.

Mehalik, M. M., Doppelt, Y., & Schunn, D. C. (2005, April). *Addressing Performance of a Design-Based, Systems Approach for Teaching Science in Eighth Grade.* Paper presented at the National Association of Research in Science Teaching, Dallas, TX.

Mehalic, M., Doppelt, Y. Schunn, C. (2008). Middle-school science through design-based learning versus scripted learning: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education*, January.

McComas, W. F. (1996). Ten myths of science: Reexamining what we think we know about the nature of science. *School Science and Mathematics, 96*(1), 10-15.

McCrory, D.L. (1987). *Technology Education: Industrial arts in transition. A review and synthesis of the research, fourth edition.* ERIC Document Reproduction Service, Information Series No. 325.

NAE (National Academy of Engineering) and NRC (National Research Council), (2006). *Tech Tally: Approaches to Assessing Technological Literacy.* Washington, D.C.: National Academy Press.

National Assessment Governing Board (2008). *Science Framework for the 2009 National Assessment of Educational Progress.* Washington, DC, September.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* VA: NCTM.

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: Author.

National Mathematics Advisory Panel (2008). *Foundations for Success: The Final Report of the National Mathematics Advisory Panel.* U.S. Department of Education: Washington, DC.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards.* Washington, DC: National Academy Press.

National Science Teachers Association (NSTA) (1996). NSTA board endorses new position statement on interdisciplinary learning, PreK-grade 4. *NSTA Reports, 6,* 8.

Pang, J. & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. *School Science and Mathematics, 100*(2).

Petrina, S. (1998). The politics of research in technology education: A critical content and discourse analysis of the Journal of Technology Education, volumes 1-8, *Journal of Technology Education, 10*(1), 27-57.

Petrina, S., Feng, F., & Kim, J. (2008). Researching cognition and technology: How we learn across the lifespan. *International Journal of Technology and Design Education, 18*(4), 375-396.

Pintrich, P. R., Marx, R. W., & Boyle, R. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 6*, 167-199.

Reiff, R., Harwood, W. S., & Phillipson, T. (2002). *A scientific method based upon research scientists' conceptions of scientific inquiry.* Paper presented at the International Conference of the Association for the education of Teachers in Science, Charlotte, NC.

Roth, W-M., (2001). Learning science through technological design. *Journal of Research in Science Teaching, 38*(7), 768-790.

Roth, W.-M., Tobin, K., & Zimmermann, A. (2002). Coteaching/cogenerative dialoguing: Learning environments research as classroom praxis. *Learning Environments Research: An International Journal, 5*, 1-28.

Royal College of Art. (1976). *Design in general education. Part one: Summary of findings and recommendations*. London: Royal College of Art.

Sanders, M. E. (2000). Web-based portfolios for technology education: A personal case study. *Journal of Technology Studies, 26*(1), 11-18.

Sanders, M. & Wells, J. (2005). STEM Graduate Education/Research Collaboratory. Paper presented to the Virginia Tech School of Education faculty, Virginia Tech.

Sanders, M. (2006, November). A rationale for new approaches to STEM education and STEM education graduate programs. Paper presented at the 93rd Mississippi Valley Technology Teacher Education Conference.

Seiler, G., Tobin, K., & Sokolic, J. (2001). Design, technology, and science: Sites for learning, resistance, and social reproduction in urban schools. *Journal of Research in Science Teaching, 38*(7), 746-767.

Shoemaker, B. (1991). Integrative education: A curriculum for the twenty-first century." *Oregon School Study Council*, *33*(2), 793-797.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Stevens, C., & Wenner, G. (1996). Elementary preservice teachers knowledge and beliefs regarding science and mathematics. *School Science and Mathematics, 96*(1), 2-9.

U. S. Department of Education (2007). *No Child Left Behind Fact Sheet.* Teacher-To-Teacher Initiative. Retrieved July 23, 2008 from http://www.ed.gov/teachers/how/tools/initiative/factsheet.pdf

Vars, G. G. (1991). Integrated curriculum in historical perspective. *Educational Leadership, 49*(2), 14-15.

de Vries, M. J. (1996). Technology education: Beyond the "technology is applied science" paradigm. *Journal of Technology Education, 8*(1), 7-15.

Waetjen, W. B. (1992). Shaping the future of a profession. In *Camelback Symposium: Critical issues in technology education* (pp. 25-30). Reston, VA: International Technology Education Association.

Warner, S. A. (2003). Teaching design: Taking the first steps. *The Technology Teacher, 62,* 7-10.

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality.* Princeton, NJ: Educational Testing Service.

Wenglinsky, H. (2002). How schools matter: The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archives 10*(12). http://epaa.asu.edu/epaa/v10n12 (accessed October 9, 2008).

Wells, J. G. (1999). *Trek 21: Educating Teachers as Agents of Technological Change.* Proposal document submitted to the U.S. Department of Education, Preparing Tomorrow's Teachers to Use Technology (PT3) program.

Wells, J., Webb-Dempsey, J., and Kuhn-Van Zant, A., (2001). Evolutions of evaluation: Trek 21 & PT3. Proceedings of the *Preparing Tomorrow's Teachers to Use Technology.*

Wells, J. G. (2008). *STEM Education: The Potential of Technology Education.* Paper presented at the 95th Annual Mississippi Valley Technology Teacher Education Conference, November 7, 2008, St. Louis, Missouri.

Wells, J., Figliano, F., Kwon, H., and Carlson, J. (2008). *Educational Research Priorities in Technology Education.* Paper presented to the Council on Technology Teacher Education at the 70th Annual International Technology Education conference, Salt Lake City, UT.

Wells, J., Pembridge, J., Greene, C., & Dobroth, M. (2009). *STM Educational Research Priorities and Future Directions.* Paper presented to the Council on Technology Teacher Education at the 71st Annual International Technology Education conference, Louisville, KY.

Westbrook, S. L. (1998). Examining the conceptual organization of students in an integrated algebra and physical science class. *School Science and Mathematics, 98*(2), 84-92.

Zuga, K.F. (1994). *Implementing technology education: A review and synthesis of the research literature.* ERIC Document Reproduction Services No. ED 372 305.

Zuga, K.F. (1995). *Struggling for a new identity. A critique of the curriculum research effort in technology education.* ERIC Document Reproduction Services No. ED 389 883.

Zuga, K.F. (1997). An analysis of technology education in the United States based upon an historical overview and review of contemporary curriculum research. *International Journal of Technology and Design Education, 7*, 203-217.

Zuga, K.F. (2001, April). *Improving Technology Education Research on Cognition.* Paper presented at the Second AAAS Technology Education

Conference, Washington, DC.

Zubrowski, B. (2002). Integrating science into design technology projects: Using a standard model in the design process. *Journal of Technology Education, 13*(2), 48-67.

Creativity and Design in Technology Education

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Chapter
11

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INTRODUCTION

"Technological design inevitably involves a certain amount—sometimes a great deal—of human creativity" (ITEA, 2000, p.91). This statement on the importance of design and creativity from *Standards for Technological Literacy* sets the stage for a discussion of the nature of design and creativity in technology education. However, a full discussion on creativity and design would go well beyond the page limitations of this chapter. Instead, this chapter will briefly explore the nature of creativity and design, and then examine selected aspects of research on those topics. The last sections of the chapter will examine selected examples of recent research on creativity and design in technology education and then will conclude with a call to action for the profession.

A helpful starting place for this exploration would be to define the terms *creativity* and *design.* The word *creativity* has many definitions. Amabile's meta-study entitled *Creativity in Context* (1996) found that most of those definitions tended to fall into two categories. Some definitions of creativity focused on the end product of an action or behavior while others focused more on the abilities and characteristics of the person performing the actions or behavior. DeBono (1992) provided a simple definition of creativity when he stated, "In some ways creativity can be defined as a search for alternatives" (p.119). DeBono's definition of creativity is harmonious with the various descriptions of creative actions and behaviors included in *Standards for Technological Literacy* (ITEA, 2000). Gardner (1993) specified the dynamics of a creative individual, which is also in agreement with what is written in *Standards for Technological Literacy*, as "a person who regularly solves problems, fashions products, or defines new questions in a domain in a way that is initially considered novel but that ultimately becomes accepted in a particular cultural setting" (p. 35).

Addressing the word *design*, Lawson (1997) noted that "…'design' is both a noun and a verb. It can refer either to the end product or to the process" (p.3). Hutchinson and Karsnitz (1994) simply stated that, "Design is the planned process of change" (p. 18). Pink (2005), writing about the shifting social paradigm from the left-brain directed world of the information age to the right-brain directed world of the conceptual age, identified design as one of the six senses that should

be developed for one to be successful in this new age. Pink's definition of design can be found in the following passage:

> It's easy to dismiss design—to relegate it to mere ornament, the prettifying of places and objects to disguise their banality. But that is a serious misunderstanding of what design is and why it matters—especially now. John Heskett, a scholar of the subject, explains it well: "[D]esign, stripped to its essence, can be defined as the human nature to shape and make our environment in ways without precedent in nature, to serve our needs and give meaning to our lives." (p. 69)

WHY ARE CREATIVITY AND DESIGN SO IMPORTANT?

Modern transportation and communication technologies have made the world seem smaller. Anyone can board a jet plane and fly at over 600 miles per hour to the other side of the planet to meet with a colleague, friend, or family member (Williams, 1987). That same person could just as easily save the travel expenses and meet, talk, and interact with the same people through the Internet in almost real time (Burke, 1996). These perceptions of a smaller world have resulted in the term *globalization,* a term of profound importance. In response to the changes that globalization brings about, several noted authors have advocated dramatic shifts in the goals, organization, and operations of American business and industry as well as its public schools. These authors include people such as Friedman (2006), Florida (2007), and Pink (2005). Friedman noted a flattening of the world's economic, cultural, and creative power structures through shifts in economic wealth to various regions of the globe such as India and China. Florida statistically mapped out the movement of a creative class of people to countries, regions, and cities that supported the expressions of their creative energies. Pink moved the economic reference points not just from the industrial age to an information age, but beyond to a conceptual age. Underlying the writing of each of these authors, whether overtly stated or implied, is the use of design and design thinking as the intellectual engine that will propel the centers of creativity in this new, globalized community. According to *Standards for Technological Literacy* (ITEA, 2000),

> Design is regarded by many as the core problem-solving process of technological development. It is as fundamental to technology as inquiry is to science and reading is to language arts. To become literate in design process requires acquiring the cognitive and procedural knowledge needed to create a design, in addition to familiarity with the processes by which design will be carried out to make a product or system. (p. 90)

In the world of the 21st century that thinkers such as Friedman, Florida, and Pink describe, design-based education and design thinking become the keys to a fulfilling, participatory life in a culture that is built upon a foundation of creative

expression. With design as its fundamental tool for the study of technology, the challenge to technology education is to provide students with their own set of keys for entry into that world. To accomplish this goal it is important for teachers and teacher educators to have a better understanding of both creativity and design.

EXAMINING THE ORIGINS OF CREATIVITY

Human creativity has many precursors. First, we have to have the basic biological attributes that would enable us to manipulate and change our natural environment. Human evolution has established four biological attributes that have distinguished us from all other creatures. These attributes are an upright skeleton, manipulative hands with opposable thumbs, three-dimensional color vision, and a complex brain (Schick & Toth 1993; McCrone, 1991; Lambert, 1987).

Second, we have to have the mental capacity to think in abstract ways. This means that we can plan for the future, learn from experience and pass that knowledge on to other members of our species, communicate through the tools of language, mentally visualize ways to solve problems (design), and a host of other intellectual skills and abilities (Csikszentmihalyi, 1996; Burke & Ornstein, 1995; DeVore, 1980; Burke, 1978; Bronowski, 1973).

Third, we have to live in an environment that supports the expressions of creative thought and behavior. The environmental considerations come in several forms. These include the physical environment, the social/cultural environment, and the environment of place in time. Expressions of creativity become difficult when any one of these environmental factors is indifferent to or even suppressive of the creative act (Csikszentmihalyi, 1996; Goleman, Kaufman & Ray, 1992; Amabile, 1989; Wallace, 1989; Hamacheck, 1979; Burke, 1978).

When all of these factors come together and support creative thoughts and actions, human beings can be amazingly imaginative, inventive, and technologically inclined. These behaviors are, in part, a reflection of how our species has come into being by adapting to, or modifying our environments to our needs and wants. Johanson, Johanson, and Edgar (1994) and Johnson (1997) pointed out that even our earliest ancestors actively exploited their environments for such things as food, shelter, tools, and the fundamentals of language and culture. These exploitations were undoubtedly fired by the developing capacity of the hominid brain for creative manipulation of the environment. The field of academic study called evolutionary psychology even posits the theory that the behavior of modern humans is directly linked to evolutionary benefits that our distant ancestors had in surviving on the savannas. One recent author from this field is Dutton (2008), who argued that Darwinian evolution played a role in generating creative capabilities in the human gene pool. These creative behaviors expressed themselves through the abilities to tell and listen to stories (imagination and anticipation of the future). The possession of these abilities with stories would, for a number of reasons, result in better reproductive opportunities. These creative predispositions would then be passed on to future generations, and thus reinforce

the cycle supporting the development of creative behaviors. Though Dutton's theory has its detractors, there seems to be general agreement that creativity and design are important mental tools that have a significant basis in the heritage of human evolution and biology.

EXAMINING THE RESEARCH ON CREATIVITY

If creativity has been such an important aspect of the success of the human lineage, then it would seem natural that the study of, and research on, creativity would be a major part of our intellectual heritage. However, Sternberg and Lubart (1999) observed that "[Though] creativity is important to society, …it traditionally has been one of psychology's orphans"(p. 4). These authors related that it was not until the second half of the 20th century that this lack of research attention was acknowledged when Guilford (1950), in his Presidential Address to the *American Psychological Association*, noted that less than 0.2% of the manuscripts published in *Psychological Abstracts* were about creativity. To test any changes that had occurred in the rate of publication since Guilford's speech, Sternberg and Lubart did a computer scan of the *PsychLit* database, for the years 1975-1994, for the keywords of *creativity*, *divergent thinking*, and *creativity measurement*. Their findings were that only 0.5% of the articles scanned concerned creativity, not a significant change from Guilford's findings. A more positive observation concerned the creation of professional journals in the field of psychology: *The Journal of Creative Behavior* (http://www.creativeeducationfoundation.org/jcb.shtml) in 1967 and *The Creativity Research Journal* (http://www.informaworld.com/smpp/title~db=all~content=t775653635) in 1988.

CREATIVITY RESEARCH METHODS AND CRITIQUES

Plucker and Renzulli (1999) have categorized most modern scientific studies on creativity into five groups: 1) psychometric - which involves the use of instruments such as the *Torrance Test of Creative Thinking*, 2) experimental – which manipulate some variable seeking to establish a cause and effect link, 3) case study – which involves a detailed examination of multiple variables affecting a given individual or small group in a given context, 4) historiometric – which draws its data about creative individuals exclusively from historical documents, and 5) biometric – which involves the use of brain function studies such as functional magnetic resonance imaging (fMRI). Various researchers from the field of psychology have used each of these five approaches to conduct research on creativity. However, there are those even in psychology who question the reliability of many of the findings from those studies. Brown (1989) provided an extensive list of perceived problems with most of the research on creativity completed using the methods previously listed. This critical atmosphere about research on creativity is something that Sternberg and Lubart (1999) blamed on six "roadblocks" (p. 4). They described the perceptual problems with research on creativity as follows:

1. The origins of the study of creativity were based in a tradition of mysticism and spirituality, which seemed indifferent and possibly runs counter to the scientific spirit.
2. Pragmatic approaches to creativity have given some the impression that the study of creativity is driven by a kind of commercialism that, while it may be successful in its own way, lacks a basis in psychological theory and verification through psychological research.
3. Early work on creativity was theoretically and methodologically adrift from the mainstream of scientific psychology, resulting in creativity sometimes being seen as peripheral to the central concerns of the field of psychology as a whole.
4. Problems with the definition of and criteria for creativity caused research difficulties. Paper-and-pencil tests of creativity resolved some of these problems but led to criticisms that the phenomenon had been trivialized.
5. Single approaches have tended to view creativity as an extraordinary result of ordinary structures or processes, so that it has not always seemed necessary to have any separate study of creativity. In effect, these approaches have subsumed creativity under them, as a special case of what is already being studied.
6. Unidisciplinary approaches to creativity have tended to view a part of the phenomenon (e.g., the cognitive processes of creativity, the personality traits of creative persons) as the whole phenomenon, often resulting in what we believe is a narrow, unsatisfying vision of creativity (p. 12).

These observations by Sternberg and Lubart about the perceptual problems associated with research on creativity in the field of psychology should serve as important guidelines for researchers in technology education. In a later section of this chapter the lack of research on creativity in technology education will be discussed. An understanding of the categories of research on creativity, and their respective critiques, would facilitate researchers in technology education to become better equipped to organize, conduct, analyze, and report their research on creativity. Arguably, developing these understandings should be a fundamental step toward building a stronger case for the value of creativity, including design by extension, in technology education.

EXAMINING DESIGN

If design is "the planned process of change" (Hutchinson & Karsnitz, 1994, p. 18), then design has been a part of the human experience since the first

australopiths, our earliest identifiable hominid ancestor, picked up a stick and used it as a tool. It has been approximately 2.5 million years since humans first learned to shape and use stone tools, since that time we have used our design abilities to create an infinite number of ways to produce, transport, build, and communicate. The "designerly" way of thinking is something that has become deeply ingrained into what it means to be human. One could pull from history example after example of individuals who have used design thinking to excel. The pyramid builders of ancient Egypt, Leonardo da Vinci, Robert Fulton, Guglielmo Marconi, and Robert Goddard are just a few of the famous figures from history who used the designerly way of thinking (Williams, 1987). It is unfortunate that, with the advent of modern compulsory education, designerly thinking, with few exceptions, has been de-emphasized or ignored completely (Pink, 2005; Davis, Hawley, McMullan, & Spilka, 1997).

Cross (2006) observed this dilemma directly when he discussed how children are taught to think in contemporary English schools. He noted that there are only two cultures of thinking that are generally recognized: the sciences, or the arts and humanities. According to Cross the designerly way of knowing is the forgotten third culture of thinking. Referencing a research project performed in 1979 by the *Royal College of Art* to help describe the identifying characteristics of designerly ways of knowing, Cross stated:

> • The central concern of Design is 'the conception and realization of new things'.
> • It encompasses the appreciation of 'material culture' and the application of 'the arts of planning, inventing, making and doing'.
> • At its core is the 'language' of 'modeling'; it is possible to develop students' aptitudes in this 'language', equivalent to aptitudes in the 'language' of the sciences (numeracy) and the 'language' of humanities (literacy).
> • Design has its own distinct 'things to know, ways of knowing them, and ways of finding out about them' (p. 1).

Davis (2006, personal communication), who has researched and written about design-based education for more than 30 years, elaborated on this concept of designerly ways of knowing even further by defining a design-based approach to teaching and learning as being:

> • Open-Ended: the outcome is not known before the student begins and has many right answers.
> • Authentic: it models adult problem-solving and its outcomes can be evaluated through physical artifacts with specific properties/affordances.
> • Integrated: it requires the synthesis of information and methods from many fields.
> • Responsive: it focuses on context and audience by

> addressing the technological, cultural, cognitive, social, physical, and economic dimensions of problems.
> • Values-Oriented: it requires the reconciliation of competing priorities against some ranking of values.

RESEARCHING DESIGN THINKING

In an effort to better understand the differences in thinking cultures, Lawson (1997) performed a series of manipulative experiments comparing the differences between how people from science and design backgrounds think. The findings of the study found that people with science backgrounds "focused their attention on understanding the underlying rules," where as those with a design background "were obsessed with achieving the desired result". Lawson summarized these results as indicating scientists have a "problem-focused strategy" and designers have a "solution-focused strategy" (p.42). A follow-up series of experiments with young people at different stages of their education indicated that the problem solving strategies employed by scientists and designers were learned behaviors and not something that was an innate part of their thinking styles.

In another research study Davis, Hawley, McMullan, and Spilka (1997), with funding from the National Endowment for the Arts, examined the use of design as a method of instruction in K-12 classrooms across all subject areas. The study was titled *Design as a Catalyst for Learning*. The researchers surveyed 160 teachers from across the United States and integrated findings from direct observations taken during ten site visits. The conclusions and recommendations from this research stated that:

- Teachers have a range of understanding for the design process and design thinking.
- There is confusion about the difference between project-based learning with a predetermined outcome and design-based learning which is based on inquiry and discovery.
- Designerly ways of knowing are not typically taught to teachers in their pre-service experiences, and therefore indicates a need for changes in teacher education.
- Successful, sustainable design-based education requires support from administration and the entire infrastructure of a school district.
- There is a need to develop a research base that substantiates the benefits of design-based education toward the academic success of students.
- There is a need for developing and integrating into the school culture assessment tools that are appropriate for the design-based approach to education.
- There is a lack of adequate resources, such as reference materials, lesson plans, textbooks, and networking

systems available to teachers who want to use the design-based approach to teaching and learning (Davis, Hawley, McMullan, and Spilka, 1997).

From a broad perspective, research on design processes, design thinking, design-based education, and design knowledge has developed into a rich area of study. Several journals explore these subjects extensively, including *Design Studies* (http://www.elsevier.com/wps/find/journaldescription.cws_home/30409/description#description), the *International Journal of Design* (http://www.ijdesign.org/ojs/index.php/IJDesign/), and the *Journal of Design Research* (http://www.inderscience.com/browse/index.php?journalCODE=jdr). Further research efforts from academia on design related topics are also being encouraged through the unique, interdisciplinary graduate program in design at North Carolina State University. Davis (2008), who is the head of the program, made the case for the value of graduate studies that result in doctoral research on design-related issues. The specialized program on design-based learning promotes itself as developing "research that helps educators use the analytical and synthetic processes of design and the active learning strategies of design education to reform teaching, learning, learning environments, and learning products" (N.C. State College of Design, 2007, ¶ 4). Finally, there are several organizations that also support and encourage research on design-related topics including the *Design Research Society* (http://www.designresearchsociety.org/), the *International Association of Societies of Design Research* (www.iasdr.org), and the *Industrial Designers Society of America* (http://www.idsa.org/).

RESEARCH ON CREATIVITY AND DESIGN IN TECHNOLOGY EDUCATION

One way to measure the status of a topic in a profession is to measure how much the topic is being discussed in its literature. As noted earlier, Sternberg and Lubart (1999) took such a measurement of the term *creativity* in the psychological literature. Their basic technique of scanning for key words or terms was used by this writer to measure the discussion in technology education. The terms used for this scan of the literature were *creative* and/or *creativity*, *design*, *problem solving*, *innovation*, and *invention*. The scan was done of two commonly read journals for technology education, *The Technology Teacher* (*TTT*) (ITEA, 1995) and the *Journal of Technology Education* (*JTE*) (Digital Library & Archives, 2009). For the most recent ten years (1998-2008), a search of *TTT* found only three articles with the words *creative* or *creativity* in the title, 29 with the word *design*, one with the term *problem solving*, three with the word *innovation*, and one with the word *invention*. Several of the article titles contained multiple search words, so the total number of articles identified was 34. The total number of article titles examined in *TTT* was 350. That means that slightly more then 10% of the articles over that time period had some overt acknowledgement of creativity and design in some

variation. In the *JTE* the results for the same time period found three titles that contained *creative* or *creativity*, 25 contained the word *design*, six used the term *problem solving*, one title contained the word *innovation*, and none used the word *invention*. The total number of articles, editorials, and book reviews examined was 145. Thirty-one (31) of those entries contained one or more of the search terms. In the *JTE* at least 21% of the conversation had some connection to the concepts of creativity and design. Of course the assumption is made that the use of these terms in the title indicates the focus of the article is on the concepts of creativity and design and, inversely, the lack of those terms in the title indicates that creativity and design were not the explicit topic. Furthermore, neither quantitative nor qualitative research about creativity and design appeared to have been the basis for most of the articles in *TTT*. A closer examination of the 31 articles in the *JTE* that used one or more key terms in their titles found that 18 could be readily identified as having a research focus.

Having a conversation in the professional literature of between 10% and 21 % of what is written could be considered excellent results when compared to the findings of Sternberg and Lubart (1999) from the psychology literature of only 0.5%. In total that still comes out to only 13% of the articles over that time period for both publications. A more detailed analysis of the results of the scan of the titles indicated that the profession felt more comfortable discussing a process of design and its implications for creativity than it did about creativity itself. Of the 65 identified articles, only six dealt with creativity, where as 54 articles addressed design. When compared to the total number of articles in this survey, only 1% of the articles were concerned with creativity and 11% dealt with design. One final observation on the importance of design to the profession; if the terminological search is expanded to the 20-year time frame between 1989 and 2008 an interesting phenomenon can be identified. In the ten years between 1989 and 1999 there were only nine titles in the *JTE* that used the word *design*. However, between 2000 and 2008 there were 23 instances of *design* being referred to in an article title (See Figure 1). Perhaps this is reflective of the increasing influence of *Standards for Technological Literacy* (ITEA, 2000) on the technology education profession. The prevalence of design in that document, both as a process and as a concept, may very well have sent a message to technology educators and technology education researchers about the importance of design to the profession. A question to consider from this finding is what effect a similar emphasis on creativity would have produced in the research literature.

Tracking Design in the Literature
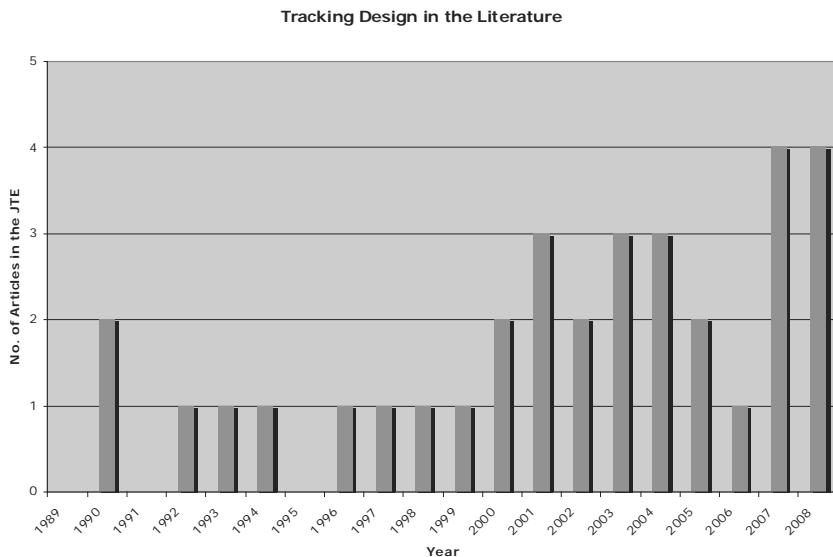
Figure 1. The number of times that the word design was used in titles of articles that appeared in the Journal of Technology Education over the twenty years between 1989 and 2008.

Another measure of the research efforts on creativity and design in the technology education profession is the monitoring of research done by Reed (2001, 2005). In 2001 Reed performed a substantial indexing of graduate studies from technology education, which he named *The Technology Education Graduate Research Database* (*TEGRD*) (p. 3). The *TEGRD* provided a database that contained graduate research (theses and dissertations) completed within technology education from 1892 to 2000. Using the same search terms as before, and filtering for the years 1998-2000 (the time covered by *TEGRD* that corresponded with the previous literature scans) it was found that only three dissertations out of 54 contained any of the terms. Reed (2005) also compiled a document entitled *Current Research Projects in Technology Education*. Based on the earliest start dates for the projects, the index covers 26 notable research projects between 1997 and 2005. Again, using the same search terms, a scan of the document found only two projects using some variation of the word *creative* and only two projects focusing on some aspect of design.

This unscientific measurement of the conversation going on in the technology education literature is not intended as an all encompassing assessment of the status of research on creativity and design in technology education. It does, however, provide poignancy to an observation made by Lewis (2005), who said:

> Creativity has strong claims toward being a foundational area
> of research in technology education. Such research can address
> a host of pressing needs, including methods of assessing
> creative performance, auxiliary instructional activities that are
> good precursors of student creative performance, professional
> development activities that improve teacher competence in
> teaching design/problem solving, and strategies employed by
>
> students as they complete creative tasks (p. 48).

Though the conversation in the profession has begun in the United States, it is clear that if creativity and design are as important as Friedman (2006), Florida (2007, 2002), and Pink (2005) described, more research efforts on the topics will need to take place.

TAKING A GLOBAL PERSPECTIVE

So far this exploration of research on creativity and design in technology education has been focused on the conversation in publications with a primary audience in the United States. However, outside of the United States an extensive body of research-based knowledge on creativity and design in technology education has been developed. This may be because in most countries of the world design is explicitly identified as the primary methodology for studying technology, i.e., *Craft, Design, and Technology* and then *Design and Technology*. Creativity is automatically brought into the international perspective, therefore, because of this emphasis on design. One international forum where this interdependence of creativity and design is continuously examined is the publication *Design and Technology: An International Journal* (http://ojs.lboro.ac.uk/ojs/index.php/ DATE/issue/archive). This journal specifically presents four or more research based articles in every issue, three times a year. Writers in this journal come from countries around the globe (including the United States) to contribute research findings that provide a deeper understanding of the role and value of creativity and design toward the study of technology education.

Another important source of guidance for researchers in technology education who want to investigate creativity and design is provided by a number of books that originated outside of the United States. One book that specifically deals with matters of research is *Researching Technology Education: Methods and Techniques* (Middleton, 2008). The various authors of the chapters provided the reader with insights on 11 different approaches to performing research on creativity and design in a technology education context. In the introductory chapter Middleton quotes himself from an earlier work to provide the rationale for a book about research methods with this statement:

> The kinds of research methodologies that have been employed
> over the last twenty years have evolved and are evolving in
> ways that are making them more suitable for researching the
> things that need to be researched about technology education.

I am not arguing that all research in technology education is compatible with this evolution but that there is evidence that it is happening. My purpose in doing so is based on the belief that using the correct research tools is as important to achieving the research aims for technology education as researching the right topics. Further, some research tools are necessary for the conduct of certain research so that availability of tools can, to some degree, determine what is researched, and what we are able to discover. Lastly, evolution can be ordered or entropic. To ensure that research provides outcomes that allow technology education to evolve in an ordered and positive way it is important to highlight positive developments in research methodologies as well as research findings (p. 2).

The book *Researching Technology Education: Methods and Techniques* was the most recent title in the *International Technology Education Series* (https://www.sensepublishers.com/index.php?manufacturers_id=24&osCsid=1a7). The previous quote originally came from the first book in the series, which was titled *International Handbook of Technology Education: State of the Art* (de Vries & Mottier, 2006). In each of these books readers can find multiple examples of research findings and research methodologies that are relevant to issues related to creativity and design. Another valuable resource book from outside of the United States was *Teaching and Learning Design and Technology* (Eggleston, 2004). The importance of this book was that it helps the reader apply research findings to teaching design and technology at the classroom level.

These few examples of research-based resources from outside of the United States cannot adequately convey the breadth and depth of the research on design and creativity that is being done elsewhere in the world. The value of cooperation toward the study of creativity and design across boundaries is immeasurable. Beginning to connect the research dialogue across gaps that may be formed because of issues related to specific professions, subject areas, national borders, publications, and types of media would be a positive step toward advocating and developing creativity and design as an integral part of an education that is appropriate for the 21st century.

SELECTED EXAMPLES OF RESEARCH ON CREATIVITY AND DESIGN

This section provides brief examples of selected research dealing with topics that are integral to fully understanding the nature of creativity and design and successfully applying that understanding in classrooms. These issues include teacher preparation, comparisons between technology education and other subject areas, action research toward applying creativity and design, and the nature of creativity and design in technology education.

Good teacher preparation is at the foundation of all successful technology education initiatives. One series of on-going research projects that has been completed on issues related to technology teacher preparation has been underway since 2002. In the first study Warner and Morford (2004) conducted a study of the status of design-based courses in undergraduate technology teacher education programs across the United States. Their research divided the study of design into two types of courses, technique-based, which were focused on the technical aspects of design, and synergistic, which "combine the technical skills with the overall thinking processes of design"(p.36). This study "found a profession that is deeply rooted in the technical aspects of the design process"(p. 44). The second part of the study investigated the design paradigm of the instructors of the design-based courses at all undergraduate technology teacher education programs in the United States (Warner, Morford-Erli, Johnson, & Greiner, 2007). The primary findings of this study revealed that a typical instructor of a design-focused course would be male, received a bachelor of science degree in 1979, received a master of science degree in 1984, received a doctorate in 1991, that doctoral was a Ph.D., was originally prepared as industrial arts education, and had a strong background in architecture and construction. The third stage of the study investigated the resources that were used to teach design-based courses at those institutions (Warner & Hickman, 2005). The findings for that study showed that 1) there were a surprisingly small number of resources commonly used across the entire population of the study, 2) there was a small number of similar resources used in any of the categories, which may reflect a lack of sources for these materials, 3) some instructors were extensive in their use of various types of media and resources, and 4) the general lack of resources used to teach design implies that the subject may not be a top priority in preparing future technology educators. Each of these studies provided the profession with knowledge of how new technology education teachers are prepared to incorporate design into their teaching repertoire through their undergraduate education. Each study also provided other researchers with various questions for additional investigation.

Technology education has been referred to as a curriculum that integrates knowledge and skills from across the academic spectrum. So what are the similarities and differences in how technology educators perceive creativity as compared to their peers in other subject areas? To answer this question Stricker (2008) did an investigation of the similarities and differences in the perceptions of creativity among art, music, and technology education teachers. Stricker's findings were summarized as follows:

> Although participants from all three subjects perceived the
> creative process as important to creative work generally,
> technology education teachers were less interested in the
> importance of the creative process than the teachers of
> art and music. In addition, technology education teachers
> perceived a product's ease of use, practical implications,

value to the community, craftsmanship, ability to respond
to a need, and general adherence to technical standards as
being important features of a creative product in their field
when compared to art and music teachers. Art teachers valued
creative personality traits significantly more than their peers
in technology education. The perception of the importance
of group work and competition was significantly higher for
technology teachers than for art teachers (p. iii).

Research is typically thought of as belonging in the domain of the university professor. However, one approach to research is readily available to the classroom teacher at any grade level and in any subject. That approach is known as action research. Ferrance (2000) defined action research with the following passage:

Typically, action research is undertaken in a school setting. It
is a reflective process that allows for inquiry and discussion
as components of the "research." Often, action research
is a collaborative activity among colleagues searching for
solutions to everyday, real problems experienced in schools, or
looking for ways to improve instruction and increase student
achievement. Rather than dealing with the theoretical, action
research allows practitioners to address those concerns that
are closest to them, ones over which they can exhibit some
influence and make change (p. 6).

If creativity and design are to be driving forces for the future of technology education then researchers from all levels must be involved. Koch and Burghardt (2002) conducted an interesting investigation about the value of action research in a design and technology education context. Their study investigated the changes brought about because of an action research requirement in two interdisciplinary (mathematics, science, and technology – MST) master's degree programs in New York State. Their findings showed that teachers changed their self perceptions from instructors to facilitators, children became engaged, active learners, and special needs students were "able to equally participate in group design projects" (¶ 34).

Finally, understanding the nature of what it means to be creative in a technological context, or explaining the nature of the designerly means of knowing, will continue to offer researchers many opportunities for further investigation. As an example, Spendlove (2008, 2007) researched the role that human emotion plays in creative behavior and design processes. The focus of the meta-study was on the importance of emotional influences on the interaction of three design domains: person, process, and product. Spendlove's findings were:

…that for truly creative, engaging learning experience,
the location of emotion is central but, more importantly,
understanding the relationship of emotion to our decision
making offers greater opportunities for our future creative
development (p.7).

Spendlove's research is just one example of the many directions research on the nature of creativity and design can take. It is representative of the type of research that provides greater understanding of creativity and design to technology education as well as to any other areas of study with a similar interest. This ability for research to have application in as broad a swath as possible will, undoubtedly, help technology education provide a significant contribution toward our understanding of creativity and design-based thinking.

A CALL TO ACTION

The purpose of this chapter was to examine the status of research on creativity and design. Toward that end, the reader has been briefly exposed to multiple issues including 1) definitions of the terms creativity and design, 2) explanations as to why having a command of creativity and design will have increasing importance in the 21st century, 3) examinations of the biological, mental, and environmental factors influencing creativity and design, 4) the status of research on creativity in the literature of psychology, 5) creativity research methods and their critiques, 6) an historical examination of design, 7) the nature of the designerly way of thinking and its role in education, 8) the defining characteristics of design-based education, 9) college graduate programs, professional organizations, journals, and books dedicated to research on creativity and design, 10) the amount of conversation on creativity and design that has occurred in the literature of the technology education profession, 11) what research efforts have occurred on the international stage, and 12) samples of selected research projects. It was impossible to cover all of this material in great depth because of space limitations. However, it was possible to see some patterns. These included the slowly increasing rate of research in the United States on design, the need for more research on the role of creativity in technology education, and that an entire body of research on these two topics has been developed in other parts of the world, most notably in countries with a *Design and Technology* approach to their curriculum. More importantly, this chapter and the list of issues that were explored provide technology educators and technology teacher educators with multiple windows of insight about opportunities for performing future research that will help to build the knowledge base of the technology education profession.

This, then, is the call for action to the technology education profession. It is our obligation to prepare the next generations for a future that will be based on creativity and design. They depend on us to be properly prepared and thus give them the keys that they need for that future. This will require the profession to dramatically increase its research and dissemination efforts on issues related to creativity and design.

REFERENCES

Amabile, T. M. (1996). *Creativity in context*. Boulder, CO:Westview Press.

Amabile, T. M. (1989). *Growing up creative: Nurturing a lifetime of creativity*. Buffalo, NY: Creative Education Foundation Press.

Bronowski, J. (1973). *The ascent of man*. Boston: Little, Brown and Company.

Brown, E. (2000). *Action research*. Providence, RI: Education Alliance. Retrieved June 7, 2009 from http://*www.alliance.brown.edu/pubs/themes_ ed/act_research.pdf*

Brown, R. (1989). Creativity: What are we to measure? In J. Glover, R. Ronning, and C. Reynolds (Eds.), *Handbook of creativity: Perspectives on individual differences* (pp. 3-32). New York: Plenum.

Burke, J. (1996). *The pinball effect: How renaissance water gardens made the carburetor possible and other journeys through knowledge*. Boston: Little, Brown and Company.

Burke, J. & Ornstein, R. (1995). *The axemaker's gift: A double-edged history of human culture.* New York: G.P. Putnam.

Burke, J. (1978). *Connections*. Boston: Little, Brown and Company.

Cross, N. (2006). *Designerly ways of knowing*. London: Springer.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention.* New York: Harper Collins.

Davis, M. (2008). Why do we need doctoral study in design? *International Journal of Design, 2*(3), 71-79.

Davis, M., Hawley, P., McMullan, B., & Spilka, G. (1997). *Design as a catalyst for learning.* Alexandria, VA: Association for Supervision and Curriculum Development.

(1992). *Serious creativity: Using the power of lateral thinking to create new ideas.* New York: Harper Business.

DeVore, P. (1980). *Technology: An introduction*. Worcester, MA: Davis.

De Vries, M. & Mottier, I. (Eds.).(2006). *International handbook of technology education: State of the art.* Rotterdam: Sense.

Digital Library & Archives (2009). *Journal of Technology Education*. Retrieved May 18, 2009 from http://scholar.lib.vt.edu/ejournals/JTE/

Dutton, D. (2008). *The art instinct: Beauty, pleasure, and human evolution*. New York: Bloomsbury.

Florida, R. (2007). *The flight of the creative class: The new global competition for talent*. New York: Collins.

Florida, R. (2002). *The rise of the creative class*. New York: Basic Books.

Friedman, T. (2006). *The world is flat: A brief history of the twenty-first century*. (2nd ed.). New York: Farrar, Straus and Giroux.

Gardner, H. (1993). *Creating minds*. New York: Basic Books.

Goleman, D., Kaufman, P. & Ray, M. (1992). *The creative spirit*. New York: Dutton.

Guilford, J.P. (1950). Creativity. *American Psychologist, 5*, 444-454

Hamachek, D. (1979). *Psychology in teaching, learning, and growth* (2nd ed.). Boston: Allyn & Bacon.

Hutchinson, J. & Karsnitz, J. (1994). *Design and problem solving in technology.* Albany, NY: Delmar.

International Technology Education Association (ITEA). (2000*). Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

International Technology Education Association (ITEA). (1995*). The Technology Teacher(TTT) and TTTe*. Retrieved May 18, 2009 from http://www.iteaconnect.org/Publications/ttt.htm

Johanson, D., Johanson, L. & Edgar, B. (1994). *Ancestors: In search of human origins*. New York: Villard Books.

Johnson, A. E. (1997, May 12). *Lower than the angels: The human evolutionary journey*. http://www.dealsonline.com/origins/

Koch, J. & Burghardt, M.D. (2002, Spring). Design technology in the elementary school-A study of teacher action research. *Journal of Technology Education, 13*(2), Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v13n2/koch.html

Lambert, D. & The Diagram Group (1987). *Field guide to early man*. New York: Facts on File.

Lawson, B. (1997). *How designers think: The design process demystified*. (3rd ed.). Burlington, MA: Architectural Press.

Lewis, T. (2005, Fall). Creativity: A framework for the design/problem solving discourse in technology education. *Journal of Technology Education*, 17(1), Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v17n1/lewis.html

McCrone, J. (1991). *The ape that spoke: Language and the evolution of the human mind*. New York: William Morrow.

Middleton, H, (Ed.).(2008). *Researching technology education: Methods and techniques*. Rotterdam: Sense

N.C. State College of Design (2007). *Design for learning*, Retrieved on June 5, 2009 from http://www.ncsu.edu/www/ncsu/design/sod5/phd/content/learning.html

Pink, D. (2005). *A whole new mind: Moving from the information age to the conceptual age*. New York: Riverhead.

Plucker, J. & Renzulli, J. (1999). Psychometric approaches to the study of human creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp.35-61). New York: Cambridge University Press.

Reed, P. (2005). *Current research project in technology education*. Retrieved May 18, 2009 from http://teched.vt.edu/ctte/HTML/Research1.html

Reed, P. (2001). *CTTE monograph #17: The technology education graduate research database 1892-2000*. Reston, VA: International Technology Education Association.

Schick, K. D. & Toth, N. (1993). *Making silent stones speak: Human evolution and the dawn of technology*. New York: Simon & Schuster.

Spendlove, D. (2008). Still thinking and feeling: The location of emotion in the creative and learning experience (Part 2), *Design and Technology Education: An International Journal, 13*(1). 11-18. Retrieved June 7, 2009 from http://ojs.lboro.ac.uk/ojs/index.php/DATE/article/viewFile/Journal_13.1_0208_RES1/39

Spendlove, D. (2007). We feel therefore we learn: The location of emotion in the creative and learning experience (Part 1), *Design and Technology Education: An International Journal, 12*(3). 7-16. Retrieved June 7, 2009 from http://ojs.lboro.ac.uk/ojs/index.php/DATE/article/viewFile/Journal_12.3_1107_RES1/46

Sternberg, R. & Lubart, T. (1999). The concepts of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp.3-15). New York: Cambridge University Press.

Stricker, D. (2008). *Perceptions of Creativity in Art, Music and Technology Education.* Unpublished doctoral dissertation, University of Minnesota.

Wallace, D. (1989). Studying the individual: The case study method and other genres. In D. Wallace & H. Gruber (Eds.), *Creative people at work*. New York: Oxford University Press.

Warner, S., Morford Erli, L., Johnson, C., & Greiner, S. (2007, Spring). Identifying the paradigm of design faculty in undergraduate technology teacher education in the United States. *Journal of Technology Education, 18*, (2) 67-86.

Warner, S., & Hickman, D. (2005, April). *Identifying resources used to teach technological design*. Paper presented at the Annual Conference of the International Technology Education Association, Kansas, MO.

Warner, S. & Morford, L. (2004, Spring). The status of design in technology teacher education in the United States. *Journal of Technology Education, 15*, (2) 33-45.

Williams, T. I. (1987). *The history of invention: From stone axes to silicon chips.* New York: Facts on File Publications.

Social Sciences

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Chapter
12

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INTRODUCTION

Technology is a human activity. Humans adapt their environment for various purposes, not in the least to survive. Technology can also serve to fulfill less crucial desires. Today those of us in industrialized countries have a lot of luxury thanks to technological developments. In other parts of the world the situation is quite different. It is becoming more and more evident that the limitations of the resources of our globe are insufficient to allow the same technological development that industrialized countries enjoy from being realized elsewhere. The ecological footprint of industrialized countries extends far beyond the geographical surface they cover and we simply do not have two or three earths, but only one. It would require such dramatic reductions in the ecological pressure that industrialized technologies put on our earth that it is not realistic to expect that we will be able to overcome the inequity. Even if we thought that we could sometime in the future, we cannot afford questioning ourselves whether the current situation is ethically justifiable or not. This is both an individual and a social question. Certainly it would help a great deal if each individual would act in a more responsible way, but even then the overall result could be unacceptable due to a lack of coordination of all those sympathetic efforts. Some improvements can only be realized at a social level.

The issue of our responsibility for technological developments raises questions that are related to the fundamental nature of technology. Is technology by definition an activity that will inevitably decrease the quality of our natural resources or not? Are we humans so inherently technological that even if we would be willing, we would not be able to abstain from some of the technological benefits that we enjoy? To be able to answer such questions it is often necessary to go even deeper and reflect on even more basic questions such as: What do we mean by technology anyway? What is a technological artifact? What is a technological system? What is technological knowledge? To be able to answer such basic questions about technology, we often also have to consider basic questions about the nature of science, given the many relationships between science as a way of getting to know the reality in which we live and technology as a way of manipulating it.

When we teach about technology we can do so in a narrow and instrumental

way. We can limit this teaching to learning some skills for living in a technological world. By doing so, we can avoid answering the sort of questions mentioned above. We need not bother students with these human, social, ethical, and conceptual questions. In fact, that is what we often did in the past. It is only in the last few decades that we have started to recognize the error in such teaching. We are now much more aware that good teaching about technology should include those questions rather than exclude them. But if we agree, then the challenge becomes how to do it. How do we make sure that the way we teach about technology, with the inclusion of those questions, is valid and valuable? From where can we gain knowledge that can help us determine that?

This chapter will highlight a number of academic disciplines that have developed in the past five decades that can serve as rich resources of inspiration for technology educators. In the 1995 Council on Technology Teacher Education (CTTE) Yearbook (Martin, 1995), both Waetjen and Wiens made the same sort of claim in their chapters. An overview of what those disciplines can offer is presented with a focus on two disciplines, namely the history and sociology of technology, and the philosophy of technology. The latter also includes the ethics of technology. The history and sociology of technology will be approached first since they have often served as a basis for reflections about the philosophy of technology. Finally, a discussion is presented how these academic disciplines can be used in developing standards for teaching about technology, for developing curriculum, instructional strategies, learning environments, and for assessment. I will also discuss what research is needed in order to make optimal use of the outcomes of such disciplines in the development of technology education.

REVIEW AND SYNTHESIS OF RESEARCH

HISTORY AND SOCIOLOGY OF TECHNOLOGY

A change has taken place in the philosophy of technology that is very similar to the change that has taken place in the philosophy of science. For example, new perspectives on humankind and the non-rational aspects of science have caused many philosophers of science to give up the idea that science is a domain that is governed by rational decisions alone. Sociological studies, such as those by Latour and Law (see Bijker & Law, 1992; de Vries, 2005 for extensive lists of references) have shown that what is regarded as scientific knowledge is not per se that which is most useful in all experimental testing. The race between competing theories is often decided by factors other than those that are purely scientific. The authority of a scientist, for instance, can have a large influence. When Newton's theory of light as a particle phenomenon and Huygens' theory of light as a wave phenomenon competed for general acceptance, it was Newton's authority and reputation that made his theory prevail over Huygens' for a period of time, in spite of the fact that it had less scientific merit. It was Kuhn (1962) that developed

a theory for the development of science in which these non-rational factors were put in a prominent place (see de Vries, 2005 for more detail about Popper, Kuhn, and other philosophers of science). According to Kuhn, the scientific community tends to stick to a theory (or paradigm, in Kuhn's terminology) rather than giving it up for the sake of one experiment that provided counterproof. Only when a critical mass of scientists gives up the belief in the current paradigm will a shift towards another paradigm occur. Since this often happens in a short period of time, Kuhn refers to it as a revolution. This is contrary to the idea of the positivists (or neopositivists) who claimed that only objective and value-free measurements count in scientific decision making. It is also contrary to Popper's claim that one counter-experiment is enough to provide absolute certainty that a hypothesis is false. This is why Popper recommended falsification rather than verification as the main criterion for the scientific nature of a hypothesis.

Kuhn's theory is a sociological one, but one supported by historical examples. The idea that social factors play an important role in the development of science became known as social constructivism. In fact, this view claims that each scientific theory is a social construct rather than an outcome of reasoning based on observations. Pickering (1984), for instance, has written a study on the emergence of the concept of quarks, which are elementary particles in high energy physics. The discovery of quarks provided new opportunities to obtain funding for new particle accelerators rather than relying on phenomena that had already been observed. In the Strong Program, the non-rational, human and social factors are seen as dominant in the development of science (Barnes, Bloor, & Henry, 1996). To others this is too extreme and they opt for a vision in which there is room for rationality. Lakatos, for instance, developed the idea of Theoretical Research Programs that have a core and cladding (de Vries, 2005). The core has a paradigmatic character and is not easily eliminated even when counterevidence is available. The cladding on the other hand consists of related but less crucial theories that have vulnerability for experimental counterevidence and thus represent a rational element. So the philosophy of science went through changes from neo-positivism and Popperianism to social constructivism because of the sociology of science and the evidence provided by case studies reported by historians of science.

The same chain of history, sociology, and philosophy can be seen in the field of technology. The philosophy of technology underwent changes similar to the philosophy of science, with historians providing case studies upon which sociologists reflected, resulting in new perspectives that were then transformed into new philosophical views.

Wybe Bijker played a key role in the changes in the sociology of technology that took place. His book on the development of the bicycle has become a classic reference for many philosophers of technology (Bijker, 1997). In his study of the history of the bicycle, Bijker (1997) showed that large front wheel, small rear wheel, design of early bicycles was popular in spite of its clumsiness as a

transportation vehicle because it allowed boys to show their cycling skills and braveness to girls (see also Bijker, Hughes, & Pinch, 1985). Thus, the reigning social perspective on the bicycle was that it was a "macho machine" rather than a means of transportation. So the success of the "High Bi" was not due to good, rational mechanics, but to its social purpose. In other words, in the view of social constructivists in technology, the bicycle was a social construct rather than the result of proper mechanical reasoning. This is parallel to a scientific theory being the result of social construction rather than scientific experimentation. It was not until women also wanted to be able to ride bicycles that they changed from "macho machines" to "transportation vehicles." Consequently, the design of the bicycle changed with the front and rear wheels being the same size. This is parallel to the paradigm shift to which Kuhn (1962) referred.

As in the philosophy of science as well as in the philosophy of technology, technologists criticize the extreme forms of social constructivism just as scientists do. Winner (1997), for instance, wrote a critical article against extreme social constructivism with the title "Opening the black box, and finding it empty." The opening of the black box was in reference to revealing the non-rational, human, and social elements of technology. The emptiness to which Winner referred was the absence of the explanatory power of the social elements of technology.

The discovery of human and social factors as important elements in the development of technical devices opened a new era for the sociology of technology. Various new theories emerged (see Staudenmaier, 1985; Bijker & Law, 1992). The most influential ones focused on the application of systems and network theory to technological development. Hughes (1985) used the history of the electrification of the U.S. to show that technological development had a systems character because it required all sorts of individuals to cooperate (Hughes, 1985).

Even before Hughes, the French philosopher Jacques Ellul had thought of technological development as a system, arguing that it cannot be readily controlled socially since the feedback mechanism is so autonomous (de Vries, 2005). Hughes' idea, however, was not so much the autonomy of feedback, but in the fact that all elements of technological development as a social system must be taken into account. The idea of interaction between social actors is a key feature in the actor-network theory that was developed by Callon (1985). Technological development from this perspective occurs as a result of the sum of forces exerted by various actors, each of whom pulls in a certain direction, based on interests, with a certain strength that is based on the effectiveness of the actor's means of power. This mechanism has a conservative effect that is akin to what Kuhn (1962) theorized for science. That is, there is a period in which a given technological paradigm reigns until a critical mass of engineers and technologists decide that the application of principles from an alternative paradigm perform better. Historian of technology Edward Constant has used the foregoing to account for the development of the jet engine (Constant, 1985).

Over time, the term paradigm was replaced by terms such as technological

regime and technological trajectory. The latter refers to the erosion of a certain path when everyone follows it. Scholars like Rip, Misa, and Schot (1995) emphasized that technological development cannot be explained by focusing exclusively on the device itself. Rather, technological development must be considered in a much broader context. As a result, the term technological landscape was popularized. Now, the consensus is that the overall development of technology is seen as an evolutionary process with periods of slow changes alternated by some dramatic and sudden changes (Basalla, 1988).

One of the important themes in the philosophy of technology was and still is its relationship with science. Here, too, historical studies have been used to derive insights about the nature of technology. In particular, studies of the history of industrial research and development laboratories proved to be applicable. Study into the history of the Philips Research Labs has shown that there are at least three patterns of interaction between the development of new scientific knowledge and the development of new technological products (de Vries, 2005). In the years between World War I (WWI) and World War II (WWII), the research lab served as a spider in the web of Philips, an electronics company. It was the main source of new inventions for the company, but there were direct and often informal relations with the company's directorate and with the factories. Later, in the two decades following WWII, the research lab became an ivory tower that produced many ideas for innovations, but many were rejected by the company's product development division. In like manner, the research lab did not hesitate to reject requests for research from the product division if they thought it was not interesting from a scientific point of view. In the late 1960s the lab's policy changed again and it became a deliverer of specific knowledge as requested by the product division that was leading the company in new product development. Studies like this show that there is no such thing as a perfect relationship between science and technology. Rather, there is a multitude of ways in which science and technology interact. Such insights have contributed to the studying the philosophy of technology as discipline from a more theoretical point of view.

PHILOSOPHY OF TECHNOLOGY

The philosophy of technology is a fairly young discipline, compared to the philosophy of science. It was not until after WWII that the philosophy of technology really got started. Before that time only a few scattered publications included the term. Perhaps the most important initial idea toward the development of the philosophy of technology was the notion that technological devices were extensions of the human body. Ernst Kapp, a German philosopher, developed this idea in the late nineteenth century (de Vries, 2005). The importance of these extensions were later emphasized by Arnold Gehlen when he described the human being as a 'Mängelwesen", that is an incomplete being (de Vries, 2005). Humans are so vulnerable that they need to have technological devices as extensions of themselves in order to survive. Then came Lewis Mumford, who wrote about the

history of technology from a philosophical perspective and showed that humans had indeed become so strongly dependent on these extensions that technology had become a dominating factor in their living environment. Mumford argued, though, that this was really a false dependency in his two volume work titled the *Myth of the Machine* (1967, 1970).

After WWII, several other philosophers took up Mumford's concern about the role of technology in culture (de Vries, 2005). This was perhaps the main reason for the emergence of the philosophy of technology as an academic discipline. This is rather surprising because technology existed, of course, long before and its impact on culture and society was already an intrinsic part of human history before the systematic reflection on technology really started. Though the philosophy of science had already been around for several decades, one can question whether it was science or technology that had the most influence on cultural and social development. In any event, it was after WWII that the interest in reflecting systematically about technology finally got off the ground. In those days, the field of philosophy was dominated by the "Continental Philosophers." These are philosophers who lived and worked on the European Continent, especially in Germany and France. This is in contrast to analytical philosophers, a new set of scholars who focused more on the aim of what philosophers do, namely the analysis of concepts in order to reach a coherent and non-contradictory set of concepts for philosophical discussions. As time went on, "Continental" lost its original meaning and now defines a type of philosophy that can perhaps be best described as asking the "ultimate questions," like why do we have technology and what does it do to us? Contemporary philosophers of technology live around the world, not just on the European Continent. Analytical philosophy should help provide a "language" of proper concepts by which the "Continental philosophers" can debate their "big questions."

In 1994 Mitcham published the results of a survey among philosophers of technology. It is still considered one of the classical works in the field. Mitcham distinguished four areas in which philosophical debates occur, namely, technology as artifacts, as knowledge, as activities, and as volition. With technology "as volition" he was referring to the fact that technology is part of what we humans are and thereby included most of the issues about which the "Continental Philosophers" wrote. In contrast, analytical philosophers of technology were included in the other three areas (Mitcham, 1994).

The analytical philosophy of technology emerged much later than the Continental philosophy of technology. Philosophers who also had a background in natural sciences, technology, or engineering were often considered analytical philosophers. For this reason they were more capable of analyzing technology "from the inside," in contrast to the outsider's perspective of the Continental Philosophers. The result was that the latter often over-generalized their findings due to a lack of in-depth information about how technology developed in practice.

What follows is a description of the other three areas Mitcham (1994)

identified: artifacts, knowledge, and activities (de Vries, 2005). One of the important insights in the area of artifacts is the dual nature of technical artifacts. On the one hand they are physical realizations. They have weight, size, color, a number of parts, various material properties, and so on. On the other hand, artifacts are devices to which we can ascribe functions. In other words, artifacts have both a physical (structural) and a functional nature. A description of the physical and structural nature can be purely descriptive of its properties. In contrast, a description of the functional nature is normative in nature. Such a description does not tell what the artifact is actually doing, but what it should enable a person to do with it. It is not intrinsic to the artifact as with its physical nature. It depends upon who is ascribing the function. One person can describe an artifact as a coffee mug and another person can describe the very same thing as a paperweight. Both ascriptions can be legitimate. Not all ascriptions, though, are legitimate, as there is a relation between the physical and functional nature. I can describe the same artifact as a flying machine, but that does not make much sense because the device does not allow me to fly with it; its physical realization is not fit for that. So the user has a certain but not unlimited freedom to ascribe functions to an artifact. There is often, though, what is called a "proper" function to the artifact. This is what the designer had originally intended for it. The designer had started with a desired function and from there on used creativity and reasoning to come up with a possible physical realization of the artifact such that it would be able to be used for what it was intended.

This basic conceptualization of technical artifacts can serve as a starting point for describing the nature of technological knowledge. At least three types of technological knowledge can be derived from this. Designers and users alike can have knowledge of the physical nature, the functional nature, and the relationships between the physical and the functional natures. Furthermore one needs knowledge of processes to be able to produce and use the artifact. These types of knowledge can be propositional in nature, meaning that they can be expressed fully in words. But the knowledge of processes is more than just propositional. How to hammer a nail into a piece of wood properly is something we cannot fully explain in words. One has to show it in order to help someone else understand it. This is what philosopher Ryle (1963) calls "knowing-how." There is much knowledge that cannot be adequately expressed in words. This is the kind of knowledge for which engineers, architects, and technicians use drawings. Ferguson (1992) has described this type of knowledge in his book *The Mind's Eye*.

To reiterate, the functional nature of artifacts is not intrinsic and can only be expressed in normative terms. This makes technological knowledge fundamentally different from scientific knowledge. For example, physicists describe only what an electron actually does and how it behaves. They do not consider the things the electron "*ought* to do." It does not make any sense for scientists to talk about good and bad electrons; however it is considered perfectly normal for an engineer or technologist to proclaim that a hammer is good or bad. The normative dimension

of some types of technological knowledge indicates that technology cannot be merely the application of scientific knowledge, because that knowledge does not comprise normativity.

In a series of historical case studies, Vincenti (1990) has further elaborated the idea that technological knowledge can be only partially derived from science. The physical and functional types of knowledge can both be further analyzed. This has been done in a field called reformational philosophy. In this type of philosophy a technical artifact is seen as an entity that functions in various aspects of reality. It is, for instance, a spatial entity (it occupies space), but also a biological one (it interacts with living beings), a social one (it has a place in social relations), an economical one (it can have an economic value), a juridical one (it can be the object of a law), an aesthetical one (it can be beautiful or ugly), and it can be the object of trust and belief (what reformational philosophy calls the pistic aspect of reality). One can study all of these aspects, but there are academic disciplines that focus only on a single aspect. For instance, sociologists focus exclusively on the social aspect while biologists focus exclusively on the biotic aspect. The broader perspective on technological knowledge emphasizes the multi-disciplinarity of technological knowledge and can therefore be considered as an analytical perspective, although it was developed in a time when the analytical philosophy of technology had only started to exist. The Dutch philosopher Hendrik van Riessen contributed significantly to this broader, multi-discipline perspective (de Vries, 2005).

Now, technology as activities (Mitcham, 1994) will be considered. Most of what has been written about this area is related to the design process. Academic reflections on the design process were not exclusively done by philosophers of technology. They were firstly done in the discipline of design methodology, in which practicing designers reflected on their own work and that of others (Cross, 1984). Later, analytical philosophers took interest in the design process and the two fields, although still separate today, began to interact. Several insights were gained in design methodology that contradicted original ideas. In the early days of design methodology there was a belief that it was possible to prescribe a single sequence for the design process that would be valid for all designing. Usually, analysis, synthesis, and evaluation were the basic stages in those early design process flowcharts. Later, under the influence of both theoretical reflections and empirical observations, this belief waned and awareness arose that different engineering domains need different design approaches. The role of prescriptive design schemes was found to be more limited and context-bound than originally thought. Also, the complexity of design processes increased due to the many individuals who want or need to influence the process such as individual designers, design teams, members of product development teams, and the governing board of the company, as well as external influences such as governmental agencies, standardization committees, interest groups, and so on (de Vries, Cross, & Grant, 1993). Out of this complexity the field of quality management arose and included

all those who had a stake in safety, within the company and external to the company. Once again, the complexity of managing quality was underestimated. Managers eventually realized that a generalized approach to quality was not effective and that the specific context in which it was to be applied had to be considered seriously.

The final domain in the philosophy of technology identified by Mitcham (1994) was technology as volition, or in other words, the consideration of technology as part and parcel of our humanity. As mentioned earlier, this domain was dominated by Continental Philosophy, and this is still the case today as evidenced by the fact that all four of Mitcham's (1994) domains are represented in the work of Continental philosophers.

One area of technology as volition is represented by the branch of philosophy known as phenomenology. The phenomenologists focused primarily on the way technology impacts our experience of the lifeworld. According to Heidegger this impact is quite negative in that technology narrows our view of reality, as if everything is merely a resource for our desire to change the environment (de Vries, 2005). It might be argued, for example, that we have lost our appreciation for the tree as an entity unto itself but instead see only the potential of the tree yielding a stack of lumber. Borgmann (1984) followed in the wake of Heidegger and coined the phrase "device paradigm." He argued that the technical artifacts we use provide us commodities in such a way that we become disengaged from the richness of the lifeworld. Instead of having the physical experience of chopping wood for heating our homes, we only have to turn the thermostat knob slightly and the room temperature increases almost instantly. This disengagement is accompanied by a loss of the uniqueness that our experiences of the lifeworld provide. The convenience of prepared foods that only require heating in a microwave oven before they are ready for consumption has resulted in a loss of diversity in taste. Borgmann's (1984) therapy for escaping the dangers of such disengagement is to do focal activities that bring back engagement. Examples include preparing meals from basic ingredients, jogging in the woods, and attending religious services.

In contrast to Heidegger and Borgmann is the thinking of Ihde (1990). He proposed that there are four ways in which relationships between humans and technology occur. In an embodiment relationship the device through which we experience or observe the world around us becomes like part of our body. For example, we do not notice the eye glasses we wear because they have become like part of our eyes. In a hermeneutical relationship, the device becomes one with the lifeworld we observe. An operator in an energy plant, for example, can "look through" the operating panel and imagine what happens behind it in the plant itself by interpreting the measurement devices on the panel. In an alterity relationship, a person can see a technical representation of the lifeworld without it actually existing in the real world. This is what happens when one is engaged with a video game or a science fiction movie. In a background relationship, the technical device operates in the background of one's mind and the person

is not aware of its existence even though it affects observations. For example, artificial lighting impacts our view as we walk on a street at night, but we might erroneously conclude that there are fewer stars in the sky. In a similar way, Ihde (1990) claimed that ignoring various relationships can distort our perception. If we do not realize, for instance, that we have to interpret the colors in a picture of the universe as temperatures rather than real color, we develop an incorrect picture of the lifeworld.

The technology as volition domain also includes philosophers who were inspired by the "Critical Theory," which is very similar to the neo-Marxist philosophy. Probably the most important philosopher in this stream is Feenberg (1999). He took Marcuse's idea that the social changes that Marx expected to happen automatically could not occur without planned intervention. Feenberg proposed that this can be done in a combination of what he calls primary and secondary instrumentalization. In primary instrumentalization a social need is taken out of its social context and redefined as a technical problem for which a technical solution can be found. In secondary instrumentalization such solutions are re-embedded in a social context. In that latter process social actors can reshape technologies according to their needs. Feenberg uses the example of the French Minitel computer system to illustrate that this can really happen. Originally the Minitel had been intended as a means through which the French government could disseminate information, but hackers took over the system and started using it for the mutual exchange of information, as with the Internet now. Langdon Winner (1997) often seems rather pessimistic with this approach, as most of his examples refer to cases in which technologies were used to confirm or enhance the existing social order. Probably his best known, and often contested, example is that of the viaducts in Long Island, New York that were so low that the buses used by black people to reach the beach could not pass through them, thus making the beach available to white people only.

A third Continental philosophical stream represented in the contemporary philosophy of technology is that of pragmatism. The work of Hickman (2001) is particularly relevant. Drawing from Dewey, Hickman claims that the way engineers work should be exemplary for the way society should develop (de Vries, 2005). Engineers do not believe in *a priori* good solutions but try out various options and then let the practical outcome determine what makes sense and what does not. This is a typical example of a pragmatist approach. In addition to engineers, Hickman would like to see politicians use it as well. Rather than believing in the validity of capitalism, socialism, or some other defined ideology, Hickman feels that politicians should try out options and let practice decide what society needs.

Although all previously discussed approaches are in conflict with the pragmatic approach, probably the most fiercely opposing approach is reformational philosophy. In this approach the way we developed technology is judged in the light of religious criteria in the tradition of reformed Protestantism.

In this approach, not the outcome but the motives by which we let ourselves be led are crucial for our appreciation on technology. When we are driven by a desire to exercise control over nature and people, we will face few limitations in the way we exploit natural and human resources. If, on the other hand, we are motivated by love and care then the way we develop technology will face normative constraints related to the well being of nature and humans. The latter motive is regarded to be the direct consequence of God's will over our lives.

The conflict between pragmatism and reformational philosophy leads into the realm of ethics and technology. Pragmatism represents a consequentionalist approach in ethics. The consequences of technological developments determine our assessment of the various options about which we have to decide. Many political debates about technological issues are quickly reduced to such an approach, probably because consequences are more easily agreed upon than motives, virtues, or duties. Technology assessment is a typical instrument that is then used. This type of research aims at mapping the various types of consequences of different policy options on such areas as the natural environment, the social order, or employment.

There are other approaches that are more duty-oriented such as those specified in professional codes. An example would be a statement that bribery or espionage in business is never to be practiced. Other situations call for a virtue-oriented approach in which the focus is on what makes a person good. What should we do in order to be honest or respectful with regard to others or nature? The reformational philosophy embodies an approach in which the elements of virtue, duty, and consequences are blended into responsibility toward God and our fellow humans. This is not unique to reformational philosophy, though it exemplifies its application in practical and political terms (Schuurman, 1997). Whitbeck (1998) made an interesting suggestion when she showed how ethical problems can be solved not only by choosing between conflicting alternatives, as often happens when an ethical problem is analyzed as a dilemma, but also when a designer uses creativity to find solutions that break away from the dilemma and arrives at a synthesis that does justice to both alternatives. Motives such as responsibility, love, and care can be particularly strong driving forces in seeking such creative solutions. In the pragmatist approach one would be more tempted to calculate the effects of both alternatives and simply opt for the one that has the best results. This may, however, easily lead to sub-optimization, as most engineers know by experience.

CONSEQUENCES FOR TEACHING ABOUT TECHNOLOGY

From the preceding overview of how the history, sociology, and philosophy have affected technological development, a strong rationale can be developed for the kinds of research that is still needed to develop a sound academic and theoretical basis for technology education. In the first place, the outcomes of the disciplines

discussed increase the awareness of important aspects of technology that need to be represented somehow in our teaching about technology (deVries & Tamir, 1997). The history and sociology of technology show how technological developments are very much influenced by the interaction between social actors and cannot be adequately represented by the work of engineers alone, as we have thought in the past. By engaging students exclusively in activities that focus on making devices, we have created a narrow image of technology as if it was just a matter of choosing the right tools and using them properly. By having students do design projects without any reference to the social context in which they are to be used and the prospective users, students can logically conclude that the development of new products is something that engineers can do on their own, in isolation from the rest of society. Even when we do not do it explicitly, such teaching practice communicates this notion quite effectively. Knowing that technology is a human and social activity should have consequences for the standards we develop for teaching about technology, for the development of curricula that enable us to realize those standards, and even in the details of specific lessons that we plan and what learning we assess. If we do not include these aspects in our assessment, in effect we minimize their importance and students will certainly interpret our assessment that way. The various approaches elaborated in the "technology as volition" area of the philosophy of technology emphasize the various ways of appreciating the way technology as a human and social enterprise develops. This is something that needs to be discussed at all levels, not only in higher education. Educators should look for ways to transpose these complex ideas into simple terms for understanding by younger learners. If this is not done, distorted ideas about technology will be created in the minds of young people that will be difficult to correct later on. Moreover, our educational strategies and learning environments should be designed to stimulate an awareness and understanding of the historical and social dimensions of technology. If the posters we put on the classroom walls illustrate only devices and machines, the importance of the human and social dimension of technology is rendered of lesser or no importance compared to the technical details of the devices and machines illustrated. Through the Internet, DVDs, and other developing instructional technology, the historical and social aspects of technology can be brought into the classrooms in a lively and realistic way. This will create the proper context for students to reflect on the human and social aspects of technology while they do their practical work in technology education projects. Creating such a context, however, does not occur automatically, but instead requires careful and intentional development of the materials with which the students work.

The analytical philosophy is very useful if we seek to present technological concepts in such a way that they become understandable for students. It is the main aim of analytical philosophy to reduce and simplify complex issues, returning them to their essential basics. Arguably, this basic understanding is exactly what we need. We need to constantly seek to reduce the complexity of reality in order to make it understandable by students while at the same time helping them to

understand the full richness of this reality. In this way analytical philosophy can help implement instructional strategies in which this basic understanding becomes the starting point for teaching concepts in technology. It can also assist in effective assessment by helping to identify whether or not our teaching practice has led to true understanding.

The use of insights from the history, sociology, and philosophy of technology can be an opportunity for technology education. To some extent it has already happened in practice. Both *Standards for Technological Literacy* (ITEA, 2000) and the reports on technological literacy produced by the National Academy of Engineering (Pearson & Young, 2002; Garmire & Pearson, 2006) have made use of the outcomes of history, sociology, and philosophy of technology, as evidenced by the references they cite. At the same time, there is a serious shortfall in the respect that there are but a few examples of where this transfer involved the collaboration of historians, sociologists, and philosophers of technology on the one hand, with technology educators on the other. In most cases the technology educators themselves have to make sense of what they find in the writings of the historians, sociologists, and philosophers. This is indeed a challenge since the publications from these fields were written for specialists in the respective fields and are often difficult for "outsiders" such as technology educators to understand.

Many technology teacher education programs are located on the same campus as research programs for the history, sociology, and philosophy of technology, yet there is little or no contact between them. Often a sociological barrier exists as well for technology educators to interact with the historians, sociologists, and philosophers due to the perception that they will not be accepted or respected by their academic counterparts. Real or imagined, it seems to be a prevalent feeling. This sentiment has also been noted by Pearson (2004) with respect to engineering and technology education.

On the contrary, though, there are examples of cases in which a dialog between technology educators and historians, sociologists, and philosophers of technology proved to be fruitful. Such an example is the symposium that was held in 2007, organized by Dakers, Dow, and de Vries at the University of Glasgow. The event attracted some of the world's leading philosophers of technology, including Andrew Feenberg, Don Ihde, Joseph Pitt, and Leonard Waks. The symposium resulted in an open and thought-provoking discussion among all participants. At such occasions not only do educators get a good understanding of the current insights into the nature of technology, as developed by historians, sociologists and philosophers, but also both parties find ways to work together to develop effective ways to transpose those insights into teachable terms at various levels. It is imperative that such initiatives be replicated in other locations.

CONCLUSIONS AND SUMMARY

This chapter presented a survey of the ideas concerning the nature of technology that the history, sociology, and philosophy of technology can offer to technology

educators. It was also argued that the use of those insights offers opportunities for a sound intellectual basis for technology education in all its aspects: standards, curriculum, instructional strategies, learning environments, and assessment. Also, it was shown that the transfer of those ideas to education, ideally speaking, should be a matter of dialog between educators and the historians, sociologists, and philosophers who have developed those ideas. Hopefully this chapter will encourage and stimulate technology educators to seek working relationships with experts in these other disciplines for the benefit of all.

REFERENCES

Barnes, B., Bloor, D. & Henry, J. (1996). *Scientific knowledge: a sociological analysis*. London: Athlone.

Basalla, G. (1988). *The evolution of technology*. Cambridge, MA: Cambridge University Press.

Bijker, W. E. (1997). *Of bicycles, bakelites, and bulbs: toward a theory of sociotechnical change*. Cambridge, MA: MIT Press.

Bijker, W. E., Hughes, T. P. & Pinch, T. J. (Eds.) (1985). *The social construction of technological systems: new directions in the sociology and history of technology*. Cambridge, MA.: MIT Press.

Bijker, W. E. & Law, J. (Eds.) (1992). *Shaping technology, building society: studies in sociotechnical change*. London: MIT Press.

Borgmann, A. (1984). *Technology and the character of contemporary life: a philosophical inquiry*. Chicago, IL: University of Chicago Press.

Callon, M. (1985). Society in the making: the study of technology as the tool for sociological analysis. In Bijker, W. E., Hughes, T. P. & Pinch, T. J. (Eds.). *The social construction of technological systems: new directions in the sociology and history of technology*. Cambridge, MA.: MIT Press.

Constant, E. W., II (1985). The social locus of technological practice: community, system, or organization? In Bijker, W. E., Hughes, T. P. & Pinch, T. J. (Eds.). *The social construction of technological systems: new directions in the sociology and history of technology*. Cambridge, MA.: MIT Press.

Cross, N. G. (1984). *Developments in design methodology*. Chichester: Wiley.

Dakers, J., Dow, W., & de Vries, M. J. (Eds.). (2007). International conference on design and technology education research. Glasgow, Scotland: Eighteenth annual Pupils Attitudes Towards Technology (PATT-15) Conference.

de Vries, M. J. de & Tamir, A. (Eds.) (1997). *Shaping concepts of technology: From philosophical perspectives to mental images*. Dordrecht: Kluwer Academic Publishers.

de Vries, M. J. de, Cross, N. G. & Grant, D (Eds.) (1993). *Design methodology and relationships with science*. Dordrecht, Netherlands: Kluwer Academic Publishers.

de Vries, M. J. (2005). *Teaching about technology. An introduction to the philosophy of technology for non-philosophers*. Dordrecht, Netherlands: Springer.

Feenberg, A. (1999). *Questioning technology*. London: Routledge.

Ferguson, E. S. (1992). *Engineering and the mind's eye*. London: MIT Press.

Garmire, E. & Pearson, G. (2006). *Tech tally. Approaches to assessing technological literacy*. Washington, DC: National Academy of Engineering.

Hickman, L. (2001). *Philosophical tools for technological culture*. Bloomington and Indianapolis: Indiana University Press.

Hughes, T. (1985). The evolution of large technological systems. In Bijker, W. E., Hughes, T. P. & Pinch, T. J. (Eds.). *The social construction of technological systems: new directions in the sociology and history of technology*. Cambridge, MA.: MIT Press.

Ihde, D. (1990). *Technology and the lifeworld: From garden to earth*. Bloomington: Indiana University Press.

International Technology Education Association (ITEA). (2000). *Standards for technological literacy. Content for the study of technology*. Reston, VA: Author.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Martin, G. E. (1995). *Foundations of technology education*. Peoria, IL: Glencoe/McGraw-Hill.

Mitcham, C. (1994). *Thinking through technology*. Chicago, IL: University of Chicago Press.

Mumford, L. (1970). *The pentagon of power: the myth of the machine, Volume II*. New York, NY: Harcourt Brace Jovanovich.

Mumford, L. (1967). *The myth of the machine: Technics and human development.* New York, NY: Harcourt Brace Jovanovich.

Pearson, G. (2004). Collaboration conundrum. *Journal of Technology Education, 15*(2), 66-76.

Pearson, G. & Young, A.T. (Editors) (2002). *Technically speaking. Why all Americans need to know more about technology*. Washington, DC: National Academy Press.

Pickering, A. (1984). *Constructing quarks: a sociological history of particle physics*. Edinburgh: Edinburgh University Press.

Rip, A., Misa, T. J. & Schot, J. (Eds.) (1995). *Managing technology in society: the approach of constructive technology assessment*. London: Pinter.

Ryle, G. (1963). *The concept of mind*. London: Hutchinson.

Schuurman, E. (1997). *Perspectives on technology and culture*. Potchefstroom: Institute for Reformational Studies.

Staudenmaier, J. M. (1985). *Technology's storytellers: reweaving the human fabric*. London: MIT Press.

Vincenti, W. G. (1990). *What engineers know and how they know it*. Baltimore:

Johns Hopkins Press.

Waetjen, W. B. (1995). Shaping the future of a profession. In Martin, G.E. (Editor). *Foundations of technology education*. Peoria, IL: Glencoe/ McGraw-Hill

Whitbeck, C. (1998). *Ethics in engineering practice and research*. Cambridge: Cambridge University Press.

Wiens, A. E. (1995). Technology and liberal education. In Martin, G.E. (Editor). *Foundations of technology education*. Peoria, IL: Glencoe/McGraw-Hill.

Winner, L. (1997). *Autonomous technology: Technics-out-of-control as a theme in political thought*. London: MIT Press.

Research Related to Informal and Extracurricular Technology Education

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Chapter
13

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INTRODUCTION

The contemporary view of a technologically literate individual is someone with the ability to use, manage, assess, and understand technology (ITEA, 2000). In most cases, the full realization of these skills includes experiences outside the school setting. This chapter presents a review and synthesis of recent research relating to voluntary activities for K-12 students, outside of the school day, in which technological literacy is deliberately promoted. These activities fall into two general categories:

Extracurricular technology education takes place during out-of-school time. These programs have some degree of structure and some clear way of identifying participants. They may reinforce the local technology curriculum, but are not designed to remediate or act as a delivery method for the curriculum.

Informal technology education is relatively unstructured. These activities are usually administered at museums or in similar environments. They are 'informal' insofar as participants are encouraged to visit topics nonlinearly—skipping some, repeating others, and dropping yet others midcourse. The exemplar is a hands-on exhibit at a science-and-technology museum, which may interest a participant sufficiently to result in him or her enrolling in a museum-sponsored program which may in some cases be indistinguishable from an extracurricular program.

Extracurricular and informal technology education can, however, be distinguished from co-curricular technology organizations, which require or assume enrollment in specific classes or curricula. In the technology education field in the U.S., these include the Technology Student Association (TSA), Technology Education Collegiate Association (TECA), Skills USA–VICA, and the Junior Engineering Technical Society (JETS). The research related to such student organizations is reviewed in Chapter 5. While co-curricular organizations have out-of-school components and in many studies are not distinguished from extracurricular activities, they are not a focus of this chapter.

BENEFITS OF EXTRACURRICULAR AND OTHER OUT-OF-SCHOOL ACTIVITIES

Sponsored extracurricular and informal activities, both anecdotally and in the literature, are usually viewed as valuable experiences for students. Although concerns about the quantity of simultaneous children's activities became a national news item in 2002 (e.g., James, 2002; cf. Melman, Little & Akin-Little, 2007), longitudinal studies and evaluations of specific programs have consistently found a variety of benefits for children engaged in out-of-school activities.

Academic benefits appear to be easier to isolate and identify as children get older. For example, Dumias (2006), using the U.S. Department of Education's Early Childhood Longitudinal Study and controlling for socioeconomic factors, found positive impacts of extracurricular activities on standardized reading scores and on teacher-reported mathematics ability, but no significant impacts on standardized math scores or teacher-reported language arts skills. In a study of North Carolina middle-schoolers, Akos (2006) also found academic benefits, noting that "in addition to achievement, psychosocial adjustment and in particular, students' feelings of connectedness and perceptions of positive aspects following a transition into middle school were also moderately related to participation in extracurricular activities" (n.p.).

Gardner, Roth, and Brooks-Gunn (2008) researched the connections between participation in high-school extracurricular activities and success two and eight years after high school. Among their findings was that "more intensive participation was also associated with greater educational, civic, and occupational success in young adulthood" (p. 814). Research based on a longitudinal study of adolescents in Maryland had similar results (Fredricks & Eccles, 2006).

Researchers have also identified social and personal benefits for students who are members of traditionally underserved groups. Among these are "greater school self-esteem and school bonding" in a study of 140 African-American children in grades 6 to 9 (Dotterer, McHale, & Crouter, 2007, p. 391) and "educational persistence and healthy development" among at-risk students (Peck, Roeser, Zarrett, & Eccles, 2008, p. 163). In studying elementary children's activities, Dumias (2006) found in general "that less-privileged children benefit more from participation in (extracurricular) activities than do more-privileged children" (p. 117).

TECHNOLOGY-EDUCATION RESEARCH PRIOR TO 1999

In this, chapter the technology-education literature is reviewed in an effort to synthesize the findings of recent studies related to extracurricular and informal activities. Specifically, the synthesis focuses on the past decade (1999 to 2009). But it is instructive to outline the trends that led to the current perspective of the field toward extracurricular activities.

Published research related to extracurricular activities in technology education

began shortly after the first doctorates in industrial arts were awarded in the early 1900's. However, while extracurricular programming has long been an accepted area of research in the field, studies have been relatively rare.

In its *Research in Industrial Education* series, the U.S. Office of Education (e.g., Strong, 1961) identified 4,335 research studies from 1930 through 1961, classifying each under a single subject heading. The "extracurricular" category contained 57 studies. Text searches of two bibliographic databases restricted to graduate-student research (Foster, 1992a and Reed, 2001) for terms like "student association," "extracurricular," "after/school," "club," and the names of specific organizations, resulted in fifteen matches between 1961 and 2000.

In general, this dearth has not been considered a substantial concern since general reviews of industrial-arts research began appearing in the 1960s, including three yearbooks of the American Council on Industrial Arts Teacher Education and the first two editions of the *Review and Synthesis of Research in Industrial Arts* (Streichler, 1966; and Householder & Suess, 1969). Research on extracurricular programs was occasionally mentioned in these publications, but not as an area of need. This trend would continue with the later editions of the *Review and Synthesi*s (Dyrenfurth & Householder, 1979; McCrory, 1987; Zuga, 1994) and other reviews by Foster (1992b), Lewis (1999) and others.

By the late 1990s, a new type of technology-related, extracurricular program was emerging: national design competitions for K-12 students co-sponsored by the National Science Teachers Association (NSTA) and a variety of corporations (Sanders, 2000). Mentions of "informal" education in science and technology— often related to museums—began to appear in technology-education publications, no doubt spurred on by National Science Foundation programs that used similar terminology. Additionally, a number of hands-on engineering competitions for middle- and high-school students (especially in robotics) were founded in the 1990s. This was soon followed by references to "informal" technological literacy in technology education periodicals.

REVIEW AND SYNTHESIS OF RESEARCH: 1999-2009

After reviewing the literature on extracurricular and informal technology education, it made the most sense to use separate categories for competitive events (which are usually, but not always, extracurricular) and for noncompetitive extracurricular activities. The following is the classification scheme for presenting the findings.

- Informal technology education. Generally offered by museums. The school's role is usually limited to informing students and parents about the program. Some community programs may actually compete with school-sponsored programs for children's afterschool time; others focus on weekends or times when schools are not in session.
- Competitive events. Students from across the country (or region, etc.) answer a technological challenge. Teams are usually organized by teachers

at the school level and operate as afterschool, extracurricular activities. However, neighborhood, home-school, and other informal teams also compete in these events.

- Noncompetitive extracurricular activities. These programs are usually unique to, or tailored for, the school at which they are offered. Some, such as tutoring programs, are implemented within the school (or school district) itself; others, like internships, connect students to relevant segments of the local community.

This categorization is similar to that used for the National Academies' Learning Science project (Bell, Lewenstein, Shouse, & Feder, 2009). The literature reviewed in Learning Science was divided into three categories (Table 1).

Table 1. Comparison of categorizations used in this study with those used in Learning Science. [1]Bell *et al.*, 2009, p. 18-19, 13.

Learning Science Categories[1]	Categories used in this Study
Everyday learning environments (e.g., the dinner table, a family outing, etc.)	N/A
Designed learning environments (e.g., museums, zoos, etc.)	Informal technology education
	Competitive events
Programs for science learning (…serv[ing] a subscribed group)	Noncompetitive extracurricular activities

INFORMAL TECHNOLOGY EDUCATION

According to the Association of Science-Technology Centers, about 60 million visitors entered science centers and museums in 2008in the United States alone (ASTC, 2009), suggesting that museums play an extremely important role in informal education. However, since museum visits tend to be unstructured, the challenge of quantifying their impact can be daunting.

RESEARCH ON INFORMAL TECHNOLOGY EDUCATION

The ASTC and the European Network of Science Centres and Museums (ECSITE) have recently and independently conducted extensive reviews of the literature to examine the impact of science museums and related informal learning environments (ECSITE, 2008; ASTC, 2009). These studies include significant evidence that museum exhibits increase patrons' knowledge and understanding of

science, and that these institutions provide memorable learning experiences that can have a lasting impact on their visitors' attitudes towards science. While the findings from these research reviews were derived primarily from the science and museum education literature, Pearson and Young (2002) noted that technology is the third most popular subject for exhibits, after those in physics and the life sciences, and that a considerable number of physics exhibits have technological underpinnings. Thus, the ASTC and ECSITE studies may be valuable to some technology education researchers.

The museum most frequently cited in recent technology-education literature is the Boston Museum of Science and its National Center for Technological Literacy (NCTL). Although none of these articles reports any formal research studies, they may provide background, context, and resources for those wishing to conduct such research and are therefore included in this review.

The 145-year-old museum, which has updated its mission to include a commitment to assisting educators teach these topics (NCTL, 2009), founded the NCTL in 2004. In an announcement of its launch ("Museum of Science Builds," 2005), the NCTL was described as working "closely with educators, administrators, government officials, and industry leaders to integrate engineering as a new discipline in schools and to present technology as an equal partner to science" (p. 5). In a subsequent interview, Lawrence Bell, a vice president at the museum, identified three methods by which the center would promote technological literacy:

1) by creating educational products that help promote technological literacy in all Americans,
2) by conducting research about learning and teaching about technology and engineering, and
3) by providing outreach that shares the Museum's learning and products. (Russell, 2005, p. 22)

In a recent interview, the museum's vice president for programs, recalls his institution's response when Massachusetts became the first state to include "technology" and "engineering" content in its science standards:

… we decided that helping school districts implement these standards would become an important part of our mission … Our first step was to collect all of the relevant instructional materials we could find… the result was a searchable database of instructional materials that we call the Technology and Engineering Curriculum (TEC) Review. Our second step was to develop new instructional materials where we found that existing materials did not meet our states' standards… ("What Will it Take," 2008, p. 17)

Although these materials are not extracurricular per se, an extensive list of formal findings related to them is available online (http://www.mos.org/eie/research_assessment.php#aboutresearch).

A later step was the implementation of the "Gateway to Technology and Engineering Education," summer institute in which teams of Massachusetts teachers and administrators from multiple school districts discuss their strategies for implementing the state's technology and engineering standards. Although beyond the scope of this chapter, a report highlighting the best practices and lessons learned from ten school districts that participated in the Gateway program is available online (NCTL, 2007).

Also mentioned in the technology education literature is the National Building Museum in Washington, D.C. The museum partners with federal agencies such as the U.S. Department of Labor, private corporations such as Turner Construction Company, and associations such as the American Planning Association to develop programs that engage children through problem-solving and hands-on activities ("National Building Museum Launches," 2007). Like the NCTL, this organization offers education materials which could be used in the regular classroom or as part of an extracurricular program. These include a middle-level Bridge Basics program and the Design Apprenticeship Program, which presents high school students with a design challenge for which they conceive, develop, test, and construct a solution. According to the NBM's self-reported statistics, more than 20,000 students attended 836 individual programs held in the 2007-08 academic school year and more than 300 free school programs were held at the museum for Title I schools (NBM, 2009).

Since museums strive to balance education with entertainment, and since the time spent there is almost always unstructured and of very short duration, it is difficult to quantify how much museum-goers take away from their visits (Pearson & Young, 2002). Thus, there is a need for more long-term studies of the impact of science centers on individuals. Nonetheless, given the wide variation in informal programming and the unpredictable ways in which children interact with it, it is not a surprise that "there is no instrument designed specifically to assess informal STEM learning that has been accepted by the field" (Dahlgren & Noam, 2009, p. 25).

COMPETITIVE EVENTS

Technology challenges that are sponsored by organizations outside of the schools, and implemented separately as extracurricular activities at individual school sites, usually fall into one of two categories. Success in performance-based challenges is determined at events in which students directly participate; in design contests, students submit their solution to be assessed remotely by judges. In a few national design contests, the field of competitors may be narrowed in this manner, but a group of finalists (either individuals or teams) may attend an event at which the winner is determined.

PERFORMANCE-BASED COMPETITIONS

The technology education literature contains multiple mentions each year of challenges in which K-12 students gather for tests or competitions of devices they have designed and made. Thus far, competitions that are scored, at least in part, on the performance of students' mechanical devices fall into two areas: robots and vehicles.

Among the most popular robotics challenges for high-schoolers in the U.S. are FIRST, BEST, and VEX. FIRST (the Foundation for the Inspiration and Recognition of Science and Technology), that began in 1992 in New Hampshire, challenges students to produce autonomous robots to perform specified tasks. Texas-based BEST (Boosting Engineering, Science, and Technology), founded in 1993 with assistance from Texas Instruments ("Birth of BEST," 2005), offers challenges that are similar, but which require smaller budgets. In 2005, FIRST piloted the VEX challenge, a lower-cost version of its flagship competition ("Students Compete at Robotics," 2005). The engineering community has viewed these competitions positively (e.g., Smith, 2002). The FIRST Lego League and the PowerTech Creativity Contest, started in Taiwan (Jon-Chao, Chan-Li & Ya-Ling, 2007) are among the middle-school level robotics competitions reported in the technology education literature.

The other common type of performance-based competition is the vehicular challenge. Articles have appeared in the literature about underwater, remotely operated vehicle (ROV) contests, such as the one organized by the Marine Advanced Technology Education (MATE) Center in Monterey, California (Mraz, 2007), in which high-school teams (as well as college teams) compete. Some regional MATE ROV events, like the Newfoundland and Labrador Regional ROV Competition, include high schools only ("Heritage Collegiate Claims," 2009).

Similar contests include NASA's Moonbuggy Challenge (Chadha & Gordon, 1999), open to high-schoolers, and the Junior Solar Sprint, a middle-school event sponsored by the U.S. Army ("Students Compete in Junior Solar Sprint," 2007). In addition to remotely-operated vehicle contests, some challenges involve students as operator-passengers.

Kraft (2002), for instance, discusses the national Electrathon program, describing it as consonant with the historical ideals of social reconstructionism, thus aligning it with the original purposes of industrial arts. The Electrathon is a high-school level activity in which students design and build full-scale electric vehicles, then test them in head-to-head races. Thompson and Fitzgerald (2006) describe the Indiana Super Mileage Challenge, in which high-schoolers design, build, and race super-efficient gasoline vehicles. In summarizing their overview of the program, they note that "the skills that students gain through participating in the Super Mileage Challenge are hard to measure" (p. 33).

RESEARCH RELATED TO PERFORMANCE-BASED COMPETITIVE EVENTS

Educational databases were searched for studies related to the Electrathon, Super Mileage Challenge, BEST Robotics, and FIRST Robotics and its offshoots. While each was mentioned occasionally in teacher magazines, very little research was reported. The findings here agree with those of Williams, Ma, Prejean, Ford, and Lai (2007), who did not limit their literature review to out-of-school or extracurricular activities:

> Limited research has been conducted as to the impact of educational robotics activities on K–12 students' learning. Much of the literature on educational robotics focuses on describing the activities in robotics educational programs with some discussion of their effectiveness based on the anecdotal evidence (p. 203).

This assessment could be extended to include vehicular competitions as well. Not surprisingly, then, the official websites of robotics competitions and vehicle challenges offer testimonials, not research studies. The organizers of some, such as the MATE ROV competition, are collecting data (Zande & Brown, 2008).

Nonetheless, the meager research that is available seems to be positive. Barker and Ansorge (2007) reported that fourth, fifth, and sixth-graders in an afterschool robotics program significantly outperformed a control group on a validated science-and-technology instrument. Williams and associates (2007) used a similar design to study the efficacy of a two-week summer robotics camp in teaching physics content to middle-schoolers. They found "a statistically significant impact on students' gains in physics content knowledge" (p. 208).

Using qualitative methods with elementary children in the U.K., Petre and Price (2004) also found positive results. Verner and Ahlgren (2005) used surveys to evaluate the effectiveness of the Trinity College Fire-Fighting Home Robot Contest.

Interestingly, all of these studies were published in the educational technology literature. It should be noted that a few studies in the technology education literature—for example, Verner and Hershko's report on Israeli high school students' school graduation projects in robot design (2003), and Barak and Zadok's (2007) study of junior-high-schoolers using Lego Mindstorms—contain findings that may well be applicable to extracurricular activities, even though these were studies of curricular programs. There are also research studies of using Lego robots to teach scientific concepts in the classroom (e.g., Chambers, Carbonaro, & Murray, 2008).

DESIGN CONTESTS

Among its many K-12 resources, the U.S. Government's National Aeronautics and Space Administration (NASA) offers design challenges for schoolchildren.

Some are designed to be submitted to NASA or a co-sponsoring agency to be judged; winning entrants may receive prizes and other recognition. For example, the NASA-co-sponsored Space Day Design Challenges for fourth- through eighth-graders are designed to be conducted as either in-classroom or afterschool activities ("Space Day," 2005). Not all relate to the design of mission research, equipment, or space vehicles; for example, in one challenge:

> Students assume they are astronauts living on the Moon and
> must create an electronic newspaper that vividly describes
> what it's like to live and work on the Moon ("Space Day,"
> 2005, p. 3).

Other competitions relate more specifically to engineering problems. The Goddard Engineering Challenge Competition (e.g., "Engineering Challenge," 2002), for instance, challenged students in the Baltimore-Washington area to solve problems encountered in a NASA solar terrestrial probe mission.

Over the past decade, NASA has also worked specifically with the International Technology Education Association (ITEA) to offer a number of K-12 contests and challenges. The 2001 Cosmic Poetry Contest, for example, challenged students to write a poem focusing on one of five areas of space technology: propulsion, navigation, communication, power, and image capture ("Be a Cosmic Poet," 2001). In this case, there was an entry deadline; but in other cases, the challenges are not judged nationally (e.g., Meade, Caron, Gray, & Weaver, 2008).

Another government-sponsored design contest is the West Point Bridge Design Contest (Moore, 2005). The U.S. Military Academy has developed free bridge-testing simulation software, and challenges teams of high-schoolers "to design the least expensive bridge that will pass a simulated load test" (USMA, 2008).

Other contests (several of which were referred to by Sanders (2000)), are co-sponsored by a non-profit organization with one or more corporate underwriters. In most cases, mentors from industry lend expertise to the K-12 students competing in the contest.

TechXplore (2002), a middle- and high-school contest offered by the Electronics Industries Foundation, "pairs technical experts from electronics and high-tech companies with teams of students" who solve technical problems and present their solutions in the form of websites (p. 3). The ExploraVision contest, sponsored by Toshiba and NSTA (Peckham, 2008), was founded in 1993 and requires teams of K-12 students choose a current technology,

> …then research and explore what the technology does and
> how, when, and why it was invented. After imagining what
> that technology could be like in 20 years, students ground their
> creative ideas using real science and present their technology
> vision using written descriptions and artwork. (Heller, 2004,
> p. 24)

The National Toy Design Challenge (2005) is a program of the Sally Ride

Foundation (Hasbro and Smith College are the founding sponsors). As implied by the name of the contest, students are given a relatively open-ended challenge to design a unique toy. At least half of the members of each participating team must be girls. ExploraVision and the National Toy Design Challenge each require remote submission of entries, but regional finalist teams are invited to a national event, at which national winners are chosen (cf. the Future City Competition ("A kid's ideal living," 2008)).

RESEARCH RELATED TO DESIGN CHALLENGES

As was the case with performance-based challenges, very little research was found pertaining to extracurricular design challenges. In one exception, Chen, Chen, and Lin (2008) found no statistical correlation between geographic area and success in an annual high-school applied mechanics contest in Taiwan.

Limited research was also found in related areas, specifically when in-classroom NASA projects were assessed from the points of view of science education or educational technology. For example, Cross, Taasoobshirazi, Hendricks, and Hickey (2008) found benefits for high-school biology students when teachers encouraged scientific argumentation in the context of the use of NASA's BioBLAST software.

Most of the other research was even more tangential to extracurricular technology education, although two examples may be instructive. Howard, McGee, Schwartz, and Purcell (2000) found that constructivist inservice training using a NASA program impacted teacher epistemology, and Oliver and Fergusson (2007) reported on the use of NASA materials in combating science illiteracy as Australian youth transition into adulthood.

Devine's (2006) report on using West Point Bridge Designer is also peripherally related, as the software was used in a university classroom, and because the purpose of the article was not to report research. Nonetheless, it is of interest here because Devine teamed his civil-engineering sophomores with middle- and high-school students. Thus, while this was not an extracurricular activity for Devine's students, it was a technological, out-of-school project for the younger participants. The following comment from this article seems to be representative of much of the literature in this area:

> Although formal assessment of this project has not yet
> been accomplished, anecdotal comments and reactions
> from colleagues both at IPFW [Indiana University/Purdue
> University - Fort Wayne] and at other universities have been
> positive. Students' response to the assignment has been mixed,
> and the actual learning achieved from the assignment has not
> yet been quantified (p. 189).

NONCOMPETITIVE EXTRACURRICULAR PROGRAMS

Extracurricular programs encompass a wide range of models (Noam, Biancarosa & Dechausay, 2003). At one end of this range are programs which are deliberately unaffiliated with schools. At the other extreme are school-sponsored programs which participants often view as a continuation of the school day (see Parsad & Lewis, 2009 for a profile of these programs in U.S. elementary schools).

In the technology education literature, almost all of the articles related to non-competitive extracurricular programs fall into one of two categories: entrepreneurship-related or service-learning. While the evidence in support of these programs clearly lacks the statistical power associated with rigorous research, it is encouraging nonetheless and has the potential to motivate further inquiry into the value of these activities.

ENTREPRENEURSHIP-RELATED PROGRAMS

Extracurricular programs that emphasize entrepreneurship have been implemented at both the high school and middle school levels. As an example of the former, a technology educator in Fairfax, Virginia, established a television production company run by his students, who charged a fee for work taken in from the school system and local community (Harris, 2007). That fee was then used to compensate students for their time and to purchase equipment for the course. While Harris' results are anecdotal and small in scale, they are still promising. In addition to financial success, he notes that "in my county, vocational classes were actually encouraged to do work for the public as a way of training students for the 'dealing with customers' aspect of vocational education" (p. 23).

Holderfield and McQueeny-Tankard (2000) describe a Chicago program designed to bridge the gap between the high-school classroom and the "real world" with the help of an industry partner. The company, a product design and development firm, presented the students with a real-world design problem. The final solutions were formally presented by the student teams to a panel of judges at the company, which presented cash prizes ranging from $100 to $500.

Real-world connections can be equally beneficial at lower grade levels, as demonstrated by the Partners in Technology program at South Brunswick Middle School in North Carolina (Bishop, 2002). Begun as a small project for a graphic design firm that resulted in 40,000 printed brochures, the program has since expanded significantly and the school has established new partnerships with additional industries including the local airport and utility company. Volunteers from these organizations work with the students to help them gain insight and experience in the industrial business world.

SERVICE LEARNING

Because of its relevance to real-life experiences, a service-learning experience can both motivate students and promote their retention of course material. Due its

nature, school-based service learning is usually co-curricular. But it is inherently an out-of-school experience for students; thus service-learning research in the technology education literature is relevant here.

In 1998, Hill and Smith examined a service learning program in Ontario, studying one Grade 10 class and one Grade 11 class over a five-month period. Community-based projects included classroom objects for teaching technology at local elementary schools as well as projects for a local retirement home. Participating students benefited in multiple ways as they found the course more challenging and more relevant.

> In a somewhat similar case study, Jensen and Burr (2006) reported the results of a service-learning experience conducted among U.S. secondary students in a construction technology course. The research was conducted in an attempt to understand the relationship between students' commitment to a service-learning project and their commitment to learn the associated course content. The results of the comparison showed that those students who were most motivated and committed were also those whose perceived confidence and perceived knowledge of content made the greatest increases (p. 23-24).

The authors note that while the findings are encouraging, they are not necessarily applicable to a more general student population. They go on to suggest that more definitive, quantitative studies be carried out to further investigate the impact of service learning. Similar anecdotal evidence of the positive effects of service learning was observed among technology teacher education students at Brigham Young University (Burr, 2001) and Southeastern Louisiana University (Bonnette 2006), suggesting that benefits can also be realized from this type of experience at the post-secondary level.

OTHER NON-COMPETITIVE EXTRACURRICULAR PROGRAMS

In addition to entrepreneurship-related and service learning programs, the category of non-competitive extracurricular programs also encompasses summer camps, such as the National Society of Black Engineers' (NSBE's) Summer Engineer Experience for Kids (SEEK). Co-sponsored by several corporations and the Society of Automotive Engineers, this free three-week camp targets urban African-American third through eighth graders, introducing them to engineering through hands-on projects (Loftus, 2008). At Northeastern University, a two-week summer science camp attracts a diverse group of Boston-area middle-schoolers and follows up with them and their parents several times a year to ensure their awareness of math and science requirements for engineering. A more advanced summer bridge program at the university provides not only a preview of basic engineering but focuses on building the confidence of young African-

Americans. These programs have resulted in a retention rate among African-Americans at Northeastern that is double the national average (Loftus, 2008). However, extensive research on these and similar programs has yet to appear in the technology education literature.

Mentorship programs are another example of extracurricular activities with great potential. For instance, Rose Hulman's *Recruitment Into Science and Engineering* (RISE) project is designed to expose local middle and high school students to engineering with mentoring by NSBE members and hands-on projects like building a balsa wood bridge (Loftus, 2008). At Kingswood Regional High School in Wolfeboro, New Hampshire, an e-Mentor program is being used by aerospace students whose mentors include NASA scientists and engineers, as well as pilots and active duty personnel from the Air Force Association (Caron, 2008). As with most of the programs described in this section, the results are very positive, yet too anecdotal to be interpreted as genuine research.

CONCLUSIONS AND SUMMARY

In the past ten years, nearly a hundred peer-reviewed articles primarily related to K-12 extracurricular or informal activities have been published in the technology education literature. Most of these are intended to be more journalistic than scholarly, and most of the remainder derive their scholarliness from positioning individual activities within philosophical frameworks. While this is undoubtedly bona-fide research, we found very few studies which could form (or contribute to) the basis of further research into the connections between technological literacy and extracurricular or informal programs. This finding mirrors the conclusions of Dahlgren and Noam (2009).

Yet there are some very good reasons that such programs might appear to be under-researched. Chief among these is that as a profession, technology education is struggling to define technological literacy, to delimit its content, and to clarify its curriculum. One may wonder how we even know what topics are extracurricular if we're still deciding which are intracurricular. More to the point, as we seek to establish and maintain technology as a curricular area, extracurricular activities will naturally not be among the most critical areas of research.

Perhaps another reason is that such research strikes scholars as unnecessary. To the degree that extracurricular technology activities are like other extracurricular activities, there's a fair amount of research on afterschool, out-of-school, and informal education. As for the things that make technology activities special, there may be applicable (intra)curricular research. After all, many of the hallmarks of successful extracurricular activities are already present in best-practice technology education, including the lab atmosphere, the teacher's role as an advisor or mentor, and the focus on an authentic project. Nonetheless, researchers applying the findings of extracurricular studies to classroom settings should consider demographics to avoid making apples-to-oranges comparisons, as the literature suggests that some extracurricular technology programs may

serve the most vulnerable populations. Consequently, much of the research on learning in these programs focuses on a specialized subset of the overall student population.

For example, Ingels, Dalton, and LoGerfo (2008) studied high-school seniors' participation in six types of school-sponsored extracurricular activities. In five of the activities (student government, honor society, sports/athletics, newspaper/ yearbook, and academic clubs), students in the highest socio-economic (SES) quartile had the highest participation rates across all four time points studied (1972, 1980, 1992, and 2004). The reverse was true across all time points for the sixth activity type: vocational clubs.

SES-based differences are also clear in studies of participation rates of elementary children, especially since extracurricular programs for younger students serve the additional purpose of child care (cf. Parsad & Lewis, 2009). Students who attend care-focused programs are more likely to come from lower SES homes (NCES, 2006).

Finally, researchers will note that many related research studies reside in other fields of literature, not only because of the interconnected nature of STEM, but also due to the broader questions related to the cognitive sciences that can be asked when evaluating an extracurricular program. Meaningful outcomes can be very difficult to measure or compare due to the varied and informal nature of the activities being assessed. Indeed,

> the very premise of engaging learners in activities largely for the purposes of promoting future learning experiences beyond the immediate environment runs counter to the prevalent model of assessing learning on the basis of a well-defined educational treatment (e.g., the lesson, the unit, the year's math curriculum) (Bell et al., 2009, p. 56).

AREAS OF NEEDED RESEARCH

The foregoing suggests that further research is needed in this area, but a number of questions should be addressed before devising a comprehensive research agenda for technology-related extracurricular activities. Primarily, scholars need to ask what the relationship is between extracurricular or informal experiences and learning about technology. For example, what technological-literacy goals should be promoted via extracurricular activities? Additionally, what other goals are there for students in extracurricular or out-of-school technology programs? Fundamentally, is it appropriate to expect academic (i.e., curricular) outcomes from extracurricular activities.

A second issue is what constitutes a technology extracurricular activity or informal technology education program. For example, when researching activities like the Science Olympiad (e.g., Philpot, 2008) or the Super Mileage Challenge, is it useful to distinguish between applied-science programs and technology programs? To what degree should free activities for children at home-improvement

and hobby superstores be considered informal technology education? Are these substantially different from museum offerings? What about children who learn the exact same home-improvement skills at home with a parent? The answer to questions of this nature may establish what outcomes to measure or help determine whether technology is so broad that such distinctions are trivial.

Moreover, could technology activities that take place during regular school hours be considered extracurricular in some cases? For example, several of the projects reported in the *Journal of Industrial Teacher Education*, volume 39, number 3 (e.g., Hutchinson, 2002; Benenson & Piggott, 2002; Satchwell & Loepp, 2002) involved pilot-testing curricular units with K-12 students. The impacts of these pilot tests on these children may have been very similar to impacts found in extracurricular settings—especially when pilot-testing took place outside of the regular schedule or classroom. Similarly, Mettas and Constantinou (2008) studied the impacts on preservice teachers in Cyprus who worked with primary children on technology fair projects; the experiences of those children may be valuable to researchers studying extracurricular technology activities insofar as they perceived the activity as extracurricular.

The work of Petrina, Feng, and Kim (e.g., 2008) also raises the question—what constitutes a technology extracurricular activity or informal technology education?—but in a different way. Their research on how people learn technology across the lifespan may prompt the profession to reconsider the value in distinguishing among curricular, co-curricular, extracurricular, and informal experiences, at least in their impacts on K-12 students' learning "about, through and for technology" (p. 390).

A third area that needs clarity is determining how research on extracurricular activities fits into the goals of the profession. The role of professional development and teacher preparation programs in the development of extracurricular or informal activities needs to be determined. If we truly desire "Technology for All," might a focus on extracurricular activities—which are traditionally based on student interest—be counterproductive? Professional development and teacher preparation programs, after all, are primarily concerned with what is in the curriculum, not outside of it. On the other hand, should we recognize that curricular "coverage" of technological literacy across the country is varied at best? If that is the case, perhaps professional development and teacher preparation programs should promote extracurricular programs as widely as possible.

A related question is whether technology education researchers can leverage the findings from research in informal science education—and specifically from the conclusions and recommendations of the National Academies' Learning Science project (Bell et al., 2009). Although the outcomes of Learning Science pertain to out-of-school learning about science (as opposed to technology), several of the project's recommendations are germane here, particularly Recommendations 5, 6, and 7 (Bell et al., 2009, p. 310-311), which recognize that in addition to conducting research per se, we must encourage the publication of research, the framing of theories, and the development of unobtrusive assessment methods.

FINAL THOUGHTS

In a case of publicity that would ordinarily be welcome to the technology education community, Time magazine's March 19, 2007 edition included brief mention of both Robocup 2007 and the NASA Moonbuggy Race. Disappointingly, these were listed alongside the Calaveras Jumping Frog Jubilee and the World Snail Racing Championships in a sidebar headed "The Wide, Weird World of Sports" (What's Next, 2007).

Just as news outlets seem to have the tendency to describe extracurricular technology competitions as if they were athletic events, educational researchers often seem to study extracurricular and informal activities as if they were curricular programs. And just as news outlets only rarely cover extracurricular technology competitions, educators only rarely publish actual research about out-of-school activities.

Ultimately, these programs are not viewed with the seriousness with which we consider the school curriculum. Until this changes, those researching extracurricular technology programs will either have to conduct foundational research or to rely on inferences made from studies only partially applicable to their objects of study.

REFERENCES

Akos, P. (2006). Extracurricular participation and the transition to middle school. *Research in Middle Level Education Online, 29*(9), 1-9.

ASTC. (2009). *2008 ASTC sourcebook of statistics and analysis*. Washington, DC: Author.

Barak, M. & Zadok, Y. (2007). Robotics projects and learning concepts in science, technology and problem solving. *International Journal of Technology & Design Education* [online edition].

Barker, B. & Ansorge, J. (2007). Robotics as means to increase achievement scores in an informal learning environment. *Journal of Research on Technology in Education, 39*(3), 229–243.

Be a Cosmic Poet. (2001). *The Technology Teacher, 60*(8), 14-16.

Bell, P., Lewenstein, B., Shouse, A. & Feder, M. (eds.) (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: National Academies Press.

Benenson, G. & Piggott, F. (2002). Introducing technology as a school subject: A collaborative design challenge for educators. *Journal of Industrial Teacher Education, 39*(3), 67-87.

Bishop, A. (2002). Partners in technology. *The Technology Teacher, 61*(4), 26-28.

Bonnette, R. (2006). Out of the classroom and into the community. *The Technology Teacher, 65*(5), 6-11.

Burr, K. (2001). Building for hope: Progressive service learning enhances education. *Journal of Industrial Teacher Education, 38*(4), 84-93.

Cahalan, M., Ingels, S., Burns, L., Planty, M.& Daniel, B. (2006). *United States high school sophomores: A twenty-two year comparison, 1980-2002*. Washington, DC: National Center for Education Statistics.

Caron, D. W. (2008). Starting an e-mentor program. *The Technology Teacher, 67*(6), 25-26.

Chadha, R. & Gordon, K. (1999). Bam! To the moon. *ASEE Prism 9*(3), 36.

Chambers, J., Carbonaro, M. & Murray, H. (2008). Developing conceptual understanding of mechanical advantage through the use of Lego robotic technology. *Australasian Journal of Educational Technology, 24*(4), 387-401.

Chen, N., Chen, C. & Lin, M. (2008). An analysis of applied mechanics contest for senior high school students in Taiwan. *Asia-Pacific Forum on Science Learning & Teaching, 9*(1).

Cross, D., Taasoobshirazi, G., Hendricks, S. & Hickey, D. (2008). Argumentation: A strategy for improving achievement and revealing scientific identities. *International Journal of Science Education, 30*(6), 837-861.

Dahlgren, C. & Noam, G. (2009). *A watershed moment: The first national conference on science & technology in out-of-school time*. Chicago: Project Exploration.

Devine, D. (2006). Students teach students with the West Point Bridge Designer. *Journal of Professional Issues in Engineering Education & Practice, 132*(3), 187-190.

Dotterer, A., McHale, S. & Crouter, A. (2007). Implications of out-of-school activities for school engagement in African American adolescents. *Journal of Youth & Adolescence, 36*(4), 391-401.

Dumais, S. (2006). Elementary school students' extracurricular activities. *Sociological Spectrum, 26*(2), 117-147.

Dyrenfurth, M. & Householder, D. (1979). *Industrial arts education: A review and synthesis of the research, 1968-1979*. Columbus, OH: Center for Vocational & Technical Education.

Engineering Challenge. (2002). *The Technology Teacher 61*(5), 3.

European Network of Science Centres and Museums (2008). *The impact of science & discovery centres: A review of worldwide studies*. Harbourside, Bristol, UK: Author.

Foster, W. (1992a). A partial bibliography of recent graduate research in technology education and related fields. *Journal of Technology Education*. Available: http://scholar.lib.vt.edu/ejournals/JTE/supplements/FosterBibliography.html

Foster, W. (1992b). Topics and methods of recent graduate student research in industrial education and related fields. *Journal of Industrial Teacher Education, 30*(1), 59-72.

Fredricks, J. & Eccles, J. (2006). Is extracurricular participation associated with beneficial outcomes? *Developmental Psychology, 42*(4), 698-713.

Gardner, M., Roth, J. & Brooks-Gunn, J. (2008). Adolescents' participation in

organized activities and developmental success 2 and 8 years after high school. *Developmental Psychology, 44*(3), 814-830.

Harris, P. (2007). Solving the money problem in a television production class. *The Technology Teacher, 66*(5), 22-28.

Heller, L. (2004). Toshiba/NSTA ExploraVision. *Tech Directions, 64*(4), 24-25.

Heritage Collegiate Claims Championship (2009). St. John's, NL: Fisheries & Marine Institute Memorial University.

Hill, A. & Smith, H. (1998). Practice meets theory in technology education. *Journal of Technology Education, 9*(2), 29-46.

Holderfield, G. & McQueeny-Tankard, C. (2000). 'It's a Real World' partnership bridges gap between classroom and business. *The Technology Teacher, 60*(2), 19-21.

Householder, D. & Suess, A. (1969). *Review and synthesis of research in industrial arts education*. Columbus, OH: Center for Vocational & Technical Education.

Howard, B., McGee, S., Schwartz, N. & Purcell, S. (2000). The experience of constructivism. *Journal of Research on Computing in Education, 32*(4), 455-465.

Hutchinson, P. (2002). Children designing and engineering. *Journal of Industrial Teacher Education, 39*(3) 122-145.

Ingels, S., Dalton, B. & LoGerfo, L. (2008). *Trends among high school seniors, 1972-2004*. Washington, DC: National Center for Education Statistics.

International Technology Education Association. (2000). *Standards for technology literacy*. Reston, VA: Author.

James, G. (2002). Ridgewood touches a nerve. *New York Times, 151*(52,068), 14NJ8.

Jensen, S. & Burr, K. (2006). Participation and learning relationships. *Journal of Industrial Teacher Education, 43*(3), 6-28.

Jon-Chao, H., Chan-Li, L. & Ya-Ling, L. (2007). Operating a successful PowerTech creativity contest. *Journal of Technology Studies 33*(1/2), 25-31.

Kid's ideal living. (2008). *Industrial Engineer, 40*(12), 11.

Kraft, T. (2002). The electric vehicle experience. *Journal of Technology Studies 28*(2), 150.

Lewis, T. (1999). Research in technology education—Some areas of need. *Journal of Technology Education, 10*(2), 41-56.

Loftus, M. (2008). Untapped potential. *ASEE Prism, 18*(2), 52-55.

McCrory, D. (1987). *Technology education: Industrial arts in transition.* Columbus, OH: Center for Vocational & Technical Education.

Meade, S., Caron, D., Gray, A. & Weaver, K. (2008). The ITEA-NASA STS-118 Design Challenges. *The Technology Teacher, 67*(4), 16-21.

Melman, S., Little, S. & Akin-Little, K. (2007). Adolescent overscheduling. *High School Journal, 90*(3), 18-30.

Mettas, A. & Constantinou, C. (2008). The technology fair: A project-based

learning approach for enhancing problem solving skills and interest in design and technology education. *International Journal of Technology & Design Education, 18*(1), 79-100.

Moore, P. (2005). The news report. *Tech Directions, 65*(5), 7-8.

Mraz, S. (2007). Unmanned, underwater, and on a mission. *Machine Design, 79*(18), 52-56.

Museum of Science Builds National Center for Technological Literacy (2005). *The Technology Teacher, 65*(3), 5.

National Building Museum Launches National Education Initiatives (2007). *The Technology Teacher, 66*(7), 2.

National Building Museum. (2009). *Educating tomorrow's leaders through design education*. Washington, DC: Author.

National Center for Education Statistics. (2006). *Digest of education statistics: 2006 digest tables*. Available: http://nces.ed.gov/programs/digest/2006menu_tables.asp

National Center for Techological Literacy. (2007). *Opening the gateway: School districts leading the technology/engineering revolution*. Boston: Boston Museum of Science.

National Center for Techological Literacy. (2009). *NCTL leadership: Sponsors and founders. Boston: Boston Museum of Science*. Boston: Boston Museum of Science.

National Toy Design Challenge. (2005). *The Technology Teacher, 64*(4), 3.

Noam, G., Biancarosa, G. & Dechausay, N. (2003). *Afterschool education: Approaches to an emerging field*. Cambridge, MA: Harvard Education.

Oliver, C. & Fergusson, J. (2007). Astrobiology: A pathway to adult science literacy? *Acta Astronautica, 61*(7/8), 716-723.

Parsad, B. & Lewis, L. (Eds). *After-school programs in public elementary schools: First look*. Washington, DC: National Center for Education Statistics.

Pearson, G. & Young, A. (2002). *Technically Speaking*. Washington, DC: National Academy Press.

Peck, S., Roeser, R., Zarrett, N. & Eccles, J. (2008). Exploring the roles of extracurricular activity quantity and quality in the educational resilience of vulnerable adolescents. *Journal of Social Issues, 64*(1), 135-156.

Peckham, S. (2008). Toshiba/NSTA ExploraVision awards. *Tech Directions, 67*(6), 8.

Petre, M. & Price, B. (2004). Using robotics to motivate 'back door' learning. *Education & Information Technologies, 9*(2), 147-158.

Petrina, S., Feng, F. & Kim, J. (2008). Researching cognition and technology: How we learn across the lifespan. *International Journal of Technology & Design Education, 18*(4), 375-396.

Philpot, C. (2008). *Science Olympiad students' nature of science understandings*. [Unpublished Dissertation]. Atlanta: Georgia State University.

Reed, P. (2001). *The technology education graduate research database: 1892-2000*. Reston, VA: Council on Technology Teacher Education.

Russell, J. (2005). The standards for technological literacy: Today the Boston Museum of Science, tomorrow the world. *The Technology Teacher, 64*(6), 21-23.

Sanders, M. (2000). Power play or no play? In G. Martin (ed), *Technology education for the 21st century*. Peoria, IL: Glencoe/McGraw-Hill.

Satchwell, R. & Loepp, F. (2002). Designing and implementing an integrated mathematics, science, and technology curriculum for the middle school. *Journal of Industrial Teacher Education, 39*(3), 41-66.

Smith, E. (2002). Teamwork with the next generation. *Mechanical Engineering, 124*(6), 46.

Space Day 2005 Design Challenges. (2005). *The Technology Teacher, 64*(4), 3.

Streichler, J. (1966). *Review and synthesis of research in industrial arts education*. Columbus, OH: Center for Vocational & Technical Education.

Strong, M. (Ed). (1961) *Research in Industrial Education*. Washington, DC: US Office of Education.

Students Compete at Robotics Competition. (2005). *The Technology Teacher, 65*(3), 36.

Students Compete in Junior Solar Sprint. (2007). *Solar Today, 21*(4), 78.

TechXplore Online Competition. (2002). *The Technology Teacher 62*(2), 3.

Birth of Best. (2005). *The Technology Teacher 64*(4), 22.

Thompson, J. & Fitzgerald, M. (2006). Super mileage challenge. *The Technology Teacher, 66* (1), 31-33.

U.S. Military Academy (2008). *Welcome to the 2009 West Point Bridge Design Contest*. Available: http://bridgecontest.usma.edu/

Verner, I & Ahlgren, D. (2005). Robot contest as a laboratory for experiential engineering education. *Journal on Educational Resources in Computing, 4*(2), 2-28.

Verner, I. & Hershko, E. (2003). School graduation project in robot design. *Journal of Technology Education, 14* (2), 40-55.

What will it take to establish technology/engineering education for all students? (2008). *The Technology Teacher, 67*(6), 16-19.

What's Next: Sports. (2007). *Time, 169*(12), 58.

Williams, D., Ma, Y., Prejean, L., Ford, M. & Lai, G. (2007). Acquisition of physics content knowledge and scientific inquiry skills in a robotics summer camp. *Journal of Research on Technology in Education, 40*(2), 201-216.

Zande, J. & Brown, C. (2008). ROV competition helps students develop technical skills and build marine technical workforce. IEEE Robotics & Automation, 15(1), 18-20.

Zuga, K. F. (1994). *Implementing technology education: A review and synthesis of the research literature*. Columbus, OH: Center for Vocational & Technical Education.

Recommendations for Technology Education Research

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Chapter
14

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INTRODUCTION

The preceding chapters cover a necessarily wide range of topics and as such can be seen as having the divergent purpose of surveying the various published research related to technology education and areas that influence technology education practice and research. The goal of this final chapter is to draw on the various recommendations of the preceding chapters to synthesize a set of overall priorities and recommendations. In synthesizing a set of recommendations, this chapter is necessarily convergent in nature, focusing on the priorities for future research given the wide range of research possibilities and the finite number of researchers.

In order to accomplish this, and to present a set of recommendations, the following approach has been taken. Firstly, the central arguments and recommendations of chapter authors are summarized and a synthesis provided. Secondly, data on the kinds of research that has been undertaken over the last fourteen years is examined to provide the context for the analysis of the literature proposing research agendas and priorities, which is then addressed. Finally, all of the above are drawn on to provide a set of recommendations for directions and priorities for future technology education research for teachers, researchers, teacher educators, and research students. Priorities are necessary because one conclusion from the preceding chapters is that the need for research in technology education far exceeds the capacity of those engaged in research. Thus we need to focus on those areas of research that will be most helpful in generating new knowledge and improving the quality of teaching and learning in technology education and in promoting the discipline.

CHAPTER AUTHOR RECOMMENDATIONS

In chapter two Ritz argues that one way to improve the quality of technology education learning experiences and the curriculum decisions made in the area would be to teach research methods to undergraduate technology teacher education students that emphasis both technical and professional research. Thus Ritz's emphasis is not so much on establishing research priorities as on developing

research capability, with the implication being that this capability will increase the number of technology education teachers prepared to undertake research or be involved in research projects.

In chapter three, Ernst and Haynie briefly describe the history of technology education, define curriculum research, and review published curriculum research agendas, methods, and findings relevant to technology education. These reviews include proposals for technology education curriculum research. Ernst and Haynie refer to the Industrial Arts Curriculum Project (IACP) (Towers, et al, 1966) and the Maryland Plan (Maley, 1970) as research-based curriculum projects and note that the field testing of the curriculum was largely undertaken by technology education doctoral students.

Also noted by Ernst and Haynie were the various research efforts that informed the more recent Technology for All American's Project (TfAAP). One important conclusion they make is that the large scale, research-informed, curriculum projects like IACP and TfAAP have had, and will continue to have, a deeper and longer lasting effect on the profession than other types of curriculum research. One reason for this success implied by Ernst and Haynie was the widespread field testing of new curricula and the integral learning activities.

In chapter four Helgeson examines the role of research in the implementation of common instructional strategies in technology education. This examination is then compared to research in instructional strategies in other disciplines to establish if there are additional methodologies that might be used in technology education. The aim of the chapter is to provide a framework for a research agenda in instructional strategies in technology education. Helgeson makes one recommendation that fits with Ritz's idea in Chapter Two to provide research training for technology education undergraduate students. Helgeson recommends the establishment of research priorities for technology teachers, in addition to technology teacher educators and researchers. Helgeson also argues for research funding and research into teaching practice, learning theory and models, and the implications for learning new models.

The role of professional and student organizations in technology education and their activities in terms of research and in setting research agendas is the topic of Chapter Five. Taylor provides a concise account of the contributions of professional organizations like ITEA, NSF, NAE, NRC, AAAS, and ASEE, together with those from student organizations like TECA and TSA. Taylor notes that while many of the projects supported by professional organisations include research, there is a general lack of research into the role and contribution of student organizations to student learning. Taylor concludes that professional organizations provide the scope for future research in technology education and that research examining the contribution of student organizations is a worthy topic for future research.

Change theory for predicting the pattern of adoption of innovations (Rogers, 2003) is the topic of Loveland's chapter where he argues that technology education

could benefit from more research on the diffusion of innovations within the field. Meta studies that compare the levels of technological literacy based on the extent to which states, districts, and schools implemented *Standards for Technological Literacy* (ITEA, 2000) would be helpful in focusing efforts in the diffusion of new learning theories and ideas for our field. The innovations may be in the areas of lab facilities, teacher preparation, and professional development. As new curricula and ideas are proposed, it is important that research is conducted to investigate the effectiveness of these innovations with regard to student learning. Loveland argues that in an age of accountability research that demonstrates positive linkages between facilities, programs, and resources on the one hand, and higher student achievement on the other, will likely receive the most support. Despite rapid change, Loveland argues that little application of the principles of the change process has occurred and that developing and applying change theory to the profession, and by implication, researching the effects, is a priority for technology education research.

In exploring the issue of the kind of cognition involved in design and engineering learning, Petrina argues in Chapter Seven that the priority is not researching how individual designers or engineers think, but to address the two issues of sampling and framing. Sampling in terms of establishing who or what demonstrates design and engineering cognition. Sampling involves the issue of the appropriate unit of analysis for addressing the issue. By framing Petrina means establishing what we really mean by design and engineering. Petrina concludes that the appropriate unit of analysis for exploring design and engineering cognition is the interaction of a person or persons with the designed and engineered world. Thus, by implication, Petrina argues for the importance of researching design and engineering cognition and explicitly argues for the importance of framing the research appropriately.

In Chapter Eight Sanders explores engineering education and research and notes the influence on engineering educators of Boyer's (1993) call for educational scholarship to be defined in broader terms than research alone. Boyer (1993) argued that knowledge is acquired through synthesis, practice, and teaching, as well as through research and that much engineering education knowledge has been generated through these four aspects. Sanders provides an account of the development of engineering education research and scholarship and the key institutions and publications that have facilitated this development, and notes that much of the theory that is now being incorporated into engineering education scholarship comes from outside the field, notably from educational research. The key message from Sander's chapter is the observation that almost all engineering education research and scholarship occurs at the post-secondary level and that technology educators have an opportunity and an obligation to take a leadership role in K-12 engineering education research.

In Chapter Nine, Merrill, Reese, and Daugherty cite the number of common features across technology education and mathematics education to provide

the a priori logic for exploring the benefits to technology education of research in mathematics education. Commonalities include: (a) both disciplines have learning standards; (b) both use instructional technologies; (c) both want research to discover more effective learning; (d) both have a diversity of views as to the purpose of the subjects; (e) both contain conservative teachers and schools; (f) both disciplines call for an applied/integrative/authentic approach; and (g) both disciplines have evolved based on social needs. Merrill, Reese, and Daugherty argue further that learning task authenticity is a key determinant of the quality of student learning and as this is an issue for both mathematics and technology education, collaboration across the disciplines is essential, with research into the benefits for student learning from the collaboration a priority.

In Chapter Ten, Wells develops the argument that there is much to be learned about conducting research in technology education by observing research practice in science education. For example, Wells observes that science education has had frameworks for research since the 1920s and that the current framework is aligned with the National Science Education Standards. The implication that the current frameworks could be expected to be the result of considerable experience in both undertaking research and in making decisions about what to research and in what ways. Other researchers are drawn upon to make the argument that the priority in science education research was to explore student learning within the discipline and that this is an appropriate starting point in developing a research agenda for technology education.

Warner's conclusion in Chapter Eleven is that technology education in the 21st century will be based on creativity and design and that there are many opportunities for research in these areas related to technology education. To reach this point, Warner examines definitions of creativity and design, arguments for the increasing importance of these two areas in the 21st century, the factors that influence their presence, the nature of design thinking and the research and discussion on design contained in technology education literature along with selected examples of research projects. Thus, for Warner, researching design and creativity in the context of technology education is a key priority for technology education research.

de Vries presents a survey of ideas in Chapter Twelve concerning the nature of technology what the history, sociology, and philosophy of technology offer to technology educators. deVries also argues that the use of those insights offers opportunities for a sound intellectual basis for technology education in all its aspects including the development of standards, curriculum, instructional strategies, learning environments, and assessment. deVries argues that the best way for technology educators to draw on the collective knowledge from these fields is through dialog and that this could occur by technology educators establishing working relationships with experts in the history, sociology, and philosophy of technology. In this sense, deVries is arguing that technology education will benefit by drawing on the collective theorizing from these fields.

Foster and Dischino examined the research on informal and extracurricular technology education in Chapter Thirteen. They identified three types of activities that could be categorized as informal or extracurricular: informal technology activities, usually offered by museums; competitive events such as technological challenges; and non-competitive extracurricular activities, such as tutoring programs or internships, that link students to sections of the local community. Foster and Dischino noted that because of the unstructured nature and short duration of such activities as museum visits, it was difficult to quantify their value. They argued for long-term studies that examined the impact of science centers on student technological learning. Foster and Dischino found few studies on competitive events, with those identified being descriptive and anecdotal. Nonetheless, these reports were positive about the value of competitive events. Non-competitive extracurricular programs in technology education were found in two categories: entrepreneurship-related or service-learning. As with the other categories, there were few studies but those identified reported positive results. Foster and Dischino concluded that the first priority for research in this area is to establish the goals that ought to be pursued and what constitutes technology education's role.

In synthesizing the summaries of recommendations from the preceding chapters, the overriding priority for research in technology education is in student learning and the areas that support this learning. This includes both what students should learn and how they should learn it.

WHAT THE RESEARCH LITERATURE IS TELLING US

In 2003 de Vries presented an analysis of research published in the *International Journal of Technology and Design* (IJTDE) for the period 1994 to 2000. In that analysis, de Vries used a two-fold approach. He drew on earlier analyses by Custer (1999), Vries (1999), Foster (1992), Mottier (1997), Petrina (1998), Wicklein and Hill (1996) and Zuga (1999) to identify research topics from the literature. These were categorized into one of three categories, as explained below.

What and why to teach and learn about technology?
- Who defines goals for technology education and what goals are defined?
- How can technological literacy as a goal for technology education be defined?
- What is the nature and role of knowledge and creativity in technology education?

To whom and by whom to teach and learn about technology?
- Who participates in technology education (e.g. pupils, students, and teachers)?
- What are their preconceptions and concepts of technology?

- What subcultures are there (e.g. genders)?

How to teach and learn about technology?
- How was technology taught in the past and in what context?
- How do curriculum changes take place?
- How does curriculum integration take place (relate technology to other school subjects and to the outside world) (de Vries, 2003, p. 199).

The intent of the classification approach was to provide an analysis of existing research and thus provide the basis for identifying areas for future research. de Vries' (2003) classifications and findings are listed in Table 1 and provide a year 2000 benchmark of the literature. Using these categories, de Vries provided the linkages between categories and topics for the 99 articles surveyed in the analysis.

Table 1. Research topics by categories 1994 - 2000 (Vries, 2003, p. 201)

Category	Topics	Number of articles
(1) What and why	Design/problem solving	10
	Values	10
	National curriculum	10
	Personal development	6
	Philosophical studies	6
	Identity of technology education	6
	Relationship with science	2
	Progress in technology education	2
	CAD/graphics	2
	Research agenda	2
	Language in technology education	1
	Curriculum construction	1
	Construction kits	1
	Total	**59**
(2) To and by whom	Teachers' concepts and attitudes	7
	Pupils' concepts and attitudes	4
	Total	**11**
(3) How	Design/problem solving	13
	Tasks-skills relationships	5
	Teacher education	4
	Reasoning/concept learning	3
	Assessment tools	3
	Practical conditions	1
	Continuous learning	1
	Total	**32**

de Vries (2003) found similarities in the data he collect to studies by Zuga (1999) and Petrina (1998) in that the majority of studies were on curriculum

content (what and why). On the other hand, he found more articles on teaching practice (how) than Zuga (1999) and Petrina (1998). de Vries noted, however, that many of these studies appeared at the end of the 1994-2000 timeframe, suggesting that there was change occurring and that the differences across the studies may be more the result of when the research was published (1997 & 1998 versus data up to the year 2000).

The de Vries study provides a snapshot of research from 1994-2000 and sets the stage for comparison to later research presented in the section that follows.

The research published in the two journals that focus specifically on technology education was the focus of the analysis. These include the *Journal of Technology Education* and the *International Journal of Technology and Design Education,* for the period 2000-2008. This was done for two reasons. Firstly, both are blind reviewed, scholarly research publications with an international reputation. Secondly, the two journals represent the total publications used for earlier studies (De Vries, 2003; Petrina, 1998; Zuga, 1997), allowing comparisons across the widest possible data set. Note that only papers reporting empirical research and theorizing were included. For example, papers proposing research agendas or research priorities are not included here but are included later.

Research based on unpublished dissertations was not included (Foster, 1992). This was in consideration of the limited influence that such research typically has beyond those directly involved in the dissertation. However, published articles based on masters or doctoral research were included.

Two explanatory points need to be made about the classifications in Table 2: Firstly, some topics appear in more than one category. For example, an article on creativity could include *What to teach* if it included a rationale for teaching creativity and the same article could also include strategies for developing creativity and would therefore fit in the category *How to teach* as well. Secondly, some papers were difficult to categorize since they overlapped across several categories. In these cases the articles were placed in the category that represented what was perceived to be the major emphasis of the research. In the end, the categorization of a few of the articles could be arguable. However, it is unlikely that this would significantly affect the results or the conclusions drawn from them. Finally, the order of topics in each category is chronological. However, in cases where there were multiple articles on the same topic, the first published article determined the order.

Table 2. Number of Articles Published on Research Topics by de Vries' Categories, 2000 – 2008

Category	Topics (number of articles in each topic are indicated within parentheses)	Total No.
1. What and why	Goals (1), Sketching (1), Critical technology education (2), Design philosophy (3), Character (1), Ethics (2), New technologies (3), Science & technology (1), Authentic problems (1), Interactive media design (1), National curriculum (4), Food technology (2), Design curriculum (1), Technological knowledge (2), Values (6), Construction kits (1), Design cognition (1), Interactive design (1), Philosophical framework (1), Structural design (1), CAD (1), Cross-disciplinary studies (1), Technological literacy (1), Systems (1), Engineering design (4), Professional knowledge (1), Problem based learning (1), Curriculum development (2), Philosophy of informal learning (1), IT in technology education (1), Online learning (3), Holistic technology education (1), Standards (1), Creativity (1), Philosophy (1), Biotechnology (1), Microcontrollers (1), Engineering modelling (1),	
	Total	**60**
2. To and by whom	Student perceptions (14), Teacher perceptions (11), Trainee teacher perceptions (4), Parental perceptions (1), Prior experience (2), Gender (5), Perceptions (1), Prior knowledge (2), Concept development (2), Learning styles (1), Student attributes (1), Public perceptions (3), Student advisor perceptions (1), Leaders' perceptions (1)	
	Total	**49**
3. How	Reasoning (1), Problem-solving (5), Designing (6), Learning environment (1), Ethical judgements (1), Assessment (9), Creativity (5), Curriculum materials (1), Social & cultural influences (1), Collaborative design (3), Social interaction (1), Integration – AI & design (1), Knowledge transfer (1), Industrial project method (1), Collaborative problem-solving (2), Math through technology education (1), Outcomes based education (1), Instructional design (2), Project based learning (3), Activity theory (2), Professional development (5), Technological stance (2), Cognition & instruction (1), Collaboration – ICT & TE (1), Inclusive communities (1), Authentic learning (1), Technology & science (1), Community of practice (1), Sustainable design (1), Sustainability (1), Modelling (2), Progression (2), Conceptual development (1), Learning preference (1), Electronic portfolios (1), Design & Technology activities (2), Social constructivism (1), CAD (1), Teaching approaches (1), Syllabus implementation (1), Teaching strategies (1), Practicum (1), Design practice & maths (1), Emotions (1), Collaborative learning (1), Design process (2), Curriculum models (1), Professional thinking (1), Learning outcomes (1), Lifelong learning (1), Technology practice (1), Computer learning (1), Action research learning (1), Student performance (1), Integrating science & technology (1), Integrating maths, science & technology learning environments (1), Testing (1), Using electronic information (2), Team learning (1), Partnership centred learning (1), D & T impact on schools (1), Modular technology & achievement (1), Design drawing (1), Facilitating implementation (1), Systems approach (1), Curriculum integration (1), Technology education & maths (1), Integrating technology education (1), Project based technology (1), Technology and poetry (1), Collaborative design (1), Analogical reasoning (1), Design and science (1), Cognitive processes (1)	
	Total	**113**
	Overall total	**222**

What, then, is the research telling us and how has it changed from the earlier analyses? The most striking shift in the later data is the move from studies on *what to teach* which is down from 58.4% to 27% of all papers, to studies on *to and by whom* (up from 11% to 22%) and *how to teach*, up from 31.7% to 51%. Thus, earlier calls by Zuga and Petrina appear to have been heeded with an increase in research activity on topics such as how teachers and students perceive teaching and learning in technology education and a larger increase in studies examining how learning occurs and what needs to be done to make it effective.

There appears to be a spreading out of research topics in all areas with 92 out of a total of 321 papers, or almost a third, devoted exclusively to a single topic. Put another way, there were only 12 topics for which there were more than three published papers. This aspect of the data would appear to support the need to identify areas for research focus and thereby supports Ernst' and Haynie's argument that large scale projects have more impact and that impact is longer lasting. It is difficult to influence change among legislators, administrators, or others connected with the field if only one research study on a topic of interest can be identified over a nine year period.

The analysis of areas of concentration would appear to be in line with priority issues within and outside the field. In the category of *What to teach* the focus was on values, national curriculum, and engineering design. These represent a slight shift from the earlier analysis in which values and national curriculum were included but design and problem-solving were replaced by engineering design (see Table 3). The concentration in *To who and by whom* has broadened from teachers' and students' concepts and attitudes, to student, teachers, and teacher preparation concepts along with perceptions about a topic and gender issues. The concentration in *How to teach* has shifted from an emphasis on design and problem-solving, tasks-skills relationships, and teacher education, to assessment, designing, problem-solving, and professional development.

Table 3. Changes across the de Vries Study and the Study Herein

Categories	2000 Articles and Percent	2008 Articles and Percent
(1) What to teach?	59 (58.4%)	60 (27%)
(2) To and by whom?	11 (10.9%)	49 (22%)
(3) How?	32 (31.68%)	113 (50.9%)

In summary, there has been a shift away from research into what should be taught in technology education to research into perceptions and concepts that people have about technology education. In particular, research examining how learning occurs and the areas that contribute to improving learning, such as professional development, are being conducted. In terms of topics researched, there has been a move to more research in areas that represent contemporary curriculum directions and priorities such as engineering design and assessment.

RECOMMENDATIONS FROM THE LITERATURE ON AREAS OF NEEDED RESEARCH

Cajas (2000) reported on the recommendations from the first Project 2061 conference sponsored by the American Association for the Advancement of Science (AAAS, 1999). Cajas concluded from the conference that the priority areas for research were: what students should learn in order to achieve technological literacy, how students learn, the nature of appropriate instruction, and the professional development of teachers.

Ahlgren (1999) argued that some research studies in science education could be replicated in technology education. He referred specifically to studies that examined how students learn and understand particular topics and argued that, given the ties to past goals for technology education, new teaching and learning methods should become a focus. That is, we need to study interventions in classrooms and suggests case studies may be the most appropriate research method. Ahlgren concluded that student learning should be the highest priority for research and, with limited resources, priorities need to be established.

In reflecting on the first AAAS conference, Zuga (1999) concluded that what was required was research in the teaching methods used, the value of technology education, student cognitive and conceptual attainment, curriculum and instructional materials, and professional development. Zuga was critical of the kinds of research methods employed in research to date, citing an over-reliance on surveys and descriptive statistics that she argued cannot provide the kinds of analyses required to adequately inform the development of the discipline.

Foster (1999) argued for research as a priority and outlined a range of factors that have contributed to the decline in research by academics in the field. In advancing recommendations, Foster argued that *Standards for Technological Literacy* (ITEA, 2000) would provide a suitable starting point for research and noted the following research priorities: "The nature of knowledge and skill; cognition and meta-cognition; pedagogical effectiveness; human development issues; diversity issues; and what constitutes the essentials of education" (Foster, 1999, p. 8).

Pellegrino (2001) provided a report and paper at the second AAAS conference, based on the National Research Council's (NRC) (2000) report, *How People Learn (HPL)*, to suggest how a research agenda for technology (as well as science and mathematics) could be established. Pellegrino suggested using the principles for the design of powerful learning environments, as outlined in HPL, in technology education classes and to connect research to the resulting practice using HPL as the organizing schema. An overall priority for Pellegrino was what he described as the CIA triangle of curriculum, instruction, and assessment, and the necessity to interconnect these three parts through the application of research in order to optimize learning.

Lewis (1999) identified eight areas that he considered to have potential for research in technology education: (a) technological literacy, (b) conceptions and

misconceptions of technological phenomena, (c) perceptions of technology, (d) technology and creativity, (e) gender in technology classrooms, (f) curriculum change, (g) integration of technology with other school subjects, and (h) the work of technology teachers (Lewis, 1999, p. 43). Lewis also argues that researchers need to be prepared to use a variety of research approaches if they want to produce results that improve practice.

In responding to the paper by Lewis, Cajas (2000) argued that before any of the areas of research advanced by Lewis be undertaken, it is necessary to address the more general question of "What knowledge and skills should everybody know?" (Cajas, 2000, p. 67). Cajas argued that in the future, contemporary society will depend heavily on technology and this should determine what is taught and learned. This requires the findings of appropriate research in order for teachers to be in a position to accomplish it.

Indications of needed research in technology education have also come from influential groups not directly concerned with technology education. For example, the Committee on Technological Literacy of the National Academy of Engineering (NAE) report *Technically Speaking: Why all Americans need to know more about technology* (2002) includes a number of implications for research related to technological literacy. The report drew on a number of studies, including the ITEA-commissioned Gallup poll (ITEA, 2002) which found that 68% of the Americans surveyed thought technology was exclusively computers. The aim of the report was not aimed directly at researchers. However, a section devoted to the benefits of technological literacy listed "improved decision making; increased citizen participation; supporting a modern workforce; narrowing the digital divide; and enhancing social well-being" as important (NAE, 2002, p. 3). While the report provides situations where each of these abilities would be of benefit, it provides no research evidence to support the benefits claimed for technological literacy. Thus, establishing the nature and extent of the impact of technology education on students would appear to be an important goal.

Johnson, Burghardt, and Daugherty (2008) examined the research issues within engineering education and compared these with agendas in technology education as a way of synthesizing a set of shared or overlapping priorities. The motivation for was the initiative by engineering educators to infuse school curricula with engineering content and the similar move by technology educators to include engineering content within technology education. The recent name change of ITEA to the International Technology and Engineering Educators Association to formally include engineering is one indicator of this move. Johnson, Burghardt, and Daugherty (2008) provide a framework for future research that is designed to account for the closer relationship between technology and engineering education. The framework highlights the nature of teaching and learning, with emphasis on the role of design, together with research into content, the nature of collaboration between the two areas, and efforts to increase participation in both areas by under-represented populations.

Finally, an important point made by a number of researchers (Foster, 1999; Middleton, 2008; Zuga, 1997, 1999) is that there is an over-reliance on surveys and descriptive research. This point was made by Middleton (2008) who argued that even though technology education research can be regarded as a part of social science, there were aspects that were unique and required methods that accounted for this uniqueness. For example, student learning in technology education is mediated through visual, verbal, and enactive renditions of procedural knowledge and these renditions are not captured adequately by many social science research methods.

In summary, the leaders in the field are arguing for a concentration on research aimed at understanding how students learn in technology education. In addition, with a clear implication that change and improvement is required, leaders are calling for a concentration on research into teaching practice and professional development using methods appropriate to the discipline.

SYNTHESISING RECOMMENDATIONS AND PRIORITIES FOR RESEARCH IN TECHNOLOGY EDUCATION

There is a significant level of overlap among the recommendations of the chapter authors in this Yearbook and the published papers on research directions and priorities. In addition, there is evidence of movement in terms of research topics that support the recommendations. There is, however, evidence in the literature of a spreading out of research efforts into a wider range of topics that may have the effect of diffusing the value of the resultant research output.

The clear recommendation to come from the preceding chapters is for research into student learning that includes both what should be learned and the best way to accomplish it along with a study of the diverse mechanisms that support student learning. These range from establishing links with other curricular areas to professional and student organizations and informal and extracurricular learning. Supporting these calls for research regarding student learning in technology and engineering education are calls for training in research in undergraduate technology teacher education programs and for large-scale research projects.

The literature from 2000 to 2008 indicates a shift from a concentration on what should be taught to research on perceptions about technology education and more particularly about how students learn and how this learning might be improved and how we might establish what constitutes good learning via assessment. The exception to this shift is the emerging area of K-12 engineering education and the related issue of design.

Leading researchers in the field are also arguing for a concentration on research aimed at understanding how students learn in technology education. In addition, with a clear implication that change and improvement is required, leaders are calling for a concentration on research into teaching practice and professional development.

CHAPTER SUMMARY AND CONCLUSIONS

This final chapter examined existing research publications and then offered prioritized recommendations for future research in technology education. Initially the chapter examined the recommendations offered by the chapter authors and then analyzed research published in the *Journal of Technology Education* and the *International Journal of Technology and Design Education*. Next, articles advancing research agendas and priorities for technology education research were examined and summarized. Finally, an overall set of recommendations derived from a synthesis of the recommendations of chapter authors, the literature on research agendas and priorities, and the analysis of the empirical research was presented. In summary, the key recommendations include:

1. Research into student learning in technology education and the related areas of teaching practice and professional development;
2. Research into links with other disciplines, particularly STEM areas, given the lack of research into K-12 engineering education;
3. Large-scale research-based curriculum projects that build on the *Standards* developed by the Technology for All Americans Project; and
4. Use of appropriate research methodologies including mixed quantitative and qualitative methods.

A final note regarding future directions for technology education research. Almost all of the material in this chapter, and indeed the Yearbook has been derived from research done by technology educators and published in scholarly refereed journals and books devoted to the discipline. This is useful because it gives a reader some sense of what the researchers in the discipline are doing (Zuga, 2000). However, it doesn't give the reader much sense of the kinds of research that is being published in educational research journals outside the discipline, such as general educational research. This is a limitation Foster (1999) identified in earlier studies. To publish in such journals is important given that governments, policy makers, and curriculum decision makers are often generalists and more likely to read such journals as the *Review of Educational Research* than the *Journal of Technology Education*. To establish the number and types of papers being published in these journals and to set some recommendations for increasing the numbers would be a useful and productive endeavor.

REFERENCES

Ahlgren, A. (1999). Towards a research agenda. In *Proceedings of the first AAAS technology education research conference*, retrieved January 22, 2009 from: www.project2061.org/events/meetings/technology/papers/Ahlgren. htm

Boyer, E. L. (1993). *Scholarship reconsidered*: *Priorities of the professoriate.* San Francisco, CA: Jossey-Bass Publishing.

Cajas, F. (2000). Technology education research: potential directions, *Journal of*

Technology Education, 12(1), 75-85.

Cajas, F. (2000). Research in technology education: What are we researching?
A response to Theodore Lewis, *Journal of Technology Education, 11*(2),
61-69.

Custer, R. (1999). Technology education, the empirical evidence, in I. Mottier
& M. J. De Vries (Eds.), *Impacts of technology education, Proceedings
PATT-9 Conference, March 27-29*, 1999, PATT-Foundation, Eindhoven,
41-50.

Foster, W. T. (1999). Developing a research agenda for technology education,
Proceedings of the first AAAS technology education research conference,
retrieved January 22, 2009 from: www.project2061.org/events/meetings/
technology/papers/Foster.htm

Foster, W. T. (1992). Topics and methods of recent graduate student research
in industrial education and related fields. *Journal of Industrial Teacher
Education*, *30*(1), 59-72.

Gundem. (2000). Understanding European didactics. In B. Moon, M. Ben-Perez
& S. Brown (Eds.), *Routledge International Companion to Education*,
London: Routledge, 2350262.

Householder, D. L. (2000). Setting priorities for research in technology
education, *Proceedings of the second AAAS technology education
research conference*, retrieved January 22, 2009 from: www.project2061.
org/events/meetings/technology/tech2/Householder.htm

International Technology Education Association. (2000). *Standards for
technological literacy: Content for the study of technology*. Reston, VA:
Author.

International Technology Education Association. (2002). ITEA/Gallup Poll
reveals what Americans think about technology. *The Technology Teacher,
61*(6).

Johnson, S., Burghardt, D., & Daugherty, J. (2008). Research Frontiers –
An Emerging Research Agenda. In Custer, R. & Ereksen, T. (Eds.).
Engineering and Technology Education. Peoria, IL: Glencoe/McGraw-
Hill, 233-257.

Maley, D. (1973). *The Maryland Plan*, New York: Bruce.

Martin, G. E. (2008). What research matters most. In Middleton, H. & Pavlova,
M. (Eds.), *Exploring technology education: Solutions to issues in a
globalised world*, Vol 2, Brisbane: Griffith Institute for Educational
Research, 17-27.

Middleton, H. E. (Ed.) (2008). *Researching Technology Education: Methods and
Techniques*. Rotterdam: Sense Publishers.

Mottier, I. (1997). Summary of conference outcomes, in *Assessing Technology
Education. Proceedings PATT-8 Conference, April 17-22, 1997*, PATT-
Foundation, Eindhoven, 387-391.

National Research Council (2000). M. S. Donovan, J. D. Bransford, & J. W.

Pelligrino, (Eds.), *How people learn: Bridging research and practice.* Washington DC: National Academy Press.

Lewis, T. (1999). Research in technology education: Some areas of need. *Journal of Technology Education, 10*(2), 41-56.

Pearson, G., & Young, A. T. (Eds.) (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC: National Academy Press.

Pellegrino, J. W. (1999). Setting research agendas in science, mathematics, and technology education: The National Research Council's How people learn Report. *Proceedings of the second AAAS technology education research conference*, retrieved January 22, 2009 from: www. project2061.org/events/meetings/technology/tech2/Pellegrino.htm

Reed, P. A. (2002). Research in technology education: Back to the future, *Journal of Technology Education, 13*(2), 68-72.

Rogers, E. (2003). *Diffusion of Innovation*, Fifth Edition. New York: Free Press.

Streichler, J. (2000). The past defines the paths to be taken. In G. E. Martin (Ed.), *Technology education for the 21st century, the 49th Yearbook of the Council on Technology teacher Education*, New York: Glencoe-McGraw-Hill.

Towers, E. R., Lux, D. G., & Ray, W. E. (1966). *A rationale and structure for industrial arts subject matter*. Columbus: The Ohio State University Research Foundation.

Vries, M. J. de. (2003). Editorial, *International Journal of Technology and Design Education, 13(1), 199-205.*

Vries, M. J. de. (1999). Impacts of technology education: Summary of the conference theme and papers, in Mottier, I. & Vries, M. J. de (Eds.), *Impacts of Technology Education. Proceedings PATT-9 Conference, March 27-29, 1999*, PATT-Foundation, Eindhoven, 147-150.

Wicklein, R. & Hill, R. B. (1996). Navigating the straights with research or opinion? Setting the course for technology education, *International Journal of Technology and Design Education*, 6, 31-34.

Zuga, K. F. (1999). Thoughts on technology education research. In *Proceedings of the first AAAS technology education research conference*, retrieved January 22, 2009 from: www.project2061.org/events/meetings/technology/papers/Zuga.htm

Zuga, K. F. (1997). An analysis of technology education in the United States based upon an historical overview and review of contemporary curriculum research, *International Journal of Technology and Design Education*, 7, 2039217.

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