Exemplary Teaching Practices in Technology & Engineering Education

Editor

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PROPOSING A YEARBOOK

Each year at the ITEEA conference the CTETE 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 yearbook's substance and format. A digital copy of the proposal should be sent to the committee chairperson by February 1 of the year in which the proposal is to be considered. The following criteria are used by the committee in approving yearbook topics.

CTETE Yearbook Guidelines

A. **Purpose**

The CTETE Yearbook series is intended as a vehicle for investigating topics or issues related to technology teacher education through a structured, formal series that does not duplicate commercial textbook publishing activities.

B. **Yearbook Topic Selection Criteria**

Yearbook topics should be ones that:

1. Make a direct contribution to the understanding and improvement of technology teacher education;
2. Add to the body of knowledge about technology teacher education and to the field of technology education;
3. Do not duplicate publications from other professional groups;
4. Provide a balanced view of the theme and do 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 themselves to team authorship as opposed to single authorship.

Yearbook themes related to technology and engineering 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 generate an international dialogue on the topic; and

C. The Yearbook Proposal

1. The yearbook proposal should provide adequate detail for the Yearbook Committee to evaluate its merits.
2. The yearbook proposal should:
    a) Define and describe the theme of the yearbook;
    b) Provide a rationale for selection of the theme;
    c) Identify the need for the yearbook and its potential audience(s);
    d) Explain how the yearbook will advance the technology teacher education profession in particular and technology education in general;
    e) Provide an outline of the yearbook that 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 author(s) and backup authors;
        v. An estimated number of pages for each yearbook chapter; and
        vi. An estimated number of pages for the yearbook (the target maximum is ~250 pages).
    f) Provide a timeline for completing the yearbook.

It is understood that each yearbook chapter author will sign a CTETE *Editor/Author Agreement* and that (s)he will comply with the Agreement. Additional information on preparing CTETE yearbook proposals can be found on our web site: http://ctete.org/yearbook/

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.
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8. *Planning Industrial Arts Facilities*, 1959. Ralph K. Nair, Ed.
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10. *Graduate Study in Industrial Arts*, 1961. R.P. Norman & R.C. Bohn, Eds.
11. *Essentials of Preservice Preparation*, 1962. Donald G. Lux, Ed.
12. *Action and Thought in Industrial Arts Education*, 1963. E. Svendsen, Ed.
13. *Classroom Research in Industrial Arts*, 1964. Charles B. Porter, Ed.
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15. *Status of Research in Industrial Arts*, 1966. John D. Rowlett, Ed.
16. *Evaluation Guidelines for Contemporary Industrial Arts Programs*, 1967. Lloyd P. Nelson & William T. Sargent, Eds.
17. *A Historical Perspective of Industry*, 1968, Joseph F. Luetkemeyer Jr., Ed.
18. *Industrial Technology Education*, 1969. C. Thomas Dean & N.A. Hauer, Eds.; *Who's Who in Industrial Arts Teacher Education*, 1969. John M. Pollock & Charles A. Bunten, Eds.
19. *Industrial Arts for Disadvantaged Youth*, 1970. Ralph O. Gallington, Ed.
20. *Components of Teacher Education*, 1971. W.E. Ray & 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 & 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 & 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.E. Martin, Ed.
29. *Technology and Society: Interfaces with Industrial Arts*, 1980. Herbert A. Anderson & M. James Benson, Eds.

30. *An Interpretive History of Industrial Arts,* 1981. Richard Barella & Thomas Wright, Eds.
31. *The Contributions of Industrial Arts to Selected Areas of Education*, 1982. Donald Maley & Kendall N. Starkweather, Eds.
32. *The Dynamics of Creative Leadership for Industrial Arts Education*, 1983. Robert E. Wenig & 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 & John R. Wright, Eds.
36. *Conducting Technical Research*, 1987. Everett N. Israel & R. Thomas Wright, Eds.
37. *Instructional Strategies for Technology Education*, 1988. William H. Kemp & Anthony E. Schwaller, Eds.
38. *Technology Student Organizations*, 1989. M. Roger Betts & Arvid W. Van Dyke, Eds.
39. *Communication in Technology Education*, 1990. Jane A. Liedtke, Ed.
40. *Technological Literacy*, 1991. M.J. Dyrenfurth & M.R. Kozak, Eds.
41. *Transportation in Technology Education*, 1992. John R. Wright & Stanley Komacek, Eds.
42. *Manufacturing in Technology Education*, 1993. Richard D. Seymour & Ray L. Shackelford, Eds.
43. *Construction in Technology Education*, 1994. Jack W. Wescott & Richard M. Henak, Eds.
44. *Foundations of Technology Education*, 1995. G. Eugene Martin, Ed.
45. *Technology and the Quality of Life*, 1996. Rodney L. Custer & A. Emerson Wiens, Eds.
46. *Elementary School Technology Education*, 1997. James J. Kirkwood & Patrick N. Foster, Eds.
47. *Diversity in Technology Education*, 1998. Betty L. Rider, Ed.
48. *Advancing Professionalism in Technology Education*, 1999. Anthony F. Gilberti & David L. Rouch, Eds.
49. *Technology Education for the 21st Century: A Collection of Essays*, 2000. G. Eugene Martin, Ed.
50. *Appropriate Technology for Sustainable Living*, 2001. R.C. Wicklein, Ed.
51. *Standards for Technological Literacy: The Role of Teacher Education*, 2002. John M. Ritz, William E. Dugger, & Everett N. Israel, Eds.
52. *Selecting Instructional Strategies for Technology Education*, 2003. Kurt R. Helgeson & Anthony E. Schwaller, Eds.
53. *Ethics for Citizenship in a Technological World*, 2004. Roger B. Hill, Ed.

54. *Distance and Distributed Learning Environments: Perspectives and Strategies*, 2005. William L. Havice & Pamela A. Havice, Eds.
55. *International Technology Teacher Education*, 2006. P. John Williams, Ed.
56. *Assessment of Technology Education*, 2007. Marie C. Hoepfl & Michael R. Lindstrom, Eds.
57. *Engineering and Technology Education*, 2008. Rodney L . Custer & Thomas L. Erekson, Eds.
58. *Essential Topics for Technology Educators,* 2009. CTTE Yearbook Planning Committee, Eds.
59. *Research in Technology Education*, 2010. P.A. Reed & J. LaPorte, Eds.
60. *Creativity and Design in Technology and Engineering Education,* 2011. Scott Warner & Perry Gemmill, Eds.

All previously published yearbooks are available in digital format via the Council on Technology and Engineering Teacher Education web site (www.ctete.org); these yearbooks are digitally archived at the Virginia Tech "VTechWorks" web site: https://vtechworks.lib.vt.edu/handle/10919/5531. We extend special thanks to the Virginia Tech University Archives for their assistance in ensuring access to the CTETE Yearbook series.

PREFACE

As we work to (re)define the role of K-12 technology and engineering education in general, and more specifically its role within the rainbow of STEM education, some teacher educators have struggled to identify durable and comprehensive descriptions of classrooms and teachers that serve as ideals to illustrate the unique potential of technology and engineering education in educating our youth. The eight teachers' stories contained in this book provide details about effective approaches used by technology teachers at the elementary, middle, and high school levels, in the United States and in two international settings. I extend deep and sincere gratitude to the colleagues who authored these rich descriptions, and to the teachers and the schools they highlight in these chapters.

On a procedural note, all teachers featured in this yearbook were given the option of being identified under a pseudonym; none opted to do so. Teachers and their school principals signed participant agreements. All photographs of students are used by permission.

I hope that this 61st yearbook of the Council on Technology and Engineering Teacher Education provides helpful insights to my fellow technology and engineering teacher educators, and inspiration to current and future classroom teachers in technology and engineering education and across the STEM disciplines.

61st Yearbook Editor
Marie Hoepfl
Appalachian State University

DEDICATION

This yearbook is dedicated to the memory of two colleagues who passed away in 2016 while this yearbook was in final production. Michael Neden, a teacher educator at Pittsburg State University in Kansas, died in July 2016 after a battle with cancer. Jane Smink, a retired technology teacher educator from North Carolina, died in October 2016.

In acknowledging the work of Michael Neden, I borrow here the eloquent words of his colleague Andy Klenke, who wrote:

> The educational community lost an icon yesterday ….[whose] impact went well beyond the Pittsburg Middle School students he taught for 13 years; or his 17 years of teaching [Pittsburg State University] students. He was the most creative/innovative person I have ever met in my life. The "Explorations of Technology" program he and Max Lundquest created at Pittsburg Middle School was visited by thousands and replicated in hundreds of school districts across the U.S. His "Center Of Applied Learning" labs in the Delta County [CO] School District were amazing educational facilities inspiring thousands to change the way Technology Education was delivered. His most recent undertaking in Elementary STEM Education is an educational model which could be the catalyst for how students learn STEM in the near future. His motto was always "Go big or go home!" He was a visionary for Technology Education and an eternal advocate for kids when it came to technological literacy. He was always trying to maximize the opportunities students had by the time they left high school.

Dr. Jane Smink was a pioneer in the field of industrial arts/ technology education who remained active for four decades in the technology education community. Smink was the first woman to be elected President of the ITEA (ITEEA), in which capacity she served from 1988-1989. A North Carolina native, she earned a BS degree from Winthrop College in 1959, an MA in Industrial Arts from Appalachian State University in 1970, and a Doctor of Education degree at North Carolina State University in 1983. Over her career she worked as a classroom teacher, as a county-level CTE director, as a state-level consultant in the North Carolina Department of Public Instruction, and as a teacher educator at North Carolina A&T State University. She was named a Distinguished Technology Educator in 1991, and earned the ITEA Meritorious Service Award in 1992.

Throughout their careers, Michael Neden and Jane Smink served as strong advocates in promoting technological literacy for all students.

ABOUT THE AUTHORS

Dr. Susan Bastion is a Kansas-based psychometrician for Cisco Systems. From 2001-2015 Bastion was a full-time instructor at Pittsburg State University, where she taught undergraduate and graduate courses in technology and engineering education, assisted with curriculum development and program assessment, and worked with industrial partners.

Dr. Vinson Carter is an Assistant Professor of STEM Education at the University of Arkansas, where he teaches courses in Technology & Engineering Education and Elementary Integrated STEM Education. Carter speaks nationally on STEM education and curriculum development. He is a member of the Executive Board of Directors of the International STEM Education Association (ISEA), and was recognized in 2010 as an ITEEA/CTETE *21st Century Leadership Academy* Fellow.

Dr. Michael Daugherty is a Professor of STEM Education and Head of the Department of Curriculum and Instruction at the University of Arkansas. In 2001, Daugherty was awarded the prestigious CTETE Technology Teacher Educator of the Year, and in 2004 earned the ITEEA Award of Distinction. In 2014, Daugherty was installed as eighth Life Chair of the Mississippi Valley Conference. Daugherty is the author of 22 books and book chapters, over 60 journal articles, and numerous curriculum sets.

Dr. Wendy Fox-Turnbull is Senior Lecturer in the School of Teacher Education at University of Canterbury in Christchurch, New Zealand, where she teaches in Primary and Secondary Technology Education, Inquiry Studies, and Professional Inquiry. Fox-Turnbull is Chair of the National Council of Technology Education New Zealand (TENZ) and serves on the Canterbury TENZ Regional Committee.

Dr. William Havice is a Professor in the Eugene T. Moore School of Education at Clemson University. Havice served on the ITEEA board of directors and has been honored as an ITEEA Distinguished Technology Educator. In 2012, Havice was awarded the prestigious "Technology Teacher Educator of the Year" by the CTETE. He has been actively involved in teaching, researching, presenting and publishing on STEM education, instructional technology, and distance/distributed learning environments in K-16 for the past 38 years.

Dr. Marie Hoepfl is a Professor in the Department of Sustainable Technology & the Built Environment at Appalachian State University. Hoepfl has served several terms in various officer roles on the CTETE Executive Committee since 2002. Hoepfl has contributed four chapters to prior CTETE yearbooks, and co-edited the 2007 yearbook titled *Assessment of Technology Education.* She was named the CTETE Technology Teacher Educator of the Year in 2011 and given the ITEEA Award of Distinction in 2012.

Dr. John Iley is Professor and Chairperson of the Department of Technology & Workforce Learning at Pittsburg State University. A long-time contributor to the field of technology and engineering education, Iley was recipient of the ITEEA Lockette/ Monroe Humanitarian Award and was recognized in 2013 with the prestigious "University Professor" distinction at Pittsburg State as an "outstanding contributor in a field of specialization."

Dr. Andy Klenke is Associate Professor of Technology and Engineering Education at Pittsburg State University. Klenke has been honored with the National TEECA Distinguished Faculty Advisor Award, served as the National TEECA Advisor, and represented TECA on the ITEEA Board of Directors. Klenke has actively served the Kansas Technology Education Association and other professional organizations.

Dr. Mark Mahoney is an Associate Professor and Program Chair of Technology and Applied Design at Berea College. Mahoney worked as a classroom teacher prior to earning graduate degrees in technology education and STEM education at The Ohio State University. His research interests focus on sustainable energy systems and on students' attitudes toward STEM. Mahoney is active in his community and in several professional organizations, and currently is Treasurer on the CTETE Executive Committee.

Dr. Chris Merrill is Professor in the Department of Technology at Illinois State University, where he has been honored several times, including the College of Applied Science and Technology Outstanding Research Award in 2007 and Outstanding Teaching Award in 2012. In 2014, he was recipient of both the CTETE Technology and Engineering Educator of the Year and the ITEEA Award of Distinction. Among a number of other professional contributions, Merrill has served as Editor of the *Journal of Technology Education* since 2010.

Ms. Rebecca Petersen is an American teacher and STEM Specialist at the bilingual Anubanchonburi School in Thailand, a Thai government school for grades K-6. Her work to promote elementary STEM education has been recognized internationally, including via events like the 2013 online Global STEMx Education Conference.

Dr. Edward Reeve is a Professor in Utah State University's School of Applied Sciences, Technology, and Education, where he has taught for over 28 years. During this time he has remained active in serving the technology and engineering education community, including most recently through service as President (2010-2013) and Past President (2013-2016) of the CTETE. Reeve has been a strong advocate for international engagement and for integrative STEM education, and regularly travels to Thailand. He became President-Elect of the ITEEA in 2016.

Mr. Paul Snape is Lecturer in Technology Education, Professional Inquiry, and Professional Practice at University of Canterbury in Christchurch, New Zealand. Paul comes from a primary teaching background in urban Christchurch schools, and his interests are now principally in Technology Education and working with first-year primary teacher education students. Hi research interests include pedagogy of curriculum integration, integrated inquiry, cooperative learning, and metacognition.

Dr. Jerianne Taylor is Professor and Program Director for the Career and Technical Education Program at Appalachian State University. Taylor served as national TEECA Advisor from 2011-2013 and as TEECA Director on the ITEEA Board from 2013-2015. She is an active member of several professional organizations, and currently chairs the CTETE Curriculum Development Committee. Taylor has served as State Advisor for NC TSA since 2013, and has contributed widely to the literature on student organizations.

Dr. Scott Warner is Associate Professor in the Department of Applied Engineering, Safety, and Technology at Millersville University, where he coordinates the Master of Education in Technology & Innovation program. Warner is an active member of the ITEEA, the CTETE, and the Industrial Designers Society of America. He has authored or co-authored over 20 articles, has written four chapters in edited books, and has given over 30 presentations at regional, national, and international conferences. Warner co-edited the 2011 CTETE Yearbook *Creativity and Design in Technology and Engineering Education.*

TABLE OF CONTENTS

Research on Teaching and Learning in Project-based Learning, Technology & Engineering Education, and Related Subjects

Chapter 1

Marie Hoepfl
Appalachian State University

The Search for Exemplary Practice

Identifying Best Practices

The search for teachers who display exemplary instructional practices is something of a holy grail for teacher educators. More to the point, within technology and engineering (T&E) education we seek to identify those individuals who can serve as role models for our students, and whose teaching strategies can be distilled into sets of "best practices" for others to emulate. All of us can identify teachers from our own educational pasts who had the most positive impacts on our lives; many of us can point to technology teachers who were instrumental in shaping our own career paths. But how do we identify these influential and expert teachers, beyond just knowing one when we see one?

As Leinhardt (1990) summarized, the most commonly-used method is to seek nominations from others familiar with a teacher's work, or in some cases to look at relative student outcomes on assessments. However, "nominations are often made based on characteristics that are important in the global view of teaching (i.e., a cooperative, enthusiastic, willing worker) rather than other important but more narrow characteristics (i.e., pedagogical subject matter knowledge)" (p. 19). Identifying exemplary teachers via nomination processes can be made more rigorous by gaining multiple nominations and by looking to other measures, such as the quality of teaching materials used or student successes in competitions or on standardized tests. In order to conduct a closer analysis of best practices, however, we must explore strategies for uncovering what Leinhardt called the "craft knowledge" of teaching:

> Indeed, the very metaphor of craft knowledge evokes the guild model of hierarchy in skill, with the master modeling and passing on to the apprentice the historical art. It seems appropriate that we should seek the knowledge of the expert or, at a minimum, the reasonably successful and experienced practitioner. (Leinhardt, 1990, p. 19).

Hassard (2005) provided an even more poetic phrase to describe good teaching, which he called "professional artistry," in which you can "witness [the teacher's] imagination and creativity at play unfolding in the classroom" (p. 5). Generally speaking, nearly all accounts of excellent teaching address some aspect of what might be termed affective attributes of teachers. For example, Alsop (2005) stated "it has been widely acknowledged that pedagogical practices are inextricably tied to emotions" (p. 146), where negative emotions can overshadow efforts to structure learning in the classroom, and conversely teacher enthusiasm and confidence can serve as motivators that yield positive outcomes for students. "In research and practice the interaction of affect and cognition is largely understated. Affect is, more often than not, marginalized. In exemplary science teaching I suggest—quite simply—that it shouldn't be" (Alsop, 2005, p. 147). From this view, teaching practices refer not just to the instructional techniques used but also to the "personal dynamics between teachers and students and the interactions among students and assessments, educational technologies, laboratories, and myriad other teaching strategies" (Bybee, 2013, p. 6).

On Beyond Anecdote: Methods for Analyzing Best Practices

This Yearbook features eight case studies of exemplary T&E teachers at the elementary, middle school, and high school levels. These are descriptive looks at the kinds of philosophies, strategies, and approaches these teachers employ. Although I believe this volume will make a positive contribution, to delve deeply into the characteristics of exemplary teaching practices more systematic and rigorous analyses that employ multiple data sources are needed (Capps & Crawford, 2013). Highlighted in this section of Chapter 1 of this book are examples of studies that have attempted to do just that. Some of the key findings from these various studies are reported later in this chapter.

A recent study by Rose, Shumway, Carter, and Brown (2015) used a modified Delphi study to identify the basic competencies associated with excellence in T&E teaching that would be desired among pre-service T&E teacher education program graduates. They acknowledged that excellence "requires an interrelated set of skills, knowledge, and dispositions" (p. 17). The research team started with characteristics drawn from the Interstate Teacher Assessment and Support Consortium (InTASC) *Model Core Teaching Standards* (Council of Chief State School Officers, 2013), among other sources. As the authors of this study noted, resources such as state and national standards, evaluation systems like the National Board for Professional Teaching Standards, and the scholarly literature contain comprehensive lists of attributes of successful teachers, which comprise the "integrated, complex set of knowledge and skills known as Pedagogical Content Knowledge (PCK) (Rose et al., 2015, p. 3).

An interesting look at exemplary teaching in science education was undertaken by Alsop, Bencze, and Pedretti (2005), who edited a volume containing ten accounts of teaching written by K-12 science teachers accompanied by follow-on qualitative analyses of these accounts to elucidate the effective strategies described. The authors of the analytical chapters were tasked with "immersing themselves" in the accounts provided and with pulling out "a series of defining features to form the basis of recommendations for future practice" (Alsop, Bencze, & Pedretti, 2005, p. 93)

Tobin and Fraser (1987) described a study they conducted to assess exemplary teaching in science and mathematics in Australia. They relied on a nomination process to identify 20 exemplary teachers in Western Australia. Eleven research teams, each consisting of one or two researchers, conducted case studies of all of these teachers. Data were collected via direct observations of at least eight lessons in the classroom settings; via interviews with teachers and students; and through examination of curriculum materials, tests, and examples of student work. The work of these exemplary teachers was in each case contrasted with "comparison" teachers at each school (p. 25).

Capps and Crawford (2013) sought to examine the extent to which science teachers were actually implementing inquiry learning in their classrooms, in contrast to what the teachers stated they were doing. They used written descriptions of lessons, observations in the classroom, and interviews to characterize the targeted science teachers' instructional practices. Teachers were asked to provide descriptions of what they felt was "an exemplary, inquiry-based lesson they taught in the last two years," and semi-structured interviews with a subset of the teachers were conducted to "corroborate our interpretations and gain a greater understanding of the nature of their instructional practice" (Capps & Crawford, 2013, p. 504).

Best Practices in Context

Use of national and state standards to frame teaching practice has become an accepted and expected part of the educational process in the United States and elsewhere. Although the role of standards is not universally praised, nevertheless many would maintain that "standards have been found to drive innovation in education and can engender the implementation of assessments, teacher training, curriculum, and textbooks….[and are] necessary for transforming the ideas offered by subjects such as engineering into effective and relevant instructional practices" (Carr, Bennett, & Strobel, 2012, p. 542). These relationships are illustrated in Figures 1 and 2.

Although standards provide essential frameworks within which subject-area education can be viewed and developed, it's important to note that as they are translated across the levels depicted in Figures 1 and 2 there can be some "errors in translation." Banks and Barlex (2014), for example, contrasted the *specified*, the *enacted,* and the *experienced* curriculum, which align, respectively, with *standards/curriculum, instructional practices,* and *students* in my model. Similarly, Tobin and Fraser (1987) talked about the "intended, implemented, perceived, and achieved curriculum" (p. 30). "It is very difficult to impose a curriculum on teachers, be it from central government or from within a school management structure" (Banks & Barlex, 2014, p. 33), in part because of the translational errors that occur from one level to another, but also because teachers may lack the desire or the capability to enact the specified curriculum. Capps and Crawford, in their comparison of what teachers *felt* they were doing (implementing exemplary inquiry learning) and what the researchers observed, found that "even some of the best teachers…struggle to enact reform-based teaching" (2013, p. 498) in science.

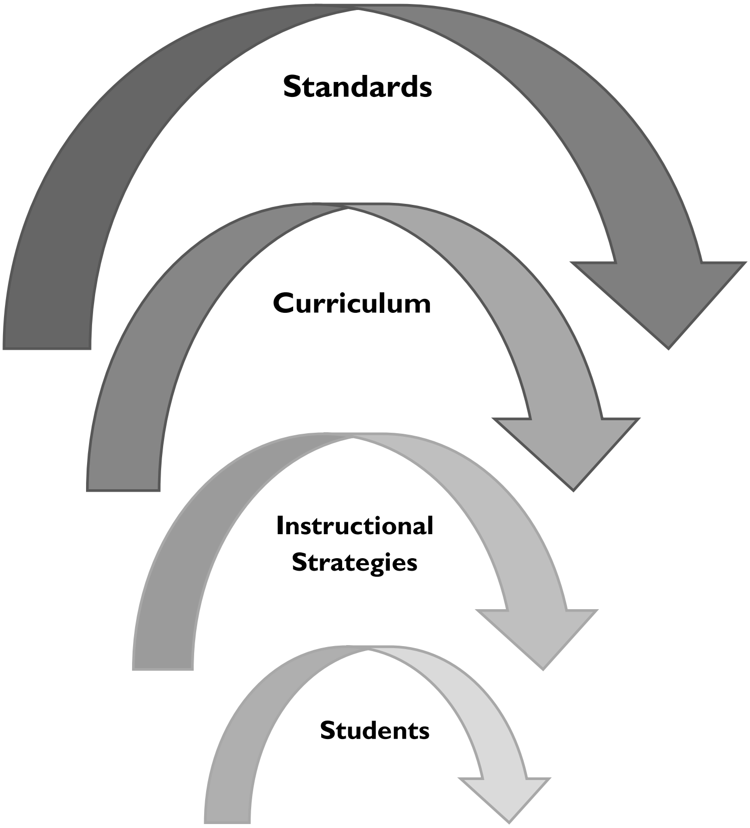

Figure 1. A graphical model of the standards-based education process.

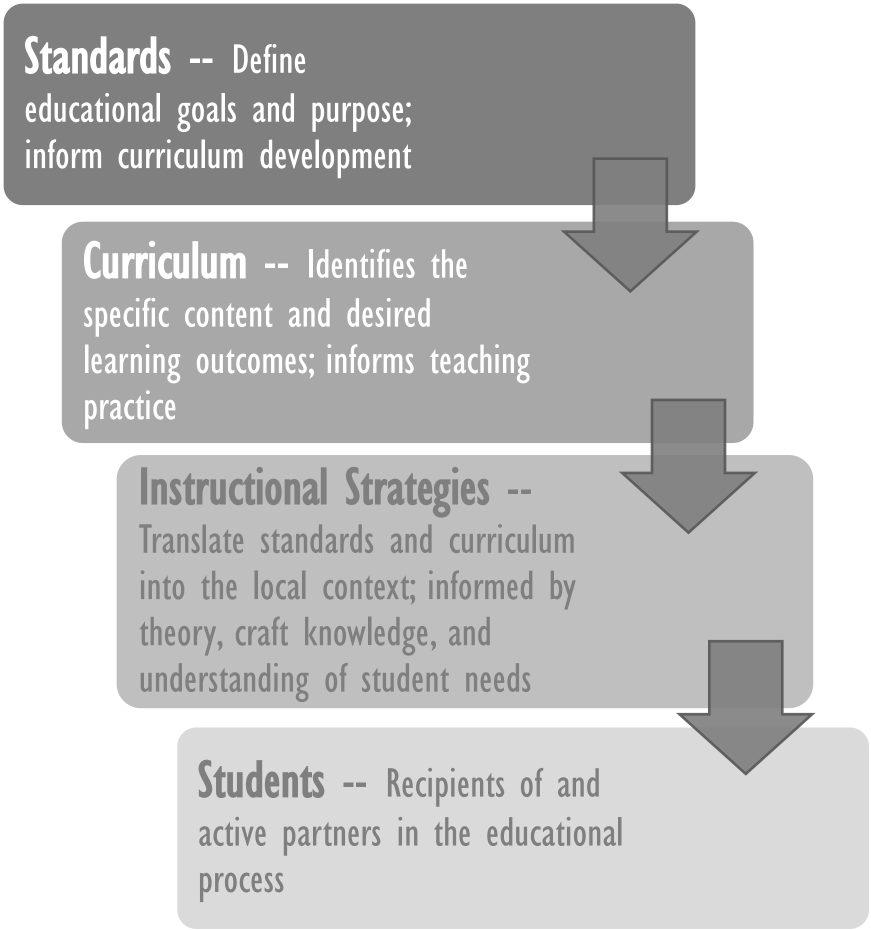

Figure 2. The function of each level within the standards-based education process.

Bybee (2000), contrasting his thinking about implementing standards-based curriculum before and after the release of national standards for science, noted with respect to the *Standards for Technological Literacy* that "although delivering a standards-based curriculum may adhere to educational theory, reform of the technology curriculum will not be [as] simple" (p. 27) as describing the characteristics of curriculum materials and instructional approaches and providing professional development experiences based on those, "because ultimately teachers have the responsibility for establishing and developing the connections between the content of the curriculum and the students' technological understanding and abilities" (p. 26). This touches on the critical role played by the students in this whole enterprise: without their willing participation in the enacted curriculum, the goals of the specified curriculum will not meet their mark; and the curriculum students actually *experience* is dependent on the skills of the teacher, the students' emotional and academic dispositions toward the content, and their ability to understand the curriculum and what is expected of them, among other factors.

Viewing Effective Teaching through the STEM Lens

It would be difficult to overstate the degree to which the acronym STEM has become ubiquitous in the last decade. Unfortunately, many use the acronym in a very ill-informed way: "*STEM* has been used as a conglomerate term, not as an integrative expression…[and] neither a clear and definitive educational purpose nor implications for school programs' instructional practices have been systematically developed" around the term (Bybee, 2013, p. 2). Nevertheless, its broad adoption in the educational lexicon serves to indicate the degree to which it has taken root (irrespective of individuals' rationales for championing STEM education). As such, it is an approach that cannot be ignored, and is instead a force that may be exploited to achieve disciplinary goals within each of the subjects represented.

As noted by Honey, Pearson, and Schweingruber (2014), the most recent standards in mathematics (*Common Core State Standards for Mathematics* [*CCSSM*]) and science (*Next Generation Science Standards* [*NGSS*]) both call for integration strategies that span the STEM fields of study and, in the case of the *NGSS*, they explicitly address technology and engineering. However, echoing the concerns of other proponents (and opponents) of integration, these authors wrote: "One challenge of implementing both the CCSSM and NGSS is to ensure the development of discipline-specific knowledge while also supporting connections across STEM" (p. 110). They further acknowledged that in the process of integration some subjects fare better than others in terms of student acquisition of desired learning outcomes.

T&E in the STEM Era

With respect to integration, Bybee (2013) provided one of the best explorations I have seen of the various perspectives that STEM integration can take, in a chapter titled "What is Your Perspective of STEM Education?" Calls for incorporating T&E into science education date back to at least 1989 and the *Science for All Americans* document, but Bybee has been involved with technology education long enough to recognize more than others in the field of science the challenges T&E face in this relationship, and "actively including technology and engineering in school programs" is the first and most significant challenge (Bybee, 2013, p. 3). Echoing this concern, Banks and Barlex (2014) wrote: "It is essential that the integrity of design & technology be maintained. It is all too easy for the learning intentions to become subverted so that the learning of mathematics or science dominates the proceedings. The simplistic and erroneous definition of technology as 'applied science' can easily lead to situations in which the application of science overrides all other considerations to the detraction of learning in design & technology" (p. 81). However, in their book Banks and Barlex do give a number of good, detailed examples of STEM integration.

Barak (2013) suggested that to overcome the difficulties inherent in adopting a STEM orientation, and in light of recent efforts to replace technology education with technology and engineering education, T&E content, instructional strategies, and assessment tools should be designed "more carefully than in the past, taking into account the cognitive aspects of learning, the types of knowledge we want to teach the students, and how to develop gradually learners' aptitudes to tackle sophisticated scientific-technological problems" (p. 328). Yet, as Rose et al. (2015) noted, "the dynamic nature of the TE content domain makes it difficult to assume where the acceptable range of content competence might lie for a TE teacher striving for excellence" (p. 4). Barak recommended creation of an educational taxonomy for T&E that identifies the type and amount of "factual, procedural and conceptual knowledge" that should be included in the T&E curriculum (p. 325).

Both technology and engineering share the burden of being the sometimes misunderstood elements in the middle of the STEM acronym:

> In contrast to science, mathematics, and even technology education, all of which have established learning standards and a long history in the K–12 curriculum, the teaching of engineering in elementary and secondary schools is still very much a work in progress, and a number of basic questions remain unanswered. How should engineering be taught in grades K–12? What types of instructional materials and curricula are being used? How does engineering education "interact" with other STEM subjects? In particular, how does K–12 engineering instruction incorporate science, technology, and mathematics concepts, and how are these subjects used to provide a context for exploring engineering concepts? (Katehi, Pearson, & Feder, 2009, p. 6)

It would be shortsighted to assume that the alliance between technology and engineering is anything but uneasy or, at the very least, ill-defined. As the tone of some passages within the NAE book illustrates, the engineering community is not ready to declare technology and engineering to be two sides of the same coin (nor, it must be said, are all technology educators ready to do so):

> The review of curricula revealed that technology in K–12 engineering education has primarily been

> used to illustrate the products of engineering and to provide a context for thinking about engineering design. In only a few cases were examples of engineering used to elucidate ideas related to other aspects of technological literacy, such as the nature and history of technology or the cultural, social, economic, and political dimensions of technology development. (Katehi, Pearson, & Feder, 2009, p. 8)

Nevertheless, as will be proposed in a later section of this chapter, compelling arguments can be made for identifying and exploring the commonalities between these two fields, and for entering into a more equal partnership with our comrades in the middle of STEM.

Good Teaching in Any Context

As mentioned earlier, many of the studies of effective teaching include reference to the affective attributes and tendencies of good teachers. In addition, there are some overarching teaching practices that can be fruitfully employed in many K-12 classrooms, regardless of the subject being taught. It is therefore important to provide an overview of these practices and characteristics before diving more specifically into the instructional strategies featured prominently in STEM classrooms.

In their examination of 20 exemplary science teachers in Western Australia, Tobin and Fraser (1987) wrote at length about one specific characteristic of these classrooms, in contrast to the comparison classrooms:

> The exemplary teachers had well-managed classes and were able to concentrate on establishing a productive learning environment. Each exemplary teacher viewed teaching in terms of facilitating student learning. …The striking similarity was in the manner in which the teachers interacted with students. Interactions were not strained, but were

> friendly, relaxed, private and respectful. Humour [*sic*] was used in a subtle and low key manner….The important similarity in the approach to teaching was that teachers created situations where students could identify and act on the instructional cues that were necessary for appropriate engagement. (p. 25)

Alsop (2005) commented on the importance of teachers' subject confidence in effective science teaching and in making science something that students care about and want to engage in. Task engagement on the part of students is shaped in large part by student interest in the learning activities and how useful students perceive the learning tasks to be. Teachers must also identify prerequisite understandings needed to connect ideas within a lesson, and provide "timely scaffolds or frameworks" to facilitate those connections. "Even when students have the necessary background knowledge, this does not ensure that they recognize its relevance" (Taber, 2005, p. 130). Good teachers will also employ a variety of techniques to engage students actively on multiple levels; Przywolnik (2005) described using role-playing and using students as "props" in demonstrating scientific concepts in astronomy, for example. Summarizing a range of other techniques, Wilson and Mant (2011) stated:

> Strategies that actively engage pupils in their learning (for example, discussion, problem solving and practical work) are recognised [*sic*] by pupils as part of an exemplary teacher's repertoire. There is also resonance with the findings of Mant, Wilson and Coates (2007) that giving space for discussion of ideas in science increases engagement and achievement and that pupils appreciate the challenge of more thinking for themselves within science lessons. (p. 124)

Hassard (2005) reported on a meta-analysis of studies that linked STEM instructional methods with increased learning outcomes and the "clustering of broad patterns of behaviors" (p. 29) or "interactive teaching strategies" that effective teachers use:

- Clarity: provides clear and understandable explanations.
- Variety: uses a variety of strategies to reinforce learning, a diversity of questions, and hands-on materials.
- Task orientation: spends more time on content than on classroom procedures.
- On-task behaviors: maximizes the amount of time students spend engaged with materials and activities.
- Success rates: designs learning tasks that lead to high success rates but that are seen as meaningful by students.
- Use of student ideas: acknowledges, summarizes, and applies student comments to instruction, which can lead to increased self-esteem in students.
- Instructional set: helps students to conceptually organize the lesson and its content both before and after the fact.
- Questioning: asks a variety of questions and incorporates sufficient wait time.
- Enthusiasm: shows involvement, excitement, and demonstrated interest in the topic.

From the students' perspective, Wilson and Mant (2011) reported on their findings from a survey of over 5000 12-year old students to gauge their perceptions about science teachers. Among those teachers considered exemplary based on the survey methods used, the following characteristics emerged: Good teachers were said to be "clear explainers," to engage students in discussion and problem solving activities, to incorporate less teacher lecture and demonstration and more work by the students on their own, and to contextualize the science content (p. 124).

Trends and Innovations in STEM Education

Many modern accounts of teaching practice within STEM education include the words "problem-based learning," "inquiry," "problem solving," or "design." These types of approaches are believed to involve students in learning that allows them to think critically, to become more actively engaged, and to construct more enduring understanding of the topics. These approaches are also seen as being inherently interdisciplinary, a key element of good STEM educational experiences (Asghar, Ellington, Rice, Johnson, & Prime, 2012).

Asghar et al. (2012) wrote about a state-funded professional development project in Maryland whose goal was to help teachers and school administrators design and implement STEM academies within their districts. The model they used was problem-based learning and the focus of their research was on "teachers' experiences of professional development for interdisciplinary teaching in STEM" (p. 87). They assumed that math and science teachers, whose preparation is so discipline-specific, "would need focused professional development to equip them to transcend those disciplinary boundaries in order to teach interdisciplinary subject matter" (p. 87). These researchers acknowledged that math and science teachers often lack experience in technology and engineering skills, may have limited experience with problem-based learning, and may face difficulties in managing collaborative problem-based learning and assessment. Affirming the focus on problem-based learning and STEM integration, Honey, Pearson, and Schweingruber (2014) wrote that "engineering design, like problem-based learning (PBL), is associated with a large number of efforts to teach the STEM subjects in an integrated fashion. Science inquiry, engineering design, and PBL share features that can provide students with opportunities to apply STEM concepts and engage in STEM practices in interesting and relevant contexts" (p. 43).

Based on their survey of 49 National Science Foundation Advanced Technological Education (ATE) program awardees whose projects focused on some aspect of K-12 education, Strobel and Mendoza Diaz (2012) characterized the elements of these projects. The primary audiences for the projects represented were students (33%) or teachers (33%), and among the dominant pedagogical models used within these projects "hands-on" learning ranked the highest, at 32%, followed by "project based learning" (30%) and "laboratory practice" (22%). "Guided inquiry" was identified by 18% (p. 13). In their discussion, Strobel and Mendoza Diaz stated: "Pertaining to the issue of pedagogical considerations, it was notable that most ATE project representatives have interest and knowledge in new approaches to technology and engineering education, namely, 'hands-on' activities, project based learning, or even guided inquiry (p. 18).

Through his examination of the STEM literature, Anderson (2010) identified the following characteristics of high quality STEM programs:

1. Programs should broadly address student learning, including core content knowledge and critical thinking skills as defined by the relevant standards from professional organizations such as the International Technology and Engineering Educators Association (ITEA), the International Society for Technology in Education (ISTE), the National Research Council (NRC), the National Council for Teachers of Mathematics (NCTM), and the National Science Teachers Association (NSTA);
2. Programs should address student engagement (by illustrating the value of STEM in students' lives, as well as building interest in STEM fields and encouraging students to pursue STEM-related careers);
3. Programs should have an over-arching STEM "framework" which clearly maps standards for knowledge, skills, and dispositions to curricular activities;
4. Programs should integrate the teaching of all four STEM areas into a "meta-discipline";

5. Programs should ensure that all students have an opportunity to learn the "design" process (a core part of engineering), including "Global Engineering" (a system design process for a geographically distributed environment);
6. Programs should provide opportunities for open-ended "research-based" activities supported by cutting-edge technology;
7. Programs should provide activities that are hands-on, technology-based, applied, holistic, real world, integrative, collaborative, and personalized;
8. Programs should have a strong evaluative component that allows both formative and summative evaluation;
9. Programs should have a strong professional development component for teachers and administrators;
10. Programs should develop partnerships among a broad range of education stakeholders, including schools, businesses, higher education, government, and community, in order to provide authentic mentoring relationships and internships for students. (pp. 2-3)

Not all of these elements relate specifically to the teacher, but this list does serve to highlight and summarize the attributes associated with good STEM education, some of which will be examined more fully in the remainder of this chapter.

The Role of the Teacher as Facilitator

A great number of articles describing effective teaching in technology and other STEM subjects refer to the teacher as a "facilitator." It is helpful to elaborate on what we mean by this term, and Hassard (2005) provides a list of characteristics of the "facilitative science teacher" (p. 372). These teachers have effective classroom management behaviors, including awareness of what is happening in the classroom, ability to effectively handle multiple classroom activities at the same time, ability to make smooth transitions between activities, and ability to maintain momentum within a lesson. They are capable of enabling laboratory and small-group work, including providing for individual accountability, positive interdependence, and development of interpersonal skills among students. Such teachers can also encourage higher-level thinking skills by allowing students to help each other, giving students opportunities to revise their work, providing models of successful work, and implementing review and feedback sessions.

As facilitator, the teacher must provide for meaningful and effective learning situations, but will take more of a side, or what some term a consulting, role. Knowing when to step in to help students is a skill that can be developed with experience. "The amount and extent of intervention necessary is not easy to judge. Too early and too directive an intervention and students will, thereafter, wait for teachers to tell them how to do it. Too late and too vague an intervention and students are likely to give up in exasperation" (Hodson, 2005, p. 102).

Inquiry Learning

Inquiry-based instruction is considered an important teaching strategy in science because it involves students in investigating questions and using data to answer those questions. According to Capps and Crawford (2013), reviews of the literature on science learning "indicated a clear positive trend between inquiry-based instruction and conceptual understanding for students" (p. 498). Yager (2009) emphasized that inquiry is "central" to how practice in science is defined (p. x), and by engaging in inquiry learning students can gain insights into the nature of science, which is seen as an essential part of understanding in science. "For example, students should understand that scientists ask questions, perform different types of investigations, and produce explanations based on their observations…. Abilities to do inquiry include asking and identifying questions, planning and designing experiments, collecting data, using data, and connecting data as evidence with explanations" (Capps & Crawford, 2013, p. 499).

Project-Based Learning

Project-based learning has historically been, and currently remains, a hallmark of instruction within technology education classrooms. Nevertheless, it is also considered a feature of modern STEM classrooms because it emphasizes activities that are interdisciplinary and student-centered. The same can be said about problem-based learning, but there are distinctions between the two:

> The difference between project-based learning and problem-based learning is essentially one of *ownership* of the learning activities. PBL has tended to be a way of configuring the curriculum and relating what students know to actual, real-world problems.… Project-based learning has been more about a pupil choosing an extended activity that [he or she] is interested in and using it as a vehicle for demonstrating current capabilities…. the degree of latitude actually allowed to the pupils to follow their own interests in project-based learning has to be tempered by restraints of available resources and time, classroom management issues…and the ever-pressing need to "cover the syllabus." (Banks & Barlex, 2014, p. 141).

In light of concerns about resources, Banks and Barlex (2014) suggested that project-based approaches be balanced with other types of instructional strategies, such as demonstrations, discussions, and shorter-duration activities. They described, for example, "design-and-make" activities chosen by the teacher to specifically address some aspect of the curriculum and through which students' skills and knowledge base can be progressively built up (p. 143).

Problem-Based Learning

A key characteristic of PBL is that learning is more open-ended, initiated by presenting students with a "problematic situation," followed by activity that is more student-directed and focused on problem solutions or end products that are not specified by the teacher (Asghar et al., 2012). "Hence, in PBL the learners are charged with both defining the problem, developing the solution and identifying the resources to refine their solutions, and the tutor serves as one possible resource to achieve their goals" (p. 95). PBL is considered to be a form of problem-solving, and is "grounded in constructivist pedagogy" (Hill & Smith, 2005, p. 136). Hill and Smith identify recurrent characteristics of PBL: It makes use of "real-life problems" and engages students in "authentic activities" that are interdisciplinary in nature; students work in groups; "learners are encouraged to think critically, creatively and reflectively;" and the faculty who facilitate these learning experiences "guide, probe and support group and individual learning" (Hill & Smith, 2005, p. 137). According to Hill and Smith, PBL "continues to define technology and technology education today and is also proving relevant to science education" (p. 136).

Another typical feature of PBL is that assessment is integrated into the lessons, during which students evaluate their work on an ongoing basis and teachers provide formative feedback (Banks & Barlex, 2014).

Using slightly different language, Hawkins (2014) described "challenge-based learning" (p. 83) activities that she has used with her middle school students in Tennessee. These activities were drawn from a set of "Legacy Cycle" lessons where challenges served as "anchors for learning." In one example, The

"TN River Crisis Challenge" (p. 84), Hawkins' students acted as an emergency response team monitoring and finding solutions for a scenario in which an earthquake threatened dams along the Tennessee River. Hawkins noted that her "struggling" learners "showed the best gains through this kind of scenario-based learning" (p. 86).

Alsop (2005) commented that tasks which incorporate student choice are more relevant in terms of adoption of mastery goals for students. He noted, however, "a delicate balance [must be] struck between self-direction and teacher mentoring" (p. 152). Alsop also acknowledged that what makes something relevant to students differs depending on the learner, but suggested that "situating school science activities within the context of…socio-scientific issues (concerning health and the environment) can serve to increase relevance" to students (p.155).

Other STEM Strategies

Based on these short descriptions of prominent approaches to STEM teaching and learning it should be clear that they are not the only recommended instructional strategies, and how and where they are employed depends on the setting, the learners, and the goals of particular curricular units. This section includes discussion of other recommended strategies for teaching in STEM.

In describing how teachers can "establish a culture of learning" consistent with the theories of Vygotsky, Hassard (2005) identified "talking science, reading science, [and] writing science" (p. 341) as critical. All of these can be considered means to engage students in active learning, and align with the engineering habits of mind described by Katehi, Pearson, and Feder (2009), as well as with the emphasis on understanding the nature of science described by Alsop et al. (2005). In a related vein, various methods can be used for supporting "argumentation" that leads to an understanding of different positions in science. These include role playing, group discussion, and use of writing where students are asked to highlight the pros and cons of issues. All of these can "enable the structuring of knowledge and understanding" (Alsop et al., 2005, p. 112).

Pedretti (2005) wrote about strategies used to teach science from a Science, Technology, Society (STS) approach. These include using historical perspectives to "give science a human face" (p. 118); using real-life "issues" as the basis for learning experiences or as curriculum organizers; use of role-play, as above, to allow students to understand the positions of various stakeholders; bringing in outside experts to provide information about the issue; and providing scaffolding for the information gathering, analysis, discussion, and organization of observations and arguments leading to decision making about the issue at hand.

Within the field of technology education, Herschbach (2009) noted that there has been an important shift toward emphasizing both the technical *and* the intellectual processes "associated with technological activity" (p. 320). "The crucial nexus is between the process functions (both domain and non-domain-specific) and the activity. It is through activity that meaning is achieved" (p. 321). These will be examined in more detail in the final section of this chapter.

Hodson (2005) noted that there is no "simple algorithm" for conducting scientific inquiry, the conduct of which can be "complex, messy, fluid and uncertain." Moreover, the outcomes of work in science (as well as in T&E, it could readily be argued) are dependent on the question under investigation, the context, the level of understanding of the learner, the facilities available in which to do the work, and more. He therefore suggested a type of "apprenticeship" in which students do science "alongside a skilled and experienced practitioner who can provide on-the-job support, criticism and advice" (Hodson, 2005, p. 101). Hodson also noted that in understanding the nature of science it's important for students to understand that science can be biased and culturally influenced; in other words, that scientists are just people, too.

Retrospect and Prospect

Everything Old is New Again

Kelley (2012) provided an excellent essay titled "Voices from the Past: Messages for a STEM Future," in which he examined the historical influences in technology education. "Technology education's longstanding history in problem- and project-based learning, design- and engineering-related pedagogical approach is over a century old and grounded in theories of Comenius, Rousseau, Pestalozzi, Froebel, Herbart, Sheldon, and Dewey" (Kelley, 2012, p. 34). He also detailed our rich history with the use of curriculum integration and the project method—the same types of "innovations" being touted today within STEM education:

> These are several of examples of the history of technology education and engineering that illustrate that both fields are returning to their pedagogical roots by providing practical applications of design and engineering instruction. Although both fields often promote these methods as new innovations, the reality is that these approaches to education are well over a century old. (p. 37)

Kelley noted that "the early roots of technology education are closely intertwined with the development of the American engineering schools" (p. 35), a shared lineage that needs to be reignited today.

One can look to the not-as-distant past to find other examples of the kinds of "contemporary" approaches associated with STEM education today. For example, in *Innovative Programs in Industrial Education* (1970), Cochran described several approaches to teaching industrial arts, among them "The Richmond Plan" (p. 34). Developed and implemented in Richmond, California, The Richmond Plan was a "two-year preengineering [*sic*] technology sequence of four integrated and correlated courses beginning in the eleventh grade" (p. 35). Collectively, these courses provided experiences in English, science (physics and chemistry), math, and "technical laboratories" (p. 35). However, in spite of the commitment to identifying the "natural relationships between the subjects" (p. 35) and clear attempts for collaboration among the teachers involved, Cochran noted "the technical area [was] used primarily for reinforcing [other academic] content and [for] motivating the student" (p. 36).

Donald Maley, in his influential *Maryland Plan,* emphasized that "industrial arts can provide meaningful educational experiences for the integration of subject matter" by adding "reality, concreteness, and relevancy" to the students' work in other classes (Maley, 1973, p. 6). The detailed map of a Grades 7 through 9 curriculum plan included elements that align with the project-based and problem-based approaches considered innovative by STEM educators today. For example, in Grade 9 the plan called for approaches ranging from "contemporary units" and "research and experimentation" to "technical development" projects (p. 124). Highlights of the latter included student selection of the focus of their "problem-project" and in-depth study of the selected topic. In Maley's estimation, such a project would facilitate student engagement and development of independent learning skills, and would "invariably" involve using an interdisciplinary approach to the problem-project (p. 124).

The Need to Strengthen Alliances

After engaging in this review of literature, an important conclusion I reached personally was of the need for technology education and engineering to work collaboratively to establish a larger T&E presence in the K-12 arena. I was therefore delighted to read the following statement from Kelley (2012);

> The author of this article would like to suggest that T and the E should work harder to provide support for one another. Of all the STEM stakeholders who sit at the "STEM table," members of the technology and engineering fields are best positioned to sit the closest;

> as a result, their contribution to K-12 STEM education will be strengthened. (p. 39).

What follow are some further supports for this argument, and some suggestions for how deeper collaboration might be structured.

The National Academy of Engineering (NAE) has perhaps done the most to move K-12 engineering into the limelight. The NAE Standards Committee has recommended integrating engineering into existing standards rather than creating stand-alone engineering content standards (Carr, Bennett, & Strobel, 2012). Nevertheless, a number of groups (including Carr et al.) have worked to identify the "big ideas" that characterize "doing engineering" (Table 1), and movement toward K-12 engineering content standards seems inevitable.

Interestingly, if one overlays lists like the one presented in Table 1 with similar lists of concepts and strategies associated with technology, considerable overlap is apparent. For example, in the list of "intellectual processes of technologists" compiled by Wicklein and Rojewski (1999; see also Hill & Wicklein, 1999), there is overlap with virtually all of the "engineering ideas" identified by Carr et al. (2012).

These common elements show that technology and engineering would not be working at cross purposes to join forces to develop curriculum models, professional development models, and instructional approaches to enhance the overall STEM landscape. In so doing, we could build a broad community of practice that could lead to effective integrated STEM education (Honey, Pearson, & Schweingruber, 2014).

Table 1. *Results of a Cross-State Analysis of Engineering Ideas Being Taught in K-12 Education* (Carr, Bennett, & Strobel, 2012, p. 556)

- Identifying criteria, constraints, and problems
- Evaluating, redesigning and modifying products and models
- Evaluating effectiveness of solutions
- Devising a product or process to solve a problem
- Describing the reasoning of designs and solutions
- Making models, prototypes, and sketches
- Designing products and systems
- Selecting appropriate materials, best solutions, or effective approaches
- Explaining the solution and design factors
- Developing plans, layouts, designs, solutions, and processes
- Creating solutions, prototypes, and graphics
- Communicating the problem, design, or solution
- Proposing solutions and designs
- Defining problems
- Brainstorming solutions, designs, design questions, and plans
- Constructing designs, prototypes, and models
- Applying criteria, constraints, and mathematical models
- Improving solutions or models
- Producing flow charts, system plans, solution designs, blue prints, and production procedures

Implications for Technology and Engineering Teacher Education

The road toward deeper collaboration may not be easy, however. The nine views of STEM education presented by Bybee (2013) is unique in that as a scientist he has so clearly described the prevailing perspectives or approaches to STEM. For example, in their "Vision of Pre-college Engineering Education," Marshall and Berland (2012) presented a typical vision of K-12 engineering education that ignores technology and posits the role of engineering as *the* tool we use to provide contexts for learning math and science. In 2014, the NSTA published *Exemplary STEM Programs* (Yager & Brunkhorst, 2014), in which technology showed up primarily in reference to instructional technologies used to teach science content.

In somewhat blunt fashion, Honey et al. (2014) provided a pragmatic observation of the limited role of technology in STEM: "Although they are in the majority by a wide margin, science and mathematics teachers are not the only teachers of K-12 STEM. Some 45 undergraduate programs in the United State prepare technology teachers" (p. 118). Our biggest challenge may indeed be having enough critical mass (in other words, enough K-12 teachers) to even be present at the metaphorical table of STEM. Recent recruiting initiatives undertaken by the ITEEA as part of its strategic plan may help to address this problem.

Bybee (2013) wrote that context-based STEM education is a challenge because it "emphasizes competency in addressing situations, problems, or issues, and not exclusively knowledge of concepts and processes within the respective STEM disciplines" (p. 3). In an effort to move STEM beyond being a mere "slogan" (p. 4) and into an approach with a clear educational purpose, Bybee recommended a focus on identifying and developing a broader STEM literacy that includes:

- knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM-related issues;
- understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;

- awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and
- willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen. (p. 5)

One of the tasks in achieving this type of STEM education will be to develop innovative models for curricula and teaching. A finding from the Rose et al. (2015) study was that "the traditional role of a TE teacher is narrowing to an implementer of curricula because competencies related to fulfilling roles of curricular developer, curriculum evaluator, and facility developer were not among those competencies judged to be critically important" (p. 18). It's possible this is due to the availability of established models like the ITEEA's *Engineering by Design* curriculum or *Project Lead the Way*, but in any case the path is clear for introduction of new approaches to STEM teaching and learning.

Regarding teacher professional development, both pre-service and in-service, challenges abound for all disciplines within the STEM spectrum to provide the kinds of resources and supports that will lead to exemplary teaching practice. For example, in promoting inquiry learning, Yager asked: "Why do we leave our students with fewer questions after our instruction than before real science experiences begin? Why do we not care more about the fact that students are less curious after instruction than before and have more negative views of science, science careers, and science teachers?" (2009, p. xiv). Capps and Crawford (2013) lamented,

> It was particularly troubling that many of the teachers in this study believed they were teaching science as inquiry even when they were not. This calls into question the impact of reform-based documents like the standards. If some of the best teachers we could recruit failed to demonstrate an understanding of

> inquiry-based instruction and did not teach science as inquiry, then who does?" (p. 523)

In their extended involvement helping Maryland school districts develop STEM education via problem-based learning, Asghar et al. (2012) found that "teachers exhibited resistance to the implementation of our model. Participants explicitly shared their apprehensions and concerns about using STEM approaches in their instructional settings during workshop discussions, individual conversations, and focus group discussions" (p. 103).

One strand of future research in T&E teacher education should focus on doing the kinds of analysis of practice demonstrated by Capps and Crawford (2013). Their detailed observations of both teaching practice and of teachers' reflection on practice could provide necessary information for creation of effective professional development models for T&E teachers.

References

Alsop, S. (2005). Motivational beliefs and classroom contextual factors: Exploring affect in accounts of exemplary practice. In S. Alsop, L. Bencze, & E. Pedretti (Eds.), *Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice* (pp. 146-159). Berkshire, England: Open University Press.

Alsop, S., Bencze, L., & Pedretti, E. (Eds.). (2005). *Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice*. Berkshire, England: Open University Press.

Anderson, D. (2010). *Research brief: S.T.E.M. initiatives.* Union Pacific Foundation: The Principals' Partnership. Retrieved from http://files.eric.ed.gov/fulltext/ED538599.pdf

Asghar, A., Ellington, R. , Rice, E. , Johnson, F. , & Prime, G.M. (2012). Supporting STEM education in secondary science contexts. *Interdisciplinary Journal of Problem-Based*

Learning, 6(2), 85-125. Retrieved from http://dx.doi.org/10.7771/1541-5015.1349

Banks, F., & Barlex, D. (2014). *Teaching STEM in the secondary school.* London: Routledge.

Barak, M. (2013). Teaching engineering and technology: Cognitive, knowledge and problem-solving taxonomies. *Journal of Engineering, Design and Technology*, *11*(3), 316 – 333. doi: 10.1108/JEDT-04-2012-0020

Bybee, R. W. (2000). Achieving technological literacy: A national imperative. *The Technology Teacher*, *60*(1), 23–28.

Bybee, R.W. (2013). *The case for STEM education: Challenges and opportunities*. Arlington, VA: National Science Teachers Association.

Capps, D.K., & Crawford, B.A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education, 24,* 497-526. doi: 10.1007/s10972-012-9314-z

Carr, R.L., Bennett, L.D., & Strobel, J. (2012). Engineering in the K-12 STEM standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education, 101*(3), 539-564.

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

Council of Chief State School Officers (CCSSO). (2013). *InTASC model core teaching standards and learning progressions for teachers 1.0.* Retrieved from http://www.ccsso.org/resources/publications/InTasc_model_core_teaching_standards_and_learning_progressions_for_teachers_10.html

Hassard, J. (2005). *The art of teaching science.* New York, NY: Oxford University Press.

Hawkins, M. (2014). STEM education in the middle school classroom. In R.E. Yager & H. Brunkhorst (Eds.), *Exemplary STEM programs: Designs for success* (pp.77-89).

Alexandria, VA: National Science Teachers Association Press.

Herschbach, D.R. (2009). *Technology education: Foundations and perspectives.* Homewood, IL: American Technical Publishers, Inc.

Hill, A.M., & Smith, H.A. (2005). Problem-based contextualized learning. In S. Alsop, L. Bencze, & E. Pedretti (Eds.), *Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice* (pp. 136-145). Berkshire, England: Open University Press.

Hill, R.B., & Wicklein, R.C. (1999). A factor analysis of primary mental processes for technological problem solving. *Journal of Industrial Teacher Education, 36*(2), 83-100.

Hodson, D. (2005). Challenging traditional views of the nature of science and scientific inquiry. In S. Alsop, L. Bencze, & E. Pedretti (Eds.), *Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice* (pp. 96-105). Berkshire, England: Open University Press.

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integraton in K-12 education: Status, prospects, and an agenda for research.* Washington, DC: National Academies Press.

Katehi, L., Pearson, G., & Feder, M. (2009). The status and nature of K–12 engineering education in the United States. *The Bridge: Linking Engineering and Society, 39*(3), 5-10.

Kelley, T.R. (2012). Voices from the past: Messages for a STEM future. *Journal of Technology Studies, 38*(1), 34-42.

Leinhardt, G. (1990). Capturing craft knowledge in teaching. *Educational Researcher, 19*(2), 18-25.

Maley, D. (1973). *The Maryland plan: The study of industry and technology in the junior high school.* New York, NY: Bruce.

Marshall, J.A., & Berland, L.K. (2012). Developing a vision of pre-college engineering education. *Journal of Pre-College Engineering Education Research, 2*(2), 36-50. doi: 10.5703/1288284314869

Pedretti, E. (2005). STSE education: Principles and practices. In S. Alsop, L. Bencze, & E. Pedretti (Eds.), *Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice* (pp. 116-126). Berkshire, England: Open University Press.

Pryzwolnik, G.A. (2005). Episodes in physics. In S. Alsop, L. Bencze, & E. Pedretti (Eds.), *Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice* (pp. 23-28). Berkshire, England: Open University Press.

Rose, M.A., Shumway, S., Carter, V., & Brown, J. (2015). Identifying characteristics of technology and engineering teachers striving for excellence using a modified Delphi. *Journal of Technology Education, 26*(2), 2-21.

Strobel, J., & Mendoza Diaz, N.V. (2012). Exploration of NSF-ATE approaches in the integration of technology and engineering education at the K-12 levels. *Advances in Engineering Education, 3*(2) 1-23.

Taber, K.S. (2005). Conceptual development. In S. Alsop, L. Bencze, & E. Pedretti (Eds.), *Analysing exemplary science teaching: Theoretical lenses and a spectrum of possibilities for practice* (pp. 127-135). Berkshire, England: Open University Press.

Tobin, K., & Fraser, B.J. (1987). *Exemplary practice in science and mathematics education.* Perth, Australia: Curtin University of Technology Science and Mathematics Education Centre.

Wicklein, R.C., & Jojewski, J.W. (1999). Toward a “unified curriculum framework” for technology education. *Journal of Industrial Teacher Education, 36*(4), 38-56.

Wilson, H., & Mant, J. (2011). What makes an exemplary teacher of science? The pupils' perspective. *School Science Review*, *93*(342), 121-125.

Yager, R.E. (2009). The centrality of inquiry for teaching and learning science. In R.E. Yager (Ed.), *Inquiry: The key to exemplary science* (pp. ix-xiv). Arlington, VA: National Science Teachers Association Press.

Elementary Education: Teaching in an Integrated STEM Program

Chapter 2

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The Dream: Developing Innovators, Educating Creative Learners

The past few years have been an amazing journey for elementary school teacher Melida Reeves. As an integrated STEM teacher at Mount Lebanon Elementary School (MLES) in South Carolina, she has developed an engineering laboratory (lab) in her elementary school. Through this engineering lab she is actively working to get all MLES students hooked on STEM learning.

As Melida reflects back on the first years of the program, she is amazed at the experiences the kindergarten students will have had by the time they reach the sixth grade. Those students will have been exposed to a wide variety of engineering fields, with hands-on experiences in many of these fields. Learning is taking place in the engineering lab because students are given the freedom to make choices and to exercise their creativity; are encouraged to take risks by thinking outside the box; and are provided an environment in which they are exposed to new, engaging experiences.

Melida has found that many students who struggled in the traditional classrooms seem to soar in the engineering lab. In the lab, students have an opportunity to learn through the application of knowledge. Melida has also noticed that many students who are considered gifted in traditional classes actually depend upon teammates who struggle in traditional classroom settings. This does so much for the struggling students' self-esteem that it carries over into other areas of their lives. Students have also begun to recognize they have talents they have never explored previously.

According to plan, learning that takes place in the classroom is reinforced in the engineering lab, but Melida is also discovering that the learning that takes place in the lab is being carried back to other classrooms. Teachers comment they can tell that students are more comfortable verbally discussing and defending their ideas, are more willing to try new methods, and are better able to explain their thinking after spending time in the engineering lab. Students are also using lessons they learned through exploration in the lab to help students in their other classes.

This chapter outlines MLES's journey in K-6 STEM integration and describes one teacher's experiences in creating and teaching in an elementary engineering lab.

The Setting: Mount Lebanon Elementary School

Mount Lebanon Elementary School (MLES) is located in a rural setting in historic Pendleton, South Carolina. MLES has an enrollment of 445 students and is part of Anderson School District Four, which has a total enrollment of 2880 students. The school district is comprised of four elementary schools, one middle school, and one high school. Anderson School District Four serves just over 1620 pre-kindergarten to grade 6 elementary students and includes an average of three teachers per grade level (Anderson School District, 2014a).

Several years ago, district leaders determined that every school in the district should pursue a "signature" learning experience, and the faculty at MLES determined that their initiative would be integrated STEM education. After the MLES faculty decided to explore integrated STEM as a school-wide signature learning experience, key faculty members and school administrators formed a STEM leadership team. The STEM leadership team began researching STEM education, participated in a STEM professional development workshop, and completed a number of site visits to other elementary schools in North and South Carolina where STEM had become a focus.

The MLES STEM Leadership Committee also began conducting research and investigations into problem-based learning methods, performance-based assessment procedures and grading methods, math curricula that would support the effort, the engineering design process, and technology integration (beyond just normal use of computer-based technology in the classroom). The MLES STEM Leadership Committee and sub-committees worked for more than a year to gather extensive information and to discuss their findings. The committees regularly reported back to the entire school faculty during the year before implementation. Eventually, the entire MLES faculty embraced the signature learning experience of integrated STEM education and became determined to be the best STEM elementary school possible. The school principal was open-minded and encouraged broad faculty input into the model that was eventually implemented.

This research effort by MLES resulted in a consensus decision by the faculty to increase class sizes in fourth grade to allow one fourth grade teacher to assume the role of "engineering lab teacher." That decision was made because an engineering lab allowed students to have unique experiences using the engineering design process while reinforcing STEM standards being delivered in all classes, and having a designated lab teacher facilitated these experiences. The faculty also decided not to use the district-adopted math series but to use *Everyday Mathematics®* instead, because they believed this approach would provide a better fit with integrated STEM and hands-on problem/project-based learning, and that it would promote the use of multiple teaching methods. In addition, the faculty decided to become a standards-based grading school, which has now become a district-wide initiative.

Soon after the curriculum approaches were determined an engineering lab teacher was chosen, and she began to develop the engineering lab. The MLES engineering lab was designed to serve all 494 students in kindergarten through sixth grade. All students participate in engineering lab classes as part of their related-arts block of instruction. This schedule was made possible by combining the school media center and computer lab as one related-arts block called informational technology. Although the schedules have been adapted several times since implementation, the overall concept has not changed. While in the engineering lab, students learn about different engineering careers and complete projects using an engineering design process centered on *The Next Generation Science Standards* (NGSS Lead States, 2013) and the *Standards for Technological Literacy* (International Technology Education Association [ITEA], 2000). The engineering lab teacher is responsible for meeting with classroom teachers to make certain the activities in the engineering lab reinforce STEM concepts and standards being delivered in the traditional K-6 classrooms, while also integrating literature and writing. The engineering lab engages students in increasingly sophisticated levels of problem-based and team-based learning, and requires students to step outside of their comfort zones and realize that they can get satisfactory results by taking different paths.

During the first year of enactment, MLES implemented one major integrated STEM unit at each grade level. The engineering lab teacher participated in a hands-on elementary STEM professional development workshop during the summer prior to the implementation of the program at MLES, and then used her newfound skills to work closely with the grade-level teachers to plan STEM units that were integrated throughout the school, and not just in the engineering lab. Teachers at most grade levels learned quickly that there were opportunities to integrate many additional STEM concepts and standards beyond those targeted within the grade-level units. Faculty throughout the school were impressed with the engagement level of the students and were very pleased to learn that the students retained STEM content information long after the units were completed. Because of this, most grade-level teachers worked together to incorporate a second or third integrated STEM unit into their curriculum within the first year.

The Engineering Lab Teacher: *Her Journey*

Melida Reeves is the engineering lab teacher and STEM facilitator at MLES. In that role she not only delivers STEM content to every student at the elementary school, but she also spends one day each week working with the other grade-level teachers to develop and analyze their STEM lesson plan ideas. Because integrated STEM education is not just about units or projects, she assists the other teachers at MLES in finding ways to incorporate more problem-centered, hands-on learning and inquiry-based learning experiences in their everyday lesson plans. As the STEM facilitator, she encourages other grade-level teachers to search for new and innovative integrated STEM units. Melida counsels the teachers to try new ideas and to develop units that are student-driven and teacher-supported. Through these efforts, she is able to enhance the integration of technology and use of the engineering design process in all classrooms. The engineering design process has quickly become the basis for most new units of instruction developed in the school—even in mathematics and literacy units. A narrative-based curriculum model has been used extensively in the curriculum overhaul, which allows for the incorporation of literature into integrated

STEM lessons and connects design challenges to literature-based content garnered from informational texts.

Melida is driven by a statement attributed to 19th century English scholar John Lubbock. Lubbock said, "The important thing is not so much that every child should be taught, as that every child should be given the wish to learn." Melida believes that teachers should strive to instill the wish to learn in all children they have the privilege to teach. She also believes integrated STEM education is an extremely valuable tool for instilling that wish to learn. Melida's journey to being named the Teacher of the Year at MLES, as well as the Anderson School District Teacher of the Year, in 2013, was not direct or traditional. Although she had a desire to be an elementary teacher from an early age, her adventurous nature convinced her to put off teaching and pursue a degree in criminal justice during college.

After working several years at the Anderson County Sheriff's Office, Melida was promoted to school resource officer. While working as a school resource officer, she had a chance to teach a few classes and interact with students of all ages. This experience reminded her of an earlier dream and she decided to "follow my heart and become a teacher." She completed a bachelor's degree in elementary education and accepted an elementary teaching position. After teaching first and third grades for five years, she attended a summer elementary *Integrated STEM Education* workshop at Clemson University and Tri-County Technical College. Based on this experience, Melida became captivated with the thought of teaching STEM at the elementary school level. This led to her assuming the engineering lab teacher position at MLES in 2012. She has since completed a master's degree in education and is currently completing a Ph.D. in educational leadership.

Melida's beliefs about students are simple and truthful: All children can and want to learn. They will do so easily if they feel valued and loved in a classroom. The teacher/student relationship must be built on trust and respect; once established, students will meet and exceed the teacher's expectations.

According to Melida, "Students want to please their teachers, so teachers should set expectations very high and students will reach them!" The one philosophical approach that undergirds all of Melida's lessons is the understanding that concepts *discovered by* students are much more likely to be remembered than things they are simply told.

Highlights: The Integrated STEM Program

The overarching goal of the integrated STEM project at MLES is to become a school where visitors easily witness engaged learning in every classroom, driven by student inquiry, high-level use of technology, and increased creative thinking that leads to high-performing students with exceptional STEM problem-solving skills. In just two years, MLES has made steady progress toward achieving this overarching goal. Grade-level teachers are developing and using more problem-based learning strategies, engineering design is present throughout lessons across the school, and student-driven instruction is the norm. Some examples of integrated STEM units include projects related to robotics, forces and motion, simple machines, bridge design, structural testing, pneumatics, computer programming, and many others. Teachers are using more technology in their classrooms, ranging from instructional technologies to programming to problem-solving applications. Although the inception of the integrated STEM project at MLES was only three years ago, teachers and administrators indicate that, as a rule, students are more open to taking risks and thinking creatively than they were before the journey began.

In the engineering lab, a new approach to mathematics instruction and an emphasis on using the engineering design methodology have transformed common classroom expectations, allowing students to move outside of their comfort zones. Instead of the traditional pattern in which teachers deliver information and students are expected to repeat that information on a test before moving on, students have been encouraged to try multiple strategies/routes to create their own solutions. Grade-level teachers and students have come to realize that not getting the "correct" answer can be a learning experience rather than a sign of failure. Now, an incorrect answer is seen as a conversation generator that causes teachers and students alike to ask questions like, "Why did it happen?" "What could we have done differently?" "How did ____ affect the outcome?" These conversations begin among kindergarten students and teachers and continue through sixth grade.

By using the engineering design process methodology, teachers continually remind students that there is a "modify" step in the design process that allows them to go back and change something, which may result in a different outcome. The engineering design process is also reflected in the standards-based grading policy at the school. Students are now more willing to take risks while completing lessons and activities because they know they will not be penalized for not getting it "right" the first time, or for taking a different route than others to reach the destination. Creative thinking is valued and praised, which encourages all students to seek opportunities to be innovative.

Reflections from an Integrated STEM Teacher

Melida readily acknowledges that her professional development in STEM has been somewhat limited. Her opportunity to serve as the engineering lab teacher and STEM coordinator for MLES resulted from her participating in summer *Integrated STEM Education* workshops and engineering camps sponsored by Clemson University and Tri-County Technical College over the course of several summers. These opportunities provided her with a chance to serve as a "translator" for engineers volunteering their time in the engineering lab. This translation helped make the material more relevant to, and more easily understood by, young learners and their teachers. She was also fortunate to have an exceptional working relationship with the Clemson and Tri-County faculty who provided knowledge and support for the effort. However, it was her belief in use of a problem-based learning model and the engineering design process as change agents that led to substantial changes in the way students at MLES learn and engage in integrated STEM education.

Discussion

Melida attributes much of the success of the STEM program at MLES to the power of teaching through an integrated STEM approach. Integrated instruction is defined as any program in which there is an *explicit assimilation* of concepts from more than one discipline (Satchwell & Loepp, 2002). Likewise, integrated STEM programs apply equal attention to the standards and objectives of two or more of the STEM fields (Laboy-Rush, 2007). Laboy-Rush noted that although there are myriad ways that schools and teachers can approach improving math and science education, often educators address the topics in silos, separate from any other subjects. When teachers expose students early to opportunities to learn math and science in interactive environments that develop communication and collaboration skills, students are more confident and competent in these subjects (Laboy-Rush, 2007).

Stohlman, Moore, and Roehrig (2012) explained STEM integration as the combination of STEM disciplinary content into one unit of instruction or lesson where the connections between the subjects and/or content are highlighted through real-world problem-solving situations. However, the authors were quick to point out that integrated STEM teaching and learning can also involve multiple classes and teachers. By integrating the disciplines, teachers are free to highlight important content and big ideas from the STEM disciplines, as well as from other associated disciplines (e.g., English language arts) where they naturally occur, providing a natural flow to the lesson. Stohlman et al. suggested that one of the primary benefits of integrated STEM is that many of the practices associated with the disciplines of science, technology, engineering, and mathematics lend themselves naturally to integrated concept delivery. This natural integration allows the teacher to focus on what Wiggins and McTighe (2005) called "enduring understandings," or big ideas that are connected or interrelated between subjects, rather than isolated facts from single disciplines. Supporting this assertion, Furner and Kumar (2007) noted that research seems to illustrate that using an integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners.

The National Academy of Engineering (NAE), in collaboration with the National Research Council (NRC), issued a report titled *STEM Integration in K-12 Education* (2014), in which they stated that the goals of integrated STEM education for students are STEM literacy, development of 21st century competencies, STEM workforce readiness, student interest and engagement, and the ability to make connections among STEM disciplines (p. 33). By launching the integrated STEM education program at the kindergarten level at MLES, faculty are able to address these goals by building confidence and interest in STEM among students at an early age. This awareness is nurtured through problem-centered learning experiences where students must learn to work as members of a team, gather research and content information, be inventive and innovative, make choices between competing factors, and defend decisions made during the learning experience. The NAE/NRC report noted that:

> It is important to provide learning opportunities that make students feel competent and give them opportunities to express that competence. Learning experiences that allow flexibility and choice for students and that make connections to the real-world are also important. Project- and problem-based experiences seem to be especially effective in supporting the development of interest and identity, suggesting that integrated STEM experiences can be

> powerful tools for building students' interest and identity in STEM fields. In sum, integrated STEM can provide opportunities for students to productively engage in STEM in ways that spark their interest and transform their identity. (National Academy of Engineering [NAE] & National Research Council [NRC], 2014, p. 97)

In nearly every model of effective STEM integration, the goal and intent is to provide students with the opportunity to construct new knowledge and problem-solving skills through the process of designing artifacts (Fortus, Krajcikb, Dershimerb, Marx, & Mamlok-Naamand, 2005). They accomplish this through a series of open-ended, hands-on activities related to a thematic or standards-based topic that addresses important concepts related to the STEM disciplines (Satchwell & Loepp, 2002). Central to this process is involving students in developing and optimizing solutions for real-world problems. Problem- or project-based learning (PPBL) experiences can increase student interest in STEM subject matter because they are authentic and because students can relate to the content while designing solutions to engaging problems (Fortus, et al., 2005). Through PPBL, learners achieve a deeper understanding of lessons as they investigate and attempt to solve real-world problems. Part of this approach's appeal is its ability to impact students of all ages—kindergarten students can collaborate on and explore problems just the same as high school students.

In its most current form, PPBL is most widely representative of teaching methods first utilized in medical education (Walker & Leary, 2009). It is characterized by learning where students are given more control over their own learning; are asked to work in groups; and, most importantly, are acquiring new knowledge as a necessary step in solving authentic, ill-structured, and interdisciplinary problems representative of professional practice (Barrows, 2002). Slight changes and adaptations have been made to PPBL by educators in an effort to reflect their teaching needs and the instructional needs of their respective disciplines. With that qualification in mind, and borrowing heavily from Barrows as one of the initial proponents of PPBL, several consistent characteristics can be generated as essential components of PPBL (Walker & Leary, 2009):

- Ill-structured problems are presented as unresolved so that students will generate not just multiple thoughts about the cause of the problem, but multiple thoughts about how to solve it (Barrows, 2002). Such problems may not have a single correct answer and should engage students in the exploration of multiple potential solutions (Hmelo-Silver & Barrows, 2006).
- PPBL utilizes a student-centered approach in which students determine at least a part of what they need to know in order to solve the problem. It is up to the learners to derive the key issues of the problems they face, define their knowledge gaps, and pursue and acquire the missing knowledge (Barrows, 2002; Hmelo-Silver & Barrows, 2006).
- Teachers act more like facilitators or tutors than didactic teachers in the learning process. These tutors prompt students with meta-cognitive questions and in subsequent sessions fade that guidance (Barrows, 2002). Tutors forgo lecturing about content in favor of modeling the kinds of learning processes that lead to success in PPBL settings (Hmelo-Silver & Barrows, 2006).
- Authenticity forms the basis of problem selection, guided by alignment to real world situations, or situations with which the student can easily connect (Barrows, 2002). This authenticity leads to inherently interdisciplinary investigations and requires students to review content and concepts from multiple disciplines (Barrows, 1996) to generate a viable and defendable solution.

PPBL is a particularly useful instructional tool for young students because small children naturally engage in problem solving during informal learning experiences and during play-time activities. Fortus et al. (2005) noted that children use the tools and materials available to adapt the environment to meet their needs, and that the ability to solve problems comes naturally to most children. PPBL is grounded in constructivist theory and has been shown to improve student achievement in higher-level cognitive tasks, such as scientific and mathematic problem solving (Satchwell & Loepp, 2002). PPBL is delivered at MLES through engaging the students in various authentic integrated STEM challenges using ill-structured, open-ended problems inspired from the community, local industry, and the home lives of students. Some examples of these locally-developed design challenges include:

- **Slow as Can Be Marble Track** – Teams of students were asked to design and build a slow-moving marble track. The dimensions and the angle of board were controlled. This challenge allowed the students to incorporate force and motion from the 3rd grade technology and science standards.
- **Drain Baby Drain** – Teams of students were asked to design a system that would allow proper drainage of the playground (water standing for days is a problem on the playground). After discussing the issue with a local landscaper and an engineer, the teams designed systems that would allow for proper drainage of the water.
- **Teach an Old Monkey a New Trick** – Teams of students were asked to modify a previous Lego build. After constructing a drumming monkey, students were asked to modify the build and re-write the programming to "teach" the monkey a new trick. This activity incorporated the design process as well as programming knowledge to modify the program.

- **The Solar System** – Teams of students were asked to design and construct a revolving solar system using recycled materials. This challenge incorporated the design process as well as 4th grade science and technology standards on solar system and electricity.

A prescriptive engineering design loop is used as a heuristic to guide student teams as they progress through individual STEM challenges. The design loop promotes effective inquiry and the systematic, iterative interaction between divergent and convergent questioning in the problem solving process (Walker & Leary, 2009). As a fairly prescriptive learning tool, the engineering design loop is crafted to augment students' abilities to confront complex problems and to reach optimal solutions. Although the human mind tends to begin considering potential solutions almost as soon as a problem is detected, the engineering design loop allows the designer to apply idea-generating strategies (e.g., problem clarification, brainstorming, and so on) in productive ways (Hutchinson, 2002). The engineering design loop also forces the designer to consider multiple solutions to a given problem before evaluating and then choosing an idea to move forward. From this "ideation" phase, the designer begins to plan the execution of the idea, works out technical details, and marshals the resources (i.e., sketches, diagrams, lists, etc.) needed to realize the envisioned solution (Hutchinson, 2002). Finally, models and prototypes are made which are tested, refined, and superseded by more finished versions until the solution is completed and tested. Publicly presenting the solution and subjecting it to open critique may expose problems missed by the designer. These processes are essential when design is employed as a learning strategy (Hutchinson, 2002). The engineering design loop developed and utilized at MLES is illustrated in Figure 1.

Figure 1. The design loop developed and utilized at MLES.

The ill-structured STEM problems used to deliver much of the content at MLES are derived from a careful review of the appropriate national standards, including the *Standards for Technological Literacy* (ITEA, 2000), *The Next Generation Science Standards* (NGSS Lead States, 2013), and selected English language arts and mathematics standards from the *Common Core State Standards Initiative* (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). It should be noted that South Carolina has not adopted either the *NGSS* or the *CCSS*, but MLES has drawn content identifiers from both sets of standards. The *Standards for Technological Literacy (STL)* and the *NGSS* have been particularly useful for the faculty at MLES because both include a sincere focus on engineering design, problem solving, gathering and analyzing pertinent data, developing solutions to societal problems, and developing and communicating solutions to given problems.

These three sets of standards also provide opportunities for teachers to make integrated connections between content areas that encourage students to draw potential solutions to given problems from various historically distinct disciplinary areas. While the *NGSS* and the *STL* provide the context for many of the engineering design problems, the *CCSS* provide the framework for addressing literacy, both oral and written. Literacy is supported through the reading and writing of informational text associated with the STEM problem under consideration, and through the oral communication of ideas and solutions. The *NGSS*, *STL*, and *CCSS* work in concert to allow students to understand how all STEM disciplines are related and how content knowledge is interconnected and builds from one discipline to another (NGSS Lead States, 2013).

MLES currently uses standards-based grading school-wide, and the success of this form of assessment resulted in it becoming a district-wide initiative. Standards-based grading or assessment is rooted in outcome-based learning tied directly with performance and content standards. The increasingly dominant implementation of the *NGSS* and *CCSS*, coupled with their targeted competencies, can be seamlessly applied to this type of grading system. According to the Anderson School District Four *Standards-Based Reporting Guide for Elementary Teachers*:

> The purpose of standards-based reporting is to communicate what students should know and be able to do. It is intended to inform parents and guardians about learning success and to guide improvements when needed.
>
> Standards-based education focuses on what a student knows, not how long it took to get there. Reporting provides separate feedback on effort and achievement. It gives students the practice they need and more than one opportunity to demonstrate success—if they need it. Each student's work is measured against the standard, not other students' performance. (Anderson School District, 2014b, p. 2)

The primary goal of standards-based grading is to create a more objective system of assessment in which students' grades are reflective of the degree to which they have met learning standards (Clark & Clark, 2014). Marzano (2000, 2010, 2011) was quick to point out that current grading practices are imprecise and that it is essential that teachers reevaluate how they assess students.

Marzano (2010) promoted the practice of monitoring a student's learning progression using a scale from 0 – 4, in which a 0 indicates "Even with help, no success;" 1 indicates "With help, partial success at a score of 2.0 or higher;" 2 indicates "simpler content;" 3 indicates "Target learning goal;" and 4 indicates "More complex content" (pp. 44-45). He contended that using standards-based grading promotes quality feedback to students about learning goals and progress through formative assessment; offers an accurate reflection between classroom grades and standardized test scores; and, most importantly, encourages student achievement (Marzano, 2011). In addition, Marzano suggested that a standards-based grading system should jettison cumulative grading practices, and instead provide students with multiple opportunities to be reevaluated on their demonstration of learning progressions. Melida strongly supports this type of assessment because it is naturally aligned with student design projects that may span the length of the semester or school year.

Melida is also supportive of the *Everyday Mathematics®* curriculum that MLES has elected to use instead of the district-wide mathematics program. *Everyday Mathematics®* is a preK-6 mathematics program designed by the University of Chicago's School Mathematics Program and is focused on developing conceptual understandings, repeated exposure for long-term learning, frequent practice of basic computation skills, and building proficiency through multiple methods (The Center for Elementary Mathematics and Science Education, 2014). The program is currently used by 4.3 million students in 220,000 classrooms in the United States.

The faculty at MLES believe that *Everyday Mathematics®* is naturally suited for project-based instruction due to its foundation on constructivist learning theory. In a constructivist mathematics classroom, both teachers and students are seen as "meaning-makers" who work together to solve problems through an active cooperative learning process (Grady, Watkins, & Montalvo, 2012). Teacher perspectives on constructivist approaches to teaching mathematics vary, and although these types of approaches may encourage mathematical thinking, they may also hinder some students in their development of basic math skills that may be better nourished in a traditional skill-and-drill mathematics environment (Vlantis, 2011).

According to the United States Department of Education's What Works Clearinghouse (2010), the *Everyday Mathematics®* curriculum combines "real-life problem solving, student communication of mathematical thinking, and appropriate use of technology" (p. 1). The What Works Clearinghouse review of the program found *Everyday Mathematics®* may serve as a catalyst for improving mathematical achievement in elementary schools through the program's practice of integrating multiple teaching strategies and its emphasis on collaborative learning.

Another key feature in the MLES engineering lab is that Melida encourages her students to take risks in their approach to solving problems. Pankove and Kogan (1967) suggested that there is a distinct connection between creativity and the act of taking risks in the classroom. However, many classrooms do not consistently provide students with opportunities to challenge themselves (Tomlinson & Javius, 2012). In a risk-taking mindset the teacher plays a key role in creating a stimulating learning environment in which students are comfortable to take academic risks in learning and creating, and this can be both an essential part of developing interest in content and intrinsically motivating to students to be lifelong learners (Mahn & John-Steiner, 2002). Mahn and John-Steiner referred to this as giving students the "gift of confidence" through the act of "emotional scaffolding." They recommended that teachers facilitate an environment in which there is "the sharing of risks in the presentation of new ideas, constructive criticism, and the creation of a safety zone" (p. 58). Beghetto (2009) referred to taking risks in a classroom setting as intellectual risk taking (IRT), and defined IRT as "engaging in adaptive learning behaviors (sharing tentative ideas, asking questions, attempting to do and learn new things) that place the learner at risk of making mistakes or appearing less competent than others" (p. 210). Providing students with comfortable learning situations in which they can engage in IRT tasks may very well promote social and cognitive development (Vygotsky, 1978; Bandura, 1986). This is precisely what Melida and the faculty at MLES are trying to realize in their fervent practice of integrated STEM education.

Conclusion

STEM education is, by now, familiar to educators and parents across the country. Without STEM knowledge, students will not be well prepared to enter college or the workforce. Innovative STEM programs such as the one at MLES stand as exemplars for elementary schools nationwide. Engaging students at the elementary level in problem/project-based learning through the integration of STEM content may have lifelong divergent effects including empowerment and enthusiasm in STEM subjects, the ability to transfer learning, and authentic technological literacy. The design of constructivist learning environments can motivate students to work together, take risks, and approach content through hands-on inquiry-based practices. The multi-faceted role of the engineering lab teacher as a teacher, curriculum planner, and professional development leader is a novel approach that could be easily replicated in elementary schools and teacher preparation programs across the country.

References

Anderson School District. (2014a). *District profile.* Retrieved from http://mles.anderson4.org/modules/cms/pages.phtml?pageid=119323&sessionid=c96acd86340b89ea21521b99cc7e7da6&sessionid=c96acd86340b89ea21521b99cc7e7da6

Anderson School District. (2014b). *Standards-based reporting guide for elementary teachers*. Pendleton, SC: Author.

Bandura, A. (1986). *Social foundations of thought and action*. Englewood Cliffs, NJ: Prentice Hall.

Barrows, H. S. (2002). Is it truly possible to have such a thing as dPBL? *Distance Education, 23*(1), 119-122.

Beghetto, R.A. (2009). Correlates of intellectual risk taking in elementary school science. *Journal of Research in Science Teaching, 46*(2), 210-223.

Clark, F., & Clark, E. (2014, April). Effective grading for Common Core State Standards. *National Council of Teachers of Mathematics Conference*, New Orleans, LA. Retrieved from http://nctm.confex.com/nctm/2014AM/webprogram/Session22221.html

The Center for Elementary Mathematics and Science Education. (2014). *Everyday Mathematics*. Retrieved from http://everydaymath.uchicago.edu/

Fortus, D., Krajcikb, J., Dershimerb, R. C., Marx, R. W., & Mamlok-Naamand, R. (2005). Design-based science and real-world problem solving. *International Journal of Science Education, 27*(7), 855–879.

Grady, M., Watkins, S., and Montalvo, G. (2012). The effect of constructivist mathematics on achievement in rural schools. *Rural Educator, 33*(3), 37-46.

Hutchinson, P. (2002). Children designing & engineering: Contextual learning units in primary design and technology. *Journal of Industrial Teacher Education 39*(3). Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v39n3/hutchinson.html.

Laboy-Rush, D. (2007). Integrated STEM education through project-based learning. *Learning.com*. Retrieved from http://www.rondout.k12.ny.us/common/pages/DisplayFile.aspx?itemId=16466975

Hmelo-Silver, C. E., & Barrows, H. S. (2006). Goals and strategies of a problem-based learning facilitator. *The Interdisciplinary Journal of Problem-based Learning, 1*(1), 21-39.

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

Mahn, H., & John-Steiner, V. (2002). The gift of confidence. In G. Claxton & G. Wells (Eds.), *Learning for Life in the 21st Century* (pp. 46-58). Oxford: Blackwell.

Marzano, R. J., (2000). *Transforming classroom grading.* Alexandria, VA: ASCD.

Marzano, R. J. (2010). *Formative assessment and standards-based grading*. Bloomington, IN: Marzano Research Laboratory.

Marzano, R. J., (2011). Grades that show what students know. *Educational Leadership, 69*(3), 34-39.

National Academy of Engineering and National Research Council. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: The National Academies Press.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards*. Washington, DC: Authors.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Pankove, E. & Kogan, N. (1968). Creative ability and risk-taking in elementary school children. *Journal of Personality, 36*(3), 420-439.

Satchwell, R., & Loepp, F. L. (2002). Designing and implementing an integrated mathematics, science, and technology curriculum for the middle school. *Journal of Industrial Teacher*

Education, 39*(3)*, *41-66.* Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v39n3/ satchwell.html

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER): 2(1)*. Retrieved from http://dx.doi.org/10.5703/1288284314653

Tomlinson, C., & McTighe, J. (2006). *Integrating differentiated instruction and understanding by design.* Alexandria, VA: ASCD.

Vlantis, T. J. (2011) *Teachers' perspectives on the Everyday Mathematics program*. (Doctoral dissertation, Hofstra University). Retrieved from http://gradworks.umi.com/34/82/3482496.html

Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Walker, A. & Leary, H. (2009). A problem based learning meta-analysis: Differences across problem types, implementation types, disciplines, and assessment levels. *Interdisciplinary Journal of Problem-based Learning 3*(1), 12-41.

What Works Clearinghouse (2007). *WWC intervention report: Everyday mathematics.* Washington, DC: U.S. Department of Education, Institute of Education Sciences.

What Works Clearinghouse (2010). *WWC intervention report: Everyday mathematics.* Washington, DC: U.S. Department of Education, Institute of Education Sciences.

Wiggins, G., & McTighe, J. (2005). *Understanding by design* (2nd ed.). Alexandria, VA: ASCD.

Teaching Elementary School STEM in Thailand

Chapter 3

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Welcome to Thailand! Located in Southeast Asia and in the tropics, it is home to more than 66 million people and is often called the "Land of Smiles" because of its friendly and good-natured people who always seem to be smiling, no matter what the situation.

One of the greatest assets a country can have is an educated workforce made up of people who can sustain themselves, participate in decisions that impact their well-being, and work together to help improve the country's economic and living conditions; Thailand is no exception to this rule. It has a well-organized school system of kindergartens, primary, lower secondary and upper secondary schools, numerous vocational colleges, and universities. Education is compulsory up to and including age 14, and the government provides free education through age 17.

Thailand is part of the Association of Southeast Asian Nations (ASEAN), a geo-political and economic organization of ten countries (i.e., Indonesia, Malaysia, the Philippines, Singapore, Thailand, Brunei, Burma [Myanmar], Cambodia, Laos, and Vietnam) in Southeast Asia (Association of Southeast Asian Nations, n.d.). In 2015, the ASEAN Economic Community (AEC) came together to transform ASEAN into a single market and production base. Important to this transformation is improving science, technology, engineering, and mathematics (STEM) education across ASEAN (Glasson & Klechaya 2013; Reeve, 2013). For example, in discussing issues about the Thai workforce, Science and Technology Minister Pichet Durongkaveroj noted that "science, technology, engineering and maths (STEM) education was crucial for Thailand's workforce to achieve the government's target of a 4% annual growth rate for industrial and labour productivity" (Wong-Anan, 2015, para. 7).

STEM education in Thailand is an emerging area and there are efforts to bring STEM into the Thai education system. These efforts are being led by Thailand's Institute for the Promotion of Teaching Science and Technology (IPST), a government organization involved in promoting STEM education and working to develop STEM education centers, standards, and curricula. However, Thailand does already have at least one outstanding STEM program at the elementary level, thanks to the pioneering efforts of "Teacher Becky," who is responsible for starting the first elementary STEM program in Thailand.

Anubanchonburi Elementary School

Teacher Becky, as she is called by her students and colleagues in Thailand, teaches in English in the 1st grade at the Anubanchonburi Elementary School. Located in Thailand's Chonburi Province, this Thai government school is the largest in the province with approximately 3,500 students, 200 Thai teachers, and 65 foreign teachers for students in kindergarten through grade 6. The school offers three programs: (1) Bilingual STEM Program (18 hours per week in English); (2) Junior English Program (11 hours; includes Science, Math, and Health in addition to English); and (3) a Regular Program (3 hours of English only). Each classroom has 35-40 students.

The STEM education program began in 2011 and each year since then has gotten bigger. Today the program is known throughout the local region and nationally. The program started small and has continued to flourish each year. The school allocates one computer with Internet access and an overhead projector to each of its 18 STEM classrooms. The program also has developed a dedicated STEM classroom. The room is available for all teachers in the school to use and is equipped with teaching materials and an engineering work space for projects, as well as a fully equipped science lab with a digital microscope.

Teacher Becky!

Teacher Becky (a.k.a. Rebecca Petersen) has a passion for teaching. She began teaching at Anubanchonburi Elementary School in 2011 in the English Program (EP). She has a bachelor's degree in elementary education and a Master of Arts degree in Elementary Education: Curriculum & Instruction, both obtained from the University of Northern Iowa. She is an exceptional elementary teacher, manager, and trainer with more than 10 years' teaching experience in Thailand. Her primary expertise is initiating and managing STEM programs in elementary schools for English Language Learners (ELLs), and conducting teacher action research.

Rebecca Petersen's journey to becoming an educator was very different from most, but now that she's working as a teacher, she has accomplished more than she ever could have thought possible. Rebecca knew at a young age that teaching was her calling, but external circumstances caused her to drop out of University of Northern Iowa's elementary education teaching program twice. After eventually graduating, she found herself not working in teaching, but as a quality analyst/paralegal for a Fortune 500 company. Rebecca found this life to be reasonably satisfying, until the events of September 11, 2001 (9/11).

When 9/11 happened, she remembers looking at the images on TV and looking up at the sky and not seeing or hearing a single plane, and she was frightened. She was frightened because she did not know why things were happening; she felt ignorant and ashamed of not knowing about the world she lived in. At that moment she also thought, if she did not know, there were also probably a lot of children in the world who did not know what was happening (and more importantly *why*), but who should. It was at this moment she knew she had to go back into teaching. She felt peace was a possibility if she could help primary students learn the importance of being an empathetic global citizen in a sustainable, connected world.

After 9/11, Teacher Becky set off on a whirlwind adventure, traveling to more than 45 countries before deciding to settle in Thailand in 2005, where she began teaching elementary school in the government school system under Thailand's Ministry of Education (MOE). From 2005 until 2010 she taught 1st grade at Anubanphanatsuksalai School. After receiving her Master's degree in 2010, she moved to the Anubanchonburi School because the Director at the school where she was teaching got promoted and recruited her to come to his new school (i.e., Anubanchonburi School) to lead his team of foreign teachers.

Rebecca credits several faculty members at the University of Northern Iowa with helping her to discover herself as a global educator. These educators/mentors were interested in her career and pushed her to do her best. She still stays in contact with her former professors, often asking them for advice and guidance (Wakeman, 2014).

Rebecca's Philosophy of Teaching

Teacher Becky's philosophy is simple: she strives to make learning practical for real-life situations, simple, and fun, with students' interests at the forefront. Her lesson ideas are grounded in systems thinking. She believes the teaching environment should cater to guiding students toward what to do when they do not understand something, supporting curiosity as the driving force of innovation, and encouraging collaboration in a democratic setting. She is a high energy, dynamic teacher who pushes her students to do their best and challenges them to think, often outside the box, to make learning exciting every day. She has been known to dye her hair in bright colors that, besides making her stand out in a crowd, helps to promote the children's creativity. Her goal is to encourage critical thinking and to develop students' self-efficacy, and the mindset that they can do anything (Dweck, 2000).

In Becky's classroom, students often drive the instruction through their curiosity about the world around them. She uses this curiosity and incorporates it into her STEM lessons and activities. She believes in student-centered learning that requires students to take an active role in their learning and teachers to become facilitators of knowledge. She also uses project-based learning activities that require students to apply STEM principles to solve open-ended problems. For example, one morning a student came to class with a broken leg and was using crutches. The class all watched in pity as the injured student struggled to enter the classroom. Teacher Becky threw out that period's planned lesson and improvised on the spot. She broke the students into small groups to discuss, design, and then present their innovative ideas of what they could make and/or do to help the injured student perform the expected daily tasks more easily. They then set out to execute the agreed-upon ideas.

Becky also believes in using social media to strengthen the home/school/community relationships; a crucial component, she feels, of bilingual communities. With the help of simple online tools such as Google Translate, students, parents, Thai teachers and the extended Thai community can stay informed about STEM activities happening in the school. For example, she keeps an active Facebook page that helps students and parents stay updated and informed, and she has been involved in posting videos through outlets such as YouTube that show how STEM is being practiced in the school (see her YouTube page https://www.youtube.com/user/BeckyThailand to find several videos highlighting the school and its programs, including the following: https://www.youtube.com/watch?v=L9Gc1fVvcyI).

STEM Education in Thailand

Teacher Becky believes she is responsible for starting one of the first STEM programs in Thailand. She learned about STEM through her educational readings and thought, "this is good stuff, and I need to be doing this with my students," and so her STEM journey began. She started to search the literature about how to integrate STEM into elementary education and she identified STEM activities that would work in Thailand. She found activities and started trying them out in a Thai context. She incorporated STEM education everywhere in her classroom, which she then proceeded to spread throughout the school campus.

Becky found that her Thai students really liked the hands-on STEM activities, because they contrasted significantly with the traditional sit/listen/write-only atmosphere of many Thai traditional classrooms. Although not Becky's first priority, English language acquisition began to rise, which made parents particularly pleased. Her Master's research posited that Thai students' English literacy is developed at an increased rate when instruction is based on STEM inquiry practices that encourage dual language communication in a democratic, multicultural, collaborative, community of learners setting (Petersen, 2013). Other teachers in the school and region also saw the excitement and the increase in student motivation that the STEM activities generated. Because of this, she became the school's STEM manager and started giving teacher trainings to show how to do STEM. Becky noted "within just a two-year period, we were acknowledged by Thailand's Ministry of Education as having the first dedicated STEM program in the country—elementary, high school or university!"

Teacher Becky has developed STEM curriculum materials that help guide the activities that students complete in her classroom. At a young age, children are very curious about the world around them and this almost always includes areas in STEM, which makes it a natural fit for learning at this age.

In the classroom, Teacher Becky provides hands-on STEM activities that she has primarily obtained through searching the Internet. She adapts these activities into a Thai context and often develops (with the help of a Thai teacher who is always present in the classroom) a presentation that covers the topic and activity in both Thai and English. In addition, for all STEM activities, she requires students to keep a bilingual "STEM journal" that documents their learning. One of her lessons was entitled "How strong is an egg?" with the objective of indirectly teaching seven-year olds how geometric domes distribute the weight of a heavy load. Her lesson began with tapping into her students' prior knowledge by showing brief video clips of dome buildings in Asia. Then she used inquiry-based instruction by asking the students what they thought they were going to learn about that morning, based on the video and the fact that there were 250 eggs next to her. Students' interest and curiosity were piqued; now it was time to head to the Lab.

Because all of her students use English as a second language, Teacher Becky values that knowing the key vocabulary and instructional words in the students' native language is crucial in order for them to reach their zones of proximal development (Vygotsky, 1978). Therefore, once in the Lab, a bilingual PowerPoint is shown with a brief question and answer session with the Thai co-teacher. When interacting with her students, Teacher Becky's sense of humor is easily understood because her dialogue is enriched with her understanding of Thai culture (e.g., her jokes about Thai chicken trucks are only understood if you live in her community). She expresses that connecting with her students via *their* current understanding of the world is necessary for STEM education to have its fullest effect. She is adamant about not wanting to use textbooks in English from abroad because of this overlooked aspect of cultural relevance.

Teacher Becky is also helping to promote STEM in Thailand and the ASEAN region for another main reason: her 10 years' experience working with STEM education specifically for English language learners has carved out a specialized niche for her. She is a sought-after speaker in Thailand and often shares what she calls her "STEM Journey" at national and international educational conferences in Thailand. For example, in 2014 at the International Science, Mathematics and Technology Education Conference (ISMTEC) in Thailand, she served as a special presenter and conducted a workshop on "Designing Planet Rovers: An Introduction to STEM for Lower Elementary Teachers" (International Science, Mathematics and Technology Education Conference [ISMTEC], 2014). In addition, she initiated a project where her school was the first elementary school in Thailand to partner with another ASEAN country (the Philippines) to serve as a student teacher placement site.

Discussion

Today, many Americans take short-term trips abroad to learn about the diverse world in which we live. Often these travelers are young people (such as recent college graduates) who want a "break" to explore the world before taking on their future careers. On these short-term trips, many become bitten by the travel bug and come home wanting to do more internationally. Teaching English abroad for a year or two is one way to achieve this goal (Bentley, 2013) and many choose this route and then return home. Teacher Becky is an exception to this rule, because she has made a long-term commitment to living abroad and to bringing STEM education to the elementary grades in the Kingdom of Thailand.

She is an exemplary teacher in the classroom and an innovator in trying to change the educational culture of a country by introducing STEM education at the elementary school level. Her journey to becoming an elementary STEM educator began as she learned more about STEM, including how it can be integrated into an existing curriculum and school framework. She accomplished this in part by simply renaming the timetable of the school day. Instead of different periods for Math, Grammar, Reading, Science, Health, etc., she changed all her teaching periods to "STEM." She used Thailand's Ministry of Education (MOE) existing curriculum indicators as a checklist; once an objective was taught and assessed, she crossed it off her list. This was her "evidence" that she not only had the available time to teach above and beyond and add things such as engineering projects, field trips, guest speakers, and parent volunteer days, but also how easily concepts connected to one another across the disciplines. For example, she completed an integrated two-week unit on the story "The Three Little Pigs" (reading, grammar, conversation, phonics). They studied about weather and wind, and how natural disasters like cyclones in Asia can affect people's lives, their environment, and ultimately the economy (science, social studies). They had a parent volunteer day (community involvement) where they went to their school's mini theater to watch a documentary about tornadoes. At this event, students were given a set amount of play money to purchase their movie ticket and food items (math, supply & demand, real-life scenarios). They had to make choices between inexpensive healthy foods and expensive unhealthy items (health, marketing, self-discipline). The unit concluded with them using the design process, applying what they learned about the properties of recycled materials (science), to create toy houses that had to stand still in a fan set to highest speed (engineering, internet technology used to research existing toy house ideas). The school's Director, students, parents and Thai teachers were quickly realizing just how important STEM education was to their children's futures, beyond just learning in English (Petersen, 2013). Becky's thinking is consistent with research that discusses how integrative approaches to teaching and learning improve students' interest and advancement in STEM learning skills (Barcelona, 2014).

However, her journey to becoming an elementary STEM educator in Thailand was not always easy, especially in a country where traditional teaching methods (e.g., rote memorization and teacher-centered instruction) are still much the norm. Teaching as a foreigner in another country was another hurdle she faced.

Teaching abroad is not always easy for Americans, because they face challenges related to language, culture, residency, teaching credentials, and more (U.S. Department of Education, n.d.). As a foreigner (often referred to as a *Farang* by the Thais), she had to persuade and convince school administrators, and even other teachers at her school, that teaching hands-on STEM is important because it may help to improve student motivation and student learning. This was accomplished by continually showing in her own instruction how the concepts of STEM are connected.

As an exemplary STEM teacher, Becky had to change the school culture. To do this, she first incorporated STEM within her own classroom. She invited her colleagues to observe in her classroom what STEM education is and how it is practiced. She showed the importance of being culturally relevant by including the Thai co-teacher throughout the entire period. She holds monthly professional development sessions to discuss best practices related to teaching STEM, several times calling in other STEM specialists so she can expand her knowledge base as well. Because Teacher Becky is a foreigner in Thailand—an outsider—she is sensitive to the language barrier and cultural nuances constantly present. In the early stages of her STEM journey she called upon IPST and coordinated a STEM hands-on training day for Thai teachers, given entirely in the Thai language. This helped Thai teachers understand that STEM was a Thai initiative as well as a western one.

Her successes converted other teachers, both Thai and foreign, in the school to join her STEM journey. This helped support her campaign for a dedicated STEM education workroom. Teacher Becky recognized the advantages of creating new learning environments atypical of today's classrooms. With so many engineering projects based on STEM, they needed space not only for the large amounts of recycled materials used, but a place where students could work collaboratively on their projects on an ongoing basis. A dedicated STEM workroom would be a more relaxed space for the students (and teachers!) to work in a more suitable real-life context to develop communication, collaboration, community, and critical thinking skills (Partnership for 21st Century Skills, n.d.), more so than knowledge dispensing. Other teachers could also go to the workroom for STEM materials and/or to have a working space to conduct their weekly grade level meetings, at which the English, Math/Science, Engineering, Computer, Health and Music teachers collaborate once a week to brainstorm connections across the disciplines. The Director quickly saw the results of such collaboration and granted space for the STEM education room. Becky feels the world's future challenges will require groups of multicultural and multilingual individuals who can peacefully work together to discover new knowledge and apply it to solving unforeseen global problems.

This important element of collaboration endures throughout Teacher Becky's journey. She continues to organize her school's in-school monthly professional development program to share STEM project ideas among the other 60+ foreign teachers. Her colleagues' excitement for developing STEM expanded into school-wide initiatives. For example, the Director of her school recently approved the design and building of a hydroponics area. The effort will be a 100% student-led initiative. Teacher Becky also became known in the region for her innovative teaching and perseverance, and she began to share ideas with other teachers in the region and beyond through local and national professional development workshops.

In addition to providing professional development to teachers in Thailand, Teacher Becky keeps informed and up-to-date by attending and presenting at both local and international STEM education conferences, and she stays professionally involved. For example, she is a member of the International Technology and Engineering Educators Association (ITEEA), National Science Teachers Association (NSTA), and National Council of Teachers of Mathematics (NCTM), and often uses their materials for guidance. During her last summer break, she attended a STEM conference in Ohio. She met professors from Fukai University in Japan who were doing research regarding the benefits of STEM problem-based instruction for English language learners. Teacher Becky attended their STEM conference in March 2016. In addition, she continually searches the Internet for activities and experiences in STEM that she can adapt to her program. The Director of her school recently announced that STEM would be extended to the first and second grades of the Junior Program in academic year 2016 (totaling approximately 35 classrooms with 35-40 students each). Teacher Becky has shown that one person can make a difference. In her case, it was bringing the first elementary STEM education program to Thailand. Teacher Becky has a passion for teaching and is committed to preparing the next generation of Thai students for the role that STEM education has in their lives.

References

Barcelona, K. (2104). 21st Century curriculum change initiative: A focus on STEM education as an integrated approach to teaching and learning. *American Journal of Educational Research*, *2*(10), 862-875. doi:10.12691/education-2-10-4. Retrieved from http://pubs.sciepub.com/education/2/10/4

Bentley, J. (2013). *10 reasons why teaching English abroad is the next step*. Retrieved from http://www.studyabroad.com/articles/10-reasons-why-teaching-english-abroad-is-the-next-step.aspx#ixzz3TimTMBBf

Dweck, C. (2000). *Self-theories: Their role in motivation, personality, and development.* New York: Taylor & Francis Group.

Glasson, G. E., & Klechaya, R. (2013). *Place-based STEM education in ASEAN countries*. Retrieved from https://www.eng.vt.edu/sites/default/files/pageattachments/place-basedstemeducationinaseancountries.pdf

International Science, Mathematics and Technology Education Conference [ISMTEC]. (2014). *Designing planet rovers: An* *introduction to STEM for lower elementary teachers*. Retrieved from http://www.ismtec.in.th/ismtec2014/index.php/pr-mrs-rebecca-petersen

Partnership for 21st Century Skills (n.d.). Retrieved from http://www.p21.org/

Petersen, R. (2013). *The effects of STEM inquiry practices on English language acquisition in a first grade classroom in Thailand.* Cedar Falls, Iowa: University of Northern Iowa Digital Collections. Retrieved from http://cdm15897.contentdm.oclc.org/cdm/singleitem/collection/mast/id/233

Reeve, E. M. (2013). *Implementing science, technology, mathematics, and engineering (STEM) education in Thailand and in ASEAN*. A report prepared for the Institute for the Promotion of Teaching Science and Technology (IPST). Retrieved from http://dpstapply.ipst.ac.th/specialproject/images/IPST_Global/document/Implementing%20STEM%20in%20ASEAN%20%20-%20IPST%20May%207%202013%20-%20Final.pdf

U.S. Department of Education. (n.d.). *Teaching overseas: Primary and secondary levels.* Retrieved from https://www2.ed.gov/about/offices/list/ous/international/usnei/international/edlite-overseas-primsec.html

Wakeman, N. (2014, September 12). *Spreading STEM throughout the world*. Retrieved from http://www.uni.edu/resources/features/spreading-stem-throughout-world

Wong-Anan, N. (2015, July 7). Worker squeeze eases as local economy slows. *Bangkok Post.* Retrieved from: http://www.bangkokpost.com/print/614892

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

An Exemplary Middle School Designerly Technology and Engineering Education Program: The Perfect Storm

Chapter 4

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An Exemplary Middle School Designerly Technology and Engineering Education Program: The Perfect Storm

In late October of 1991 three large weather systems collided in the North Atlantic Ocean off the east coast of the United States and Canada. Cold air from the northern regions of Canada had slipped down onto the northern states of the U.S. and was moving eastward over New England. This weather front eventually collided with a huge high-pressure system that had built up over southeast Canada. The third element of this storm came from Hurricane Grace, which had started near Bermuda and was moving up along the east coast of the United States. Instead of making landfall, as had been expected, Hurricane Grace swung toward the east and out to sea where she joined up with the other two weather systems. The convergence of the added energy of Hurricane Grace and the combined atmospheric pressures of the other two weather systems resulted in the creation of what National Weather Service meteorologist Robert Case called "the perfect storm" (NOAA News Online, 2000, para. 4). The writer Sebastian Junger would pick up on that phrase in an interview with Case and use it as the title for his best-selling book *The Perfect Storm* (1997), which described, among other things, the fatal consequences of the storm on the crew of the swordfish boat the *Andrea Gail*. Since the release of the book, and the subsequent movie in 2000, the term "the perfect storm" has become a part of the language "used to describe situations characterized by powerful converging forces" (Anderson, 2013, para. 1). Such converging forces are often destructive, as was the case with the storm of October 1991, but they can sometimes lead to powerfully positive outcomes.

This chapter will tell the story of one exemplary designerly middle school technology and engineering education program that represents a perfect storm of technology and engineering education through the convergence of powerful, positive forces. They include the personal experiences, education, and characteristics of the teacher; the support of his supervisor, administrators, colleagues, and community; his dynamic use of design as a teaching and learning strategy; and the importance of physical space and place and the role of the program's location within the school building.

All stories have a preface or back-story, which sets the stage. This story is no exception. The teacher and the program that will be discussed did not appear out of a vacuum. That is why, before going into the details of his program, I will briefly describe the context of designerly technology and engineering education.

A Brief History of Designerly Technology and Engineering Education

Cross (1982) referred to the design-oriented approach to investigating, interacting with, and developing the technological world as "designerly ways of knowing" (p. 223). His justifications for including designerly ways of knowing into the core of general education were based on the following aspects of how "designers work and think" (p. 226):

Designers tackle "ill-defined" problems.

- Their mode of problem-solving is "solution-focused."
- Their mode of thinking is "constructive."

- They use "codes" that translate abstract requirements into concrete objects.
- They use these codes to both "read" and "write" in "objective languages."

From these ways of knowing [Cross] drew three main areas of justification for design in general education:

- Design develops innate abilities in solving real-world, ill-defined problems.
- Design sustains cognitive development in the concrete/iconic modes of cognition.
- Design offers opportunities for development of a wide range of abilities in nonverbal thought and communication. (Cross, 1982, p. 226)

In the United States there have been examples throughout the history of manual arts, industrial arts, technology education, and technology and engineering education of programs and strategies of instruction that have used the designerly ways of knowing as defined by Cross. Perhaps one of the most significant early examples of an overt designerly approach occurred with the influence of the Arts and Crafts Movement of the late 19th and early 20th century (Bennett, 1937; Herschbach, 2009; Lewis & Zuga, 2005; Warner, 2011). Other designerly curricular efforts would continue to appear over the course of the 20th century including, but not limited to, efforts by Dewey, Bonser, and Mossman in the 1930s, Wilber and Osburn in the 1940s, Micheels and Sommers in the 1950s, Lindbeck and Scobey in the 1960s, and Maley in the 1970s (Warner, 2011). Through the 1980s and 1990s the influence of what was then called the *Craft, Design, and Technology* (CDT) program of Great Britain, as well as other similar educational programs from other countries around the world, would begin to be seen in the curricula and the supporting activities that were being used in the United States (Hutchinson, 1987). With the release of *Standards for Technological Literacy* (*SfTL;* International Technology Education Association [ITEA], 2000) the importance of design as a fundamental tool in the study of technology became undeniable (Lewis & Zuga, 2005; Warner, 2011). The increasing awareness by educators, especially young educators, of the importance of design, and the designerly ways of knowing which can be inferred from the *SfTL,* is enhanced by the fact that the technology and engineering education teacher preparation programs in the U.S. have been emphasizing that their students learn to teach toward the standards put forth in *SfTL* (Litowitz, 2014; O'Brien, Karsnitz, Van Der Sandt, Bottomley, & Parry, 2014). As a result of design placing such a large footprint on the conceptual framework of *SfTL,* nearly a generation of young teachers has been exposed to and has learned to use designerly ways of thinking and doing as a primary tool for teaching with and about technology. These historical building blocks have set the stage for today's technology and engineering educators, including the young teacher who is the focus of this chapter, to actively use the designerly approach to teaching about the human made world.

The Teacher

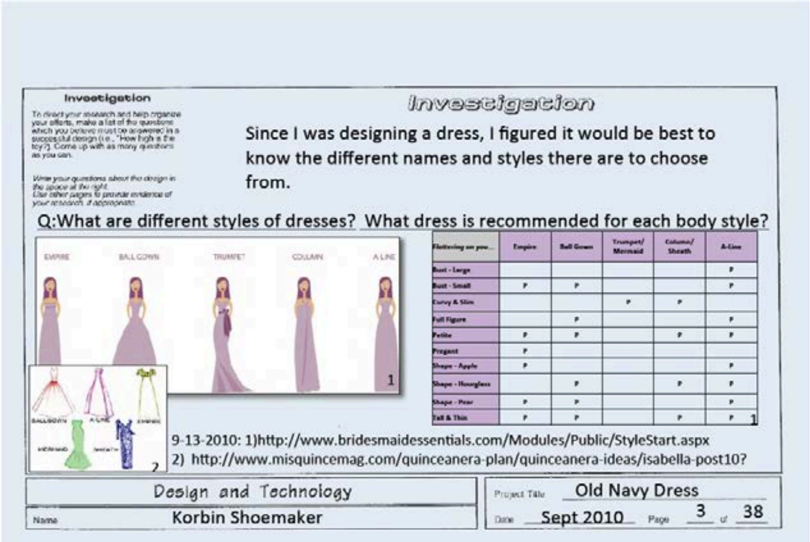
The first and perhaps most important factor toward the success of any educational program is the teacher. The technology and engineering education teacher described in this chapter is Mr. Korbin Shoemaker, who is one of the teachers at Walkersville Middle School in the Frederick County Public Schools of Maryland. Just as Hurricane Grace added additional strength to the perfect storm, Korbin's spirit, determination, and designerly frame of mind would bring new insight and educational vigor to his program.

I first met Korbin Shoemaker when he was an undergraduate student in one of the courses I teach at Millersville University. That first course was an introductory-level class on communication and information technology. Korbin did well in that class and in the other courses he took in our program, but where he really excelled was in another course I teach called

Product Design. I knew when he gave his first design presentation and later when he turned in his process portfolio that he was a natural design thinker. The first assignment I had Korbin's class do that semester was to design and make a full size paper pattern of a dress that would be sold by Old Navy to a typical 12-year-old American girl for the fall season of 2011. My expectations for this first assignment were that students would become familiar with the processes of design, learn how to organize their thinking about the design, document their research and the design work that they did for the challenge, and generally get comfortable with how to approach a design challenge. To help the class have a common reference toward how to organize their work I ask students to use the design portfolio format developed by Hutchinson and Karsnitz to accompany the book *Design and Problem Solving in Technology* (1994).

On the due date, all students give to their peers a short four-to-five minute long presentation. They are instructed to treat their presentation as though they are in front of a group of buyers from a client, in this case Old Navy, and to tell the story of their design efforts. Korbin's presentation quickly stood out. His portfolio had at least twice as many pages as the rest of the submissions. The level of detail and depth of investigation were superior (see Figure 1). I have students submit a minimum of four design options with any challenge. Korbin supplied six options. Each was drawn with precision and clarity of intent (see Figure 2). Korbin's portfolio was designerly, not only in its overall professionalism, but in how it easily met all of the criteria identified by Cross (1982).

Later that term Korbin's skills as a leader were displayed as he worked within a group of his peers to develop solutions to increasingly complex design challenges. His abilities as a teacher with a flair for designerly ways of knowing were already evident and being put to use with his peers.



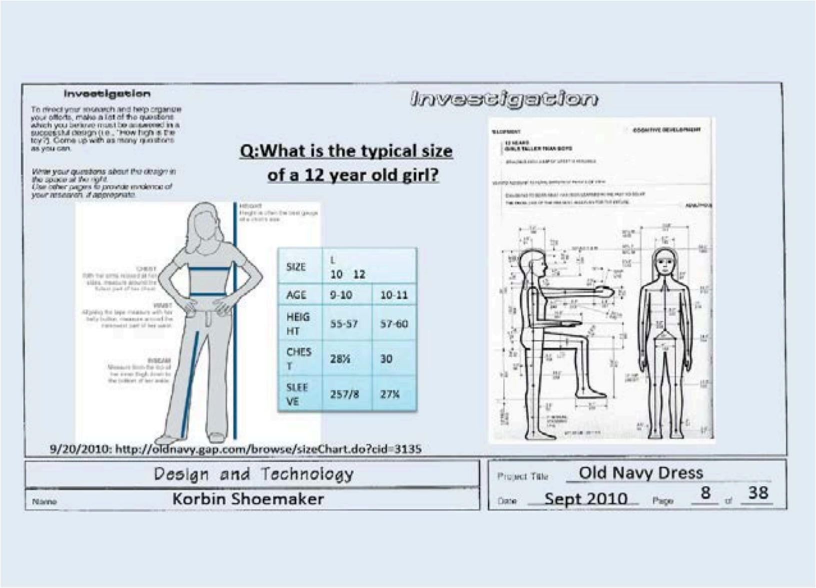


Figure 1. Sample pages from the investigation section of Korbin's first design portfolio.

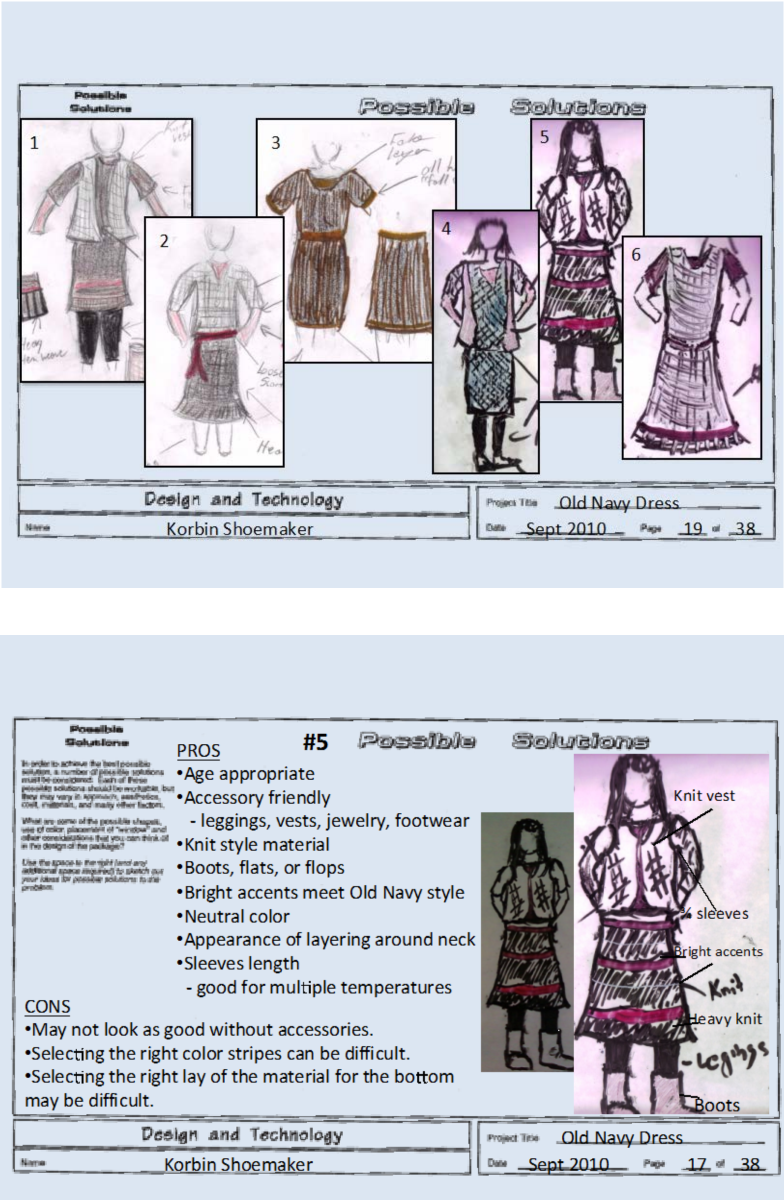


Figure 2. Design options presented in Korbin's first design portfolio along with the detailed design that was ultimately selected.

When Korbin student taught he was assigned to a program that had a very supportive cooperating teacher. Working within the existing curriculum of a more traditional manufacturing course, Korbin developed a designerly unit of instruction that enabled students to make their own design decisions toward the creation of the artifact, in this case wrought iron scroll style shelf supports. Korbin's unit of instruction contained all of the basic elements of a design-oriented lesson, including a story that set the context for the lesson, the challenge (design brief), specifications, investigation expectations for students, requirements for a minimum of three possible solutions, modeling, function testing, evaluation, and production (see Figure 3).

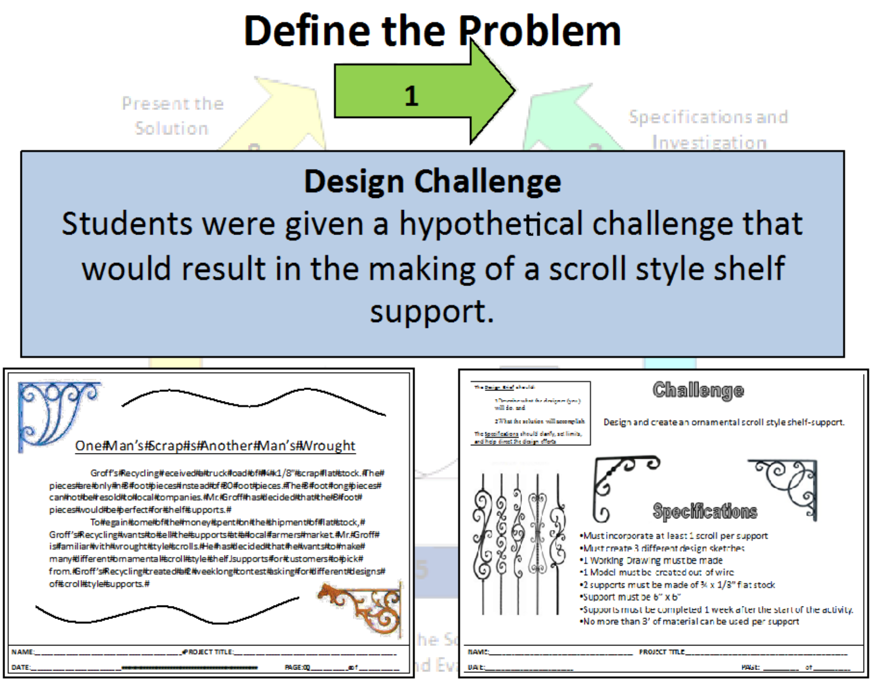


Figure 3. The first two pages of Korbin's student teaching unit of instruction using traditional metal working materials and tools as the focus of the student's designerly work.

Korbin's interest and abilities toward the designerly approach to teaching technology and engineering education were further encouraged during his graduate school experiences at Ball State University. One such experience involved a course that examined the development of creative thinking. The course made him aware of how much technology and engineering education experiences are, by their very nature, capable of developing and facilitating the creative spark. Graduate school also provided him with a range of experiences including working with professors as a graduate assistant, doing research, interacting with fellow graduate students, and working with other professionals in the field that enabled him to further evolve into what Schön (1983) referred to as the reflective practitioner.

His History with Design Thinking

Since his graduation from Millersville University I have maintained communication with Korbin, including several occasions when we spoke about the nature of his designerly frame of mind. In my first formal interview with Korbin I asked him, "What gave you the impetus to excel with design thinking?" His response was that he really got started with design-oriented thinking through his high school agriculture courses where, as he described it:

> The Ag teacher was very open. You had to submit plans. If they were approved then he would give you the materials. You went from start to finish. There were [technical] mini-lessons in the [project] so when you wanted to weld you were taught to weld, when you needed to braze you were taught to braze within those projects. I had this Ag teacher's classes for two years and they were probably the main reason I chose to become a tech ed teacher. (personal communication, June 6, 2014)

When asked how he learned to organize his design process Korbin related how his high school teacher had used questioning as a means to have each student, or groups of students, mentally plan what they were going to make and how they were going to go about making the project. The teacher's questioning created dialogue with the student about opportunities for learning the technical processes as a part of the project. This approach also enabled the students to come up with the initial idea, develop the plans, make the decisions about the materials and processes to be used, and execute those choices largely on their own under the guidance of the teacher. On reflection, Korbin recognized the importance of the amount of autonomy his teacher allowed and how that autonomy shaped his experiences in those agriculture classes and toward his approach to teaching technology and engineering education. In that same interview, Korbin further stated that learning to create a design portfolio for the Product Design course simply formalized the thinking processes he had learned to do in high school. The experiences in the Product Design course provided him with a number of designerly understandings from a teacher's perspective. They included how a process portfolio helps students organize design-based projects, how such a portfolio helps students represent their learning to others, and how to create a process portfolio so as to help students organize and document their work. These understandings were all fundamental to his success as a student teacher and later as a designerly teacher at Walkersville Middle School.

His Personal Characteristics

The dispositions of a teacher can significantly influence the dispositions of his or her students toward the material being taught. Goodlad (1984), Amabile (1989), and more recently Noddings (2003) all wrote about the importance of a teacher's joy and happiness toward what is being taught and how those emotional states impact the culture of the classroom and the learning dispositions of the students. My informal observations of Korbin over the years have provided plenty of anecdotal evidence that his dispositions toward teaching, learning, and design thinking are all positive, constructive, future directed, and at their core joyful.

A significant contribution toward an understanding of the importance of students' learning dispositions came about through the work of Costa and Kallick (2008). They began formulating in the early 1980s what they then referred to as "intelligent behaviors" (2008, p. xvi). The concept of those intelligent behaviors would eventually evolve into what they would call the *Habits of Mind*. The 16 Habits of Mind are:

- Persisting
- Managing Impulsivity
- Listening with Understanding and Empathy
- Thinking Flexibly
- Thinking About Thinking
- Striving for Accuracy
- Questioning and Posing Problems
- Applying Past Knowledge to New Situations
- Thinking and Communicating with Clarity and Precision
- Gathering Data Through All Senses
- Creating, Imagining, Innovating
- Responding with Wonderment and Awe
- Taking Responsible Risks
- Finding Humor
- Thinking Interdependently
- Remaining Open to Continuous Learning. (Costa & Kallick, 2008, pp. 18-38)

Costa (2008) described the relationship between the Habits of Mind and dispositions:

> A Habit of Mind means having a disposition toward behaving intelligently when confronted with problems. When humans experience dichotomies, are confused by dilemmas, or come face to face with uncertainties, our most effective actions require

> drawing forth certain patterns of intellectual behavior. When we draw upon these intellectual resources, the results that are produced are more powerful, of higher quality, and of greater significance than if we fail to employ them. (p. 30)

Without really knowing about Costa and Kallick's Habits of Mind when he was a student Korbin was, nonetheless, practicing those behaviors. Since entering the profession as a full-time teacher Korbin has continued to practice those behaviors, thus modeling the Habits of Mind for his students. He has also been teaching in such a way as to make the types of behaviors advocated by Costa and Kallick (2008) part of the central goals for his students' education. Korbin's students learn not only the content of the curriculum and the manipulative skills of working with a variety of technologies, they also learn the important habits of mind of the affective domain. Pink (2005) made the argument that for people to be successful participants in the "conceptual age" (p. 2) in which we are now living requires fluency in the six "senses" of design, story, symphony, empathy, play, and meaning. These senses are just another interpretation of what can more broadly be referred to as habits of mind. Pink called them "the six essential aptitudes" (p. 2). If Pink's arguments are correct, then the efforts of Korbin, and other teachers like him, are preparing students for a lifetime of success.

Arguably, the habits of mind are the thinking behaviors of anyone who is of a designerly mindset. As an example, Rossman (1964) researched the characteristics of inventors by doing a sizable survey of patent attorneys and directors of research centers—people who regularly interacted with inventors and observed how they did their work—as well as of 710 practicing inventors. Common characteristics from each of those three surveys included such behaviors as originality, analytic ability, imagination, perseverance, and observational skills (pp. 39-40). The characteristics identified by Rossman are identical, or at least complimentary, to the habits of mind and the learning behaviors that Korbin used throughout his own education, and that he continues to use and teach about today.

Wagner (2012) described similar habits of mind when he wrote about how innovation skills can be taught. In the following passage he wrote about the teachable attributes of innovation found in the literature and in the interviews he conducted:

> The "DNA" of innovators might be considered a set of skills that are essential elements in design thinking. One cannot have empathy without having practiced the skills of listening and observing. And integrative thinking begins with the ability to ask good questions and to make associations. There is also a kinship between collaboration and networking. And what all three lists [of identifiers of innovative behavior from leaders at IDEO, Google, and an article in the *Harvard Business Review*] have in common is the importance of experimenting—an activity that, at its root, requires a kind of optimism, a belief that through trial and error a deeper understanding and better approach can be discovered. (pp. 15-16)

Wagner further observed that successful innovators share the following "essential qualities:"

- curiosity, which is a habit of asking good questions and a desire to understand more deeply
- collaboration, which begins with listening to and learning from others who have perspectives and expertise that are very different from your own
- association or integrative thinking
- a bias toward action and experimentation. (Wagner, 2012, pp. 15-16)

One of the most difficult struggles for any teacher in today's American public school environment is finding a balance between the demands for student performance imposed from external forces such as administrators, politicians, the news media, and the general public and the needs of the whole child, which include the cognitive as well as the emotional, the social, the cultural, and the creative. The cognitive and the affective domains are two sides of a coin; they must co-exist symbiotically for the child to be successful, to be healthy, to be an innovator. Wagner (2012) emphasized the importance of what his list should mean to teachers when he wrote:

> As an educator and a parent what I find most significant in this list is that *they represent a set of skills and habits of mind that can be nurtured, taught, and mentored!* Many of us tend to assume that some people are born naturally creative or innovative—and others are not. But all of the experts whom I've cited share the belief that most people can become more creative and innovative—given the right environment and opportunities. (p. 16)

Whether they are called dispositions, attitudes, aptitudes, senses, or habits of mind is irrelevant. These behaviors represent the actions that Korbin has used and continues to use in his own life. They also represent the approach to thinking he teaches his students to use when learning about and interacting with technology.

The Culture of Support

The success of any classroom program is dependent on more than just the knowledge, skills, and dynamism of the teacher. There must also be a culture in place that supports and promotes his or her efforts. Such a culture includes support from administrators, colleagues, parents, students, and the general community in which the school is located. Korbin's success at Walkersville Middle School is no exception.

Administrative Support

Once Korbin completed a master's degree program at Ball State University he decided to return to the east coast. After applying at a variety of schools in several states he found himself in the position of having several job offers. He ultimately selected Walkersville Middle School for a number of reasons, including his sense that the administrators at the school and in the school district were fully supportive of technology and engineering education. His employment interviews with those administrators also gave him confidence that this position at Walkersville would give him "the most opportunities to grow" professionally (personal communication, June 4, 2015).

As part of the administrative structure of a county-based school district, Frederick County Public Schools employs district-wide coordinators for each of the content areas. In Maryland public schools, technology and engineering education falls under the administrative heading of Career and Technology Education (CTE). The CTE coordinator for Frederick County Public Schools when Korbin was hired was Eric Haines. Korbin recognized how important Eric's support was by identifying him as a mentor. Murray (2001) created a list of practices that defines someone as a mentor. According to Murray, a mentor should:

- Act as a source of information on the mission and goals of the organization
- Offer insight into the organization's philosophy of human resource development
- Tutor special skills, effective behavior, and how to function in the organization
- Give feedback on observed performances
- Coach activities that add to experience and skill development
- Serve as a confidant in times of personal crisis and problems
- Assist the protégé in plotting a career path
- Meet with the protégé at agreed times and intervals for feedback and planning. (pp. 14-15)

It has been Korbin's observation that Eric, in an informal mentoring role, helped him become familiar with the curriculum (initially it was Engineering by Design, or EbD), answered questions on instructional strategies, and coached him on matters of leadership skills. According to Korbin, those mentoring experiences have enabled him to "make the Invention and Innovation course my own and to take it to the next level." Furthermore, Eric provided opportunities for Korbin "to help develop and share resources and lead training [sessions] for the Tech Ed teachers…in Frederick County (personal communication, June 4, 2015).

DuNeen (2013) identified that "successful teachers know how to take risks" (para. 11). Taking calculated risks can best be accomplished in an environment that supports such action and recognizes that success from measured risks can return significant dividends toward the learning experiences of the students. Korbin noted the administrators at Walkersville Middle School, including principal Stacey Hiltner, are "very supportive of CTE and have allowed [me] to take risks and push the envelope on the level of what can be taught to, and completed by, middle school students" (personal communication, June 4, 2015). According to Korbin, this latitude to take measured risks enabled him to "make quick progress in developing and refining a rigorous, engaging, and meaningful [Invention and Innovation] course."

The Support of Colleagues

McDonald (2011) wrote about the importance for educators, especially new teachers, of being team players. The author wrote that toward this goal:

> The first requirement is a willingness to work with others and the ability to recognize that you can't do it all on your own. No one can meet all of the needs of all of the students who walk through our doors without help. It just isn't possible. (para. 3)

Within the CTE program at Walkersville Middle School there is one other teacher. This colleague was a veteran educator and had been at Walkersville for a number of years when Korbin was first hired. Korbin noted that his veteran colleague was a valuable ally and that

> He served as a good resource early on in my career. We have different classroom environments and we have slightly different teaching styles but together I feel students walk out of Walkersville Middle School being very well rounded in regards to their technological literacy and their CTE skills. (personal communication, June 4, 2015)

The educational experiences of the students at Walkersville Middle School are undoubtedly enriched because Korbin and his colleague have different roles and approaches. His colleague, in fact, teaches a series of elective courses including Technology Exploration to 6th graders, Communication Techniques to 7th graders, and Problem Solving to 8th graders. Korbin, on the other hand, teaches the Invention and Innovation (I&I) course to all 7th graders at Walkersville, unless a student is pulled for additional mathematics or reading intervention. In short, the differences in their courses, content, and teaching styles complement each other, just as in any team sport each player contributes a different part of the whole toward the team's success. The differences between Korbin and his colleague—his teammate in education—provide for more opportunities to meet the educational and experiential needs of a greater number of students.

With teachers from the other content areas at Walkersville, Korbin has actively sought to work as a cooperative team player. He related to me one example of how he had worked with the science teacher to help her teach about forces using water bottle rockets. Initially, the science teacher encountered all types of difficulty and student confusion by having them go right into the construction of generic water bottle rockets. Later, she spoke to Korbin as a colleague for his advice. Korbin encouraged her to try using some of the design methods from his I&I course, such as having students do research prior to the activity, creating multiple options for the rocket's design, and documenting the results of the testing of the rocket's function. As a result of this multidisciplinary exchange the science teacher has picked up a piece of the designerly perspective and now teaches at least this one activity using the organizing structure shown to her by Korbin (personal communication, June 6, 2014). This story also provides evidence of how both Korbin and the designerly techniques of instruction he uses are acknowledged, accepted, and supported by his colleagues at Walkersville Middle School.

The Support of the Community

Successful programs need the support of their community. Davis (2000), writing about the importance of the school-community relationship, stated that "when parents, families, and members of the community are involved with schools, all children benefit. Adult participation sends the message that school is important and the work children do there is worthy of adult attention" (p. iii). Korbin works hard to keep the greater Walkersville community aware of and involved in his program. He accomplishes this community awareness by actively promoting his program using his website, Twitter postings, and postings in the school's weekly newsletter. He also coordinates the annual STEM Day at Walkersville. As an important example of the community involvement this day represents, Korbin observed:

> On this day the entire school participates in a full day of STEM. Parents and [representatives from local] companies volunteer to lead hands-on STEM activities or be guest speakers. Although the support [my program receives] is year round, on STEM Day, the full support of parents and the community can truly be seen and felt. (personal communication, September 9, 2015)

Korbin's primary source of ongoing community support is through the parents of current students. His use of postings in the school's weekly newsletter and his students speaking directly to their parents about what types of activities are being done in the classroom provide many avenues of communication that lead to various levels of community support. Korbin wrote in one of our communications:

> In the weekly newsletter I will often put out requests for parents to serve as a guest speaker on a specific topic (such as Biotechnology) or to serve as a guest or judge as the students present their projects. I have found that after one parent gets involved, the word spreads and offers from other parents begin to come in. (personal communication, September 9, 2015)

The support that Korbin receives toward the continued success and growth of the CTE program at Walkersville from the school district's administration, his colleagues across the content areas, and the parents and other members of the larger community is a testament to the energy and innovation that Korbin brings to the program. The support that he receives thus enables him to direct his energies toward helping all of his students learn about technology using design as a teaching and learning strategy.

The Dynamic Use of Design as a Teaching and Learning Strategy

Design thinking and the use of technological design processes are integral to the creation, use, maintenance, disposal, and study of technology. It is because of the ubiquitous nature of technology that designerly education, presented through dynamic teachers such as Korbin and through curricula that can be adapted to change in the technological context, should be so important to general education. According to the National Middle School Association (NMSA; now known as the Association for Middle Level Education) there are at least 13 major goals that should be achieved in the middle school/middle level grades. The one goal from that list that perhaps best fits the holistic nature of the designerly approach to the study of technology states that "each young person should develop his or her strengths, particular skills, talents, or interests and have an emerging understanding of his or her potential contributions to society and to personal fulfillment" (National Middle School Association [NMSA], n.d., p. 1). At Walkersville Middle School, the use of the I&I course initially, and now a customized curriculum developed by the Frederick County Public School system, seems to have been a perfect fit toward helping Korbin achieve that goal, and to varying degrees all of the other 12 goals identified by the NMSA.

The overview for the I&I course from the ITEEA described it as providing "students with opportunities to apply the design process in the invention or innovation of a new product, process, or system" (ITEA, 2008, para. 1). The overview further noted that the activities of inventing and innovating are couched within the broader goals of teaching students how to think in a designer-like (designerly) fashion using such techniques as "brainstorming, visualizing, modeling, constructing, testing, experimenting, and refining designs" (2008, para. 1). Most recently, the course Korbin is teaching is one based on a locally-refined curriculum. This new course, also referred to as I&I, still focuses on students developing the same sets of designerly knowledge and skills as those identified in the original I&I course (personal communication, September 14, 2015).

A review of Korbin's website and its various tabs and links (https://sites.google.com/site/korbinsportfolio/contact-me) provides the viewer with a sense of how he taught the original I&I course and its subsequent replacement with the designerly perspective. One can access such things as the course syllabus and schedule, photographs of current and previous student work, lessons, stories of inventors, links to other informative sites, and a wealth of other information that his students and others use regularly (see Figure 4). This website is one of many bits of evidence of the breadth and depth of how Korbin is successfully teaching the I&I course and how students are learning to think and act in a designerly fashion.

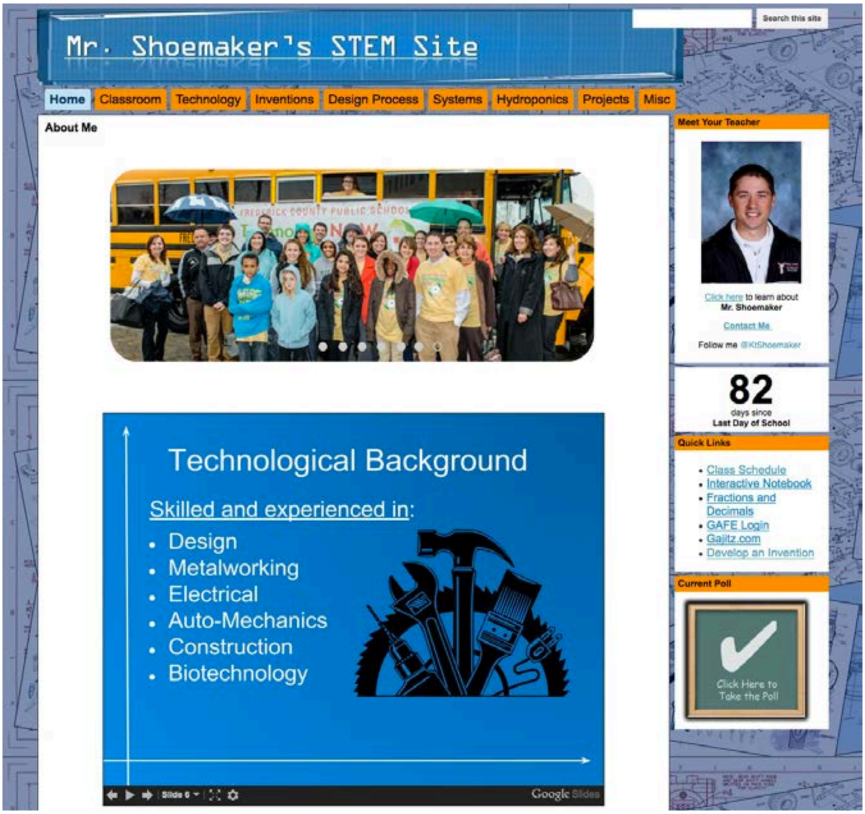


Figure 4. The top section of Korbin's homepage where students and other visitors can keep informed as to what is happening in his classroom, what is the latest in technology, and other interesting bits of technology and engineering education.

My personal observations of the operations of Korbin's class have provided me with an anthropologist's perspective of how the I&I course is being taught in a designerly fashion. The lessons, concepts, and activities that Korbin has selected are entirely appropriate for seventh grade students. His culture of designerly thinking is built upon a foundation of lessons that include such topics as transportation, bio-related technology, construction, manufacturing, and communication. He also helps students develop an understanding of the entire range of standards put forth in the *SfTL* (ITEA, 2000). Students demonstrate their understanding of these concepts in a number of ways, including electronic worksheets that are completed using the computer desk systems (see the following section of this chapter for more information on these desks), individual and group activities that are documented by students using simple process portfolios, and full-class discussions.

Although Korbin is clearly in charge of the classroom, it is also clear to even the casual observer that it is a very student-centered environment. Students are given a challenge with some type of back-story. They are given resources to work with and a simple process portfolio where they will record their design, build, and test efforts. One simple challenge that was used to teach the processes of design and which I was able to observe during a visit to Walkersville was entitled “Marshmallow Design Challenge.” Students were working in small teams. They were given a specified number of spaghetti sticks, miniature marshmallows, and various other supplies. The goal was to build the tallest tower possible within a limited time period. Before the building material packets were distributed or any building was begun students were forced to plan their efforts. The process portfolio they were given at the beginning of the activity asked them to:

- Define the problem
- Identify criteria and constraints
- Identify any questions they may have that would need investigation
- List the prior knowledge they may be bringing to the challenge
- Generate multiple ideas as to how they can solve the challenge
- Select the option that they would like to develop and make predictions as to how they think it will perform

In this preliminary stage of the activity students were given 15 minutes to plan and generate ideas, and samples of the marshmallows and the spaghetti sticks so that they could explore the properties of the material.

After the preliminary design stage students had to show their documented efforts to Korbin before they could proceed. This stopping point allowed him to take a reading of how students were doing and whether they were proceeding as expected with the activity. It was only at this point, and with his approval, that students received the full packet of materials and were able to begin construction. Students were given an additional 20 minutes to select the final design, seek approval, acquire materials, and construct their final design.

Once everything was built the class then stopped and observed the measurement and evaluation of every team's final design. The final section of the process portfolio asked the students to compare and contrast their predictions against what actually happened and to reflect on what they would have done differently if they had a chance to do a second iteration of their design.

As an outside observer I witnessed students with a wide range of cognitive and psychomotor abilities working cooperatively. Everyone was having fun and they were actively learning. Students were discussing and even debating what choices their team should make with each step of the design process. Students were making all of the choices and decisions, not Korbin. Some of the designs did not work as the students had anticipated. Korbin, using the questioning Socratic method of instruction, guided the members of a team to construct their own understanding of what did not work and why it did not work, based on the content they had learned in a previous class or through their own research. Students had been experimenting with the properties of the materials as part of their planning. They had also been experimenting with design ideas that were modified as they transitioned from the two-dimensional world of paper to the three-dimensional world of the actual structure. Wagner (2012) expressed how important experimentation (trial and error) is toward the development of an innovative disposition. What I witnessed in Korbin's classroom was by every measure an exemplary representation of how to encourage this disposition.

In conversations with Korbin since that lesson he has shared with me several things that are common to all of his classes and activities. Not all students learn at the same rate how to use the designerly approach just described, but by the time they leave his class all students have a pretty good understanding of the process. Once they learn the designerly approach it becomes a natural routine for them when they take on other problem solving challenges. Korbin's other activities are structured in much the same way as the Marshmallow Design Challenge. The use of a process portfolio to document how students worked their way through an activity or assignment puts their thinking into the metacognitive realm: students are showing him what they did and what they learned while those actions were occurring. If one of the goals of modern public education is to get students to think at a higher level, then the model demonstrated by Korbin accomplishes that goal. Finally, students like the level of autonomy they enjoy in Korbin's class, much like he himself enjoyed being allowed to make choices and decisions when he was in his agriculture courses in high school.

Korbin also shared with me that the Marshmallow Design Challenge is more of an introduction or transition activity. Although the Marshmallow Design Challenge and other such simple design challenges have their place in the teacher's repertoire, Korbin believes that in and of themselves they are insufficient and "do not offer the same opportunities as the larger, real world problem, design challenges" (personal communication, September 14, 2015). Korbin believes that most of his lessons and activities must be "larger [in context] and based on authentic problems such as designing a present-day Levitt-style house for soldiers, or designing prosthetics and assistive devices for soldiers, children in third world countries, and animals" (personal communication, September 14, 2015).

When I filter what I have just described through the three justifications for design in general education developed by Cross (1982), it is evident that in Korbin's I&I class his students are developing problem solving abilities with ill-defined problems; enhancing their cognitive development through the hands-on manipulation of tools, materials, and other physical resources; and developing thought and communication patterns (both verbal and non-verbal) that will serve them well over the course of their lives.

The Importance of Space and Place

Seelig (2012) labeled the physical space in which we live and work as an important part our habitat. In her schema of creativity, habitat is one of the six components that make up the "innovation engine" (p. 15). In a later video that can be found on YouTube (Seelig, 2014), she elaborated on the importance of that space's location, content, and organization. In the video she projected a series of pictures that showed how different and stimulating an elementary grade classroom can appear as compared to the visual sterility of a typical high school classroom. The coup de grâce of the picture series was a photograph of a cubicle farm into which students from the earlier high school scene can migrate as adults.

In a designerly environment, creativity and innovative thought and actions are integral to what is learned and what activities occur within that space. Conversely, that physical space needs to be supportive of those types of thoughts and actions. Korbin's teaching space does just that as a result of its location within the building, its layout, the teaching and learning resources found within, and the enriching details that stimulate students' senses and creativity.

The Importance of the Location of Space

Korbin's classroom/laboratory is located in a central spot within the Walkersville Middle School building. This location is not typical of many technology and engineering education classrooms and their laboratories, which are often located in a separate wing of their school because of noise concerns or other perceived problems. However, there are educational trade-offs for such placements. On this matter Blum (n.d.) wrote that "the physical organization of a school can create obstructions to engagement or foster opportunities for a positive learning climate. When . . . classrooms are arranged for optimum student learning, the focus remains on the core goals" (p. 15). By being in a central location Korbin's classroom and its activities are more visible to the daily operation of the entire school. He and his students also have more immediate access to colleagues in other content areas. This enables, to a greater degree, the content expertise of those colleagues to cross-pollinate the work that is done in Korbin's I&I course. In this case, the placement of the facility is well suited toward achieving the "opportunities" written about by Blum.

Korbin's classroom is located on the ground level in a section of the building that is single-story. The room is bordered on one long side by a hallway, on another long side with a central courtyard, and on the two short ends with other classrooms. Across the hallway are other classrooms and an intersecting hallway leading to another wing of the building. The room is accessible from the main hallway by two doorways. The space was originally built to be two separate rooms with a collapsible wall separating the area roughly in half. Unlike many middle school technology and engineering education facilities that originated with the industrial arts era, this space does not contain large industrial machines (those are located in a laboratory in another part of the building), and thus the problems of noise and dust are minimized. The location of the lab was originally established and set up by Korbin's predecessor in that position, the CTE coordinator Eric Haines. Having this space established in such a central location prior to the start of his employment is one of many fortunate circumstances that Korbin has exploited to help his program reach its full potential.

The Importance of the Space's Content and Organization

Myers and Shinberg (2011) recently wrote about the importance of both layout and content of the learning space. They summarized their findings by stating "the physical classroom environment has a direct correlation to the creative output of students" (p. 229). Korbin's space is organized and filled with resources in a way that is intended to encourage the creative and designerly actions of his students.

All students have their own desk during their assigned period in Korbin's classroom. These desks are unusual in that they can serve two functions. The first function is as a normal desk where students can do the make and build aspects of any given assignment. The second function is as an individual computer station. To enable this transformation each desk has a top that can be easily adjusted from the flat desk function to the angled computer screen function. The keyboard is accessible through a pull-out drawer and the computers are located below the desks. At each of these stations the student also has an office chair that is on wheels and that can be adjusted to accommodate the student's height and comfort needs (see Figure 5).

Figure 5. The left photograph shows a dual-purpose desk in the computer mode at front, and two desks to the back of the picture in the flat surface configuration. The right photograph shows the office chairs that are used with each desk.

The room has several cupboards that contain various resources that are stored in plastic storage boxes, tools in tool boxes or holder racks, and simple machines. The contents of the resource boxes are kept stocked or changed out as circumstances require. The tools used in the facility are mostly hand tools, small electric portable tools, and a few small benchtop machines (see Figure 6).

Figure 6. Two of the many storage and resource cabinets found in the facility.

Because the facility is long and narrow, the teacher's station is in the center of the room. That station contains a podium that includes a document camera, computer, network connections, and a central electronic smart board (see Figure 7). Information projected by the teacher through a presentation, lecture, or video can also be seen by students on large screens that are located at each end of the room (see Figure 8). Finally, the windows and glass doors of the wall that abuts the central courtyard of the building are used as part of an ongoing hydroponics activity.

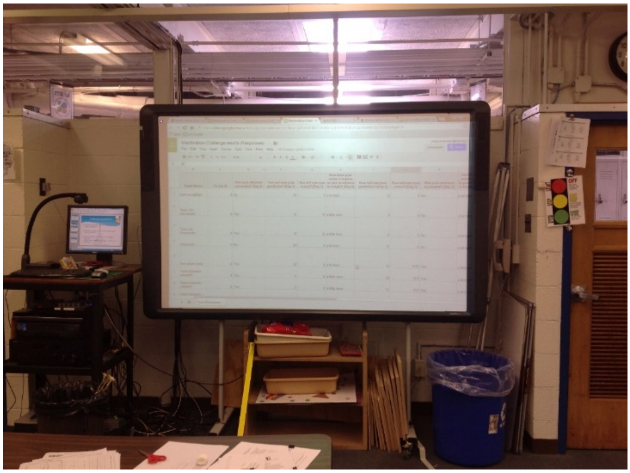


Figure 7. A view from the centrally located teacher's desk showing the teaching podium and its electronic resources that include a document camera and the smartboard.

Figure 8. Large screens are located at each end of the facility so that students throughout the room will have a clear view of the lesson, projected documents, or videos.

Daugherty, Klenke, and Neden (2008) identified a list of essential elements that a modern technology and engineering education facility should contain. That list included:

- State-of-the-art presentation center to include delivery systems, projection systems and Smartboard technology.
- Multipurpose computer platforms to allow for a variety of computer applications including 3-D computer-aided design, desktop publishing, CNC systems and other specialized computer software.
- Flexible fabrication center that promotes portability and age-appropriate equipment and tooling usage.
- Mobile supply and material platforms that support invention, innovation and testing.
- Multipurpose workstations that provide convenient work centers for projects and activities.
- Supply and equipment storage as well as appropriate safety equipment. (p. 22)

The I&I space at Walkersville Middle School provides every one of these identified essentials. Thus, the designerly and creative actions of Korbin's students are at least unencumbered, and by all indications fully enabled, by their surroundings.

The Use of Space to Stimulate the Senses and Encourage Creativity

Korbin's facility is well lit, organized, properly maintained, and decorated with educational posters and student work. These aspects of the facility contribute to students feeling like they belong in that space. One technique for helping students to feel ownership in a space is to use some of their previous work as examples that are put on display. The use of previous student work can provide inspiration and it demonstrates that the student's work is valued by the teacher and by other students (Myers & Shinberg, 2011). In Korbin's space there are examples of student work posted on display boards as well as 3-D models from previous assignments. During my interview visit I saw examples of student-created house drawings posted on a bulletin board, some models of prosthetics from a biotechnology assignment, and scale models of playgrounds (see Figure 9). Students had taken great pride in making these artifacts, as I could see from the attention to detail I found with each example.

Figure 9. Examples of student work on display in Korbin's room including architectural drawings, models of proposed prosthetics, and scale models of playgrounds.

I also observed student pride in the total "habitat" (Seelig, 2012, 2014) as they came into the room with each change of class. Students were more than willing to show me around the room and tell me about each of the activities. They also wanted to tell me about their current activity and how they thought they were going to go about designing and building the tallest spaghetti tower. Korbin's students were excited about the classroom culture he had developed and were proud of the space that made that culture possible.

Final Thoughts

The perfect storm discussed in the first part of this chapter was a force of nature that brought damage, destruction, and loss of life. It represented the confluence of forces that were powerful in and of themselves, which were then magnified by the combining of their energies. The original "perfect storm" was an event of nature that added to our lexicon a new term, which summarized the concept of how multiple variables can combine to create something that is greater than the contributing parts. Although the effects of the original perfect storm were negative, the term has now taken on a broader context to include both positive and negative meanings. For Korbin Shoemaker, a positive perfect storm occurred when he started working at Walkersville Middle School.

The track of the elements that contributed to this perfect storm began with Korbin himself as, over the course of his life, he acquired the knowledge, skills, and dispositions to make him well suited to teach a designerly middle school program. The second contributing factor into this storm was the support systems he found in the Frederick County Public Schools and at Walkersville Middle School. The support of administrators, colleagues, students, and the community toward the designerly efforts Korbin would bring to his classroom could only add to the energies he already brought to the situation. The third contributing factor that tracked into this confluence was the technology and engineering curriculum materials that were being used by schools in Maryland, including Walkersville Middle School. The Engineering by Design curriculum, and the current school district-developed curriculum, provided the perfect platform from which a designerly-minded educator like Korbin could actively nurture such thinking and behavior patterns in his students. The final factor contributing toward this perfect storm of designerly education was the location and organization of Korbin's teaching space. Undoubtedly, he would have still had a dynamic and exemplary middle school program had his classroom space been located in a less central location in the Walkersville building and had it not been initially set up by his predecessor. However, having these factors contribute to the energies of the program has only added to the power of the program's dynamic nature.

These four factors—a dynamic and designerly minded teacher, a supportive cultural environment, a curriculum that provides the designerly context (and latitude for teacher input), and the place and space from which to teach with the designerly goals in mind—combined at Walkersville Middle School to create the perfect storm of designerly middle school technology and engineering education.

Unlike the original perfect storm that was created by the uncontrollable and random powers of nature, the perfect storm of designerly middle school technology and engineering education exemplified by Korbin Shoemaker at Walkersville Middle School can be controlled and planned. The challenge to the technology and engineering education profession, and to school administrators at the local level, is to intentionally seek out young people like Korbin and nurture them to become designerly-minded teachers. This is done by supplying them with the necessary cultural supports, enabling them to learn from a variety of sources and to continue to create curricula that support the designerly mindset, and by placing technology and engineering education programs in the heart of the school building. The next generation of educators seeking to create designerly middle school technology and engineering education programs should look at the Walkersville Middle School program as an exemplary model toward which they can fashion their own program.

References

Amabile, T. (1989). *Growing up creative: Nurturing a lifetime of creativity*. Buffalo, NY: The Creative Education Foundation.

Anderson, P. (2013, August 29). *The perfect storm and the perfect metaphor* [Web log post]. Retrieved from http://www.teamcaremedicine.com/the-perfect-storm-and-the-perfect-metaphor/

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

Blum, R. (n.d.). *Best practices: Building blocks for enhancing school environment* [Monograph]. Retrieved from http://www.jhsph.edu/research/centers-and-institutes/military-child-initiative/resources/Best_Practices_monograph.pdf

Cross. N. (1982, October). Designerly ways of knowing. *Design Studies, 3*(4), 221-227.

Costa, A. L. (2008). *The school as a home for the mind: Creating mindful curriculum, instruction, and dialogue* (2nd ed.). Thousand Oaks, CA: Corwin.

Costa, A. L. & Kallick, B. (Eds.). (2008). *Learning and leading with habits of mind: 16 essential characteristics for success*. Alexandria, VA: Association for Supervision and Curriculum Development.

Daugherty, M., Klenke, A., & Neden, M. (2008, October). Creating standards-based technology education facilities. *The Technology Teacher, 68*(2), 19-26. Retrieved from http://www.pittstate.edu/dotAsset/202758.pdf

Davis, D. (2000). *Supporting parents, family, and community involvement in your school*. Portland, OR: Northwest

Educational Laboratory. Retrieved from http://www.pacer.org/mpc/pdf/titleipip/SupportingInvolvement_article.pdf

DuNeen, J. (2013, January 28). *25 things successful teachers do differently* [Web log post]. Retrieved from http://www.teachthought.com/teaching/25-things-successful-teachers-do-differently/

Goodlad, J. (1984). *A place called school: Prospects for the future*. New York: McGraw-Hill.

Herschbach, D. R. (2009). *Technology education: Foundations and perspectives*. Homewood, IL: American Technical Publishers.

Hutchinson, P. A. (1987). *Problem-solving in the British Craft, Design and Technology program* (Doctoral dissertation). New York University, New York.

Hutchinson, J. & Karsnitz, J. R. (1994). *Instructor's guide to accompany design and problem solving in technology*. Albany, NY: Delmar.

International Technology Education Association (2008). *Invention and innovation – Course overview* (2nd ed.). Retrieved from http://iteaconnect.org/EbD/Samples/MiddleSchool/ii_overview.pdf

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

Junger, S. (1997). *The perfect storm.* New York: W. W. Norton.

Lewis, T., & Zuga, K. (2005). *A conceptual framework of ideas and issues in technology education*. Columbus, OH: Technology Education Program, Science, Technology, Engineering, and Mathematics Section, School of Teaching & Learning, The Ohio State University, College of Education & Human Ecology (Supported through National Science Foundation Grant No. ESI-0138671).

Litowitz, L. (2014, Spring). A curricular analysis of undergraduate technology & engineering teacher preparation programs in the United States. *Journal of Technology Education, 25*(2), 73-84.

McDonald, E. (2011). Being a team player: Collaboration with colleagues. *Education Week*. Retrieved from http://www.educationworld.com/a_curr/columnists/mcdonald/mcdonald014.shtml

Murray, M. (2001). *Beyond the myths and magic of mentoring: How to facilitate an effective mentoring process* (2nd ed.). San Francisco, CA: Jossey-Bass.

Myers, K. L. and Shinberg, M. (2011). Physical environments for creativity and design. In S. Warner & P. Gemmill (Eds.), *Creativity and design in technology & engineering education* (pp. 212-233). Reston, VA: Council on Technology Teacher Education.

National Middle School Association. (n.d.). *This we believe executive summary*. Retrieved from https://www.uww.edu/Documents/colleges/coeps/academics/This_We_Believe_Exec_Summary.pdf

NOAA News Online (2000, June 16). *NOAA meteorologist Bob Case, The man who named the perfect storm* (Story 444). Retrieved from http://www.noaanews.noaa.gov/stories/s444.htm

Noddings, N. (2003). *Happiness and education*. New York, NY: Cambrige University.

O'Brien, S., Karsnitz, J., Van Der Sandt, S., Bottomley, L., & Parry, E. (2014). Engineering in pre-service teacher education. In S. Purzer & J. Strobel (Eds.), *Engineering in precollege settings: Synthesizing research, policy, and practices* (pp. 277-299). West Lafayette, IN: Purdue University Press.

Pink, D. H. (2005). *A whole new mind: Moving from the information age to the conceptual age*. New York: Riverhead.

Rossman, J. (1964). *Industrial creativity: The psychology of the inventor*. Hyde Park, NY: University Books.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Seelig, T. (2014). *The 6 characteristics of truly creative people* [YouTube video]. Retrieved from https://www.youtube.com/watch?v=CgCdsERkqrc

Seelig, T. (2012). *inGenius: A crash course on creativity*. New York: Harper Collins.

Wagner, T. (2012). *Creating innovators: The making of young people who will change the world*. New York: Scribner.

Warner, S. A. (2011). Providing the context for creativity and design in technology and engineering education. In S. Warner & P. Gemmill (Eds.), *Creativity and design in technology & engineering education* (pp.1-31). Reston, VA: Council on Technology Teacher Education.

Middle Grades Technology in New Zealand: An Example of Exemplary Practice

Chapter 5

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Introduction

Technology Education in New Zealand is a compulsory and distinct learning area of the New Zealand Curriculum. This chapter presents a case study of a program in which gifted and talented students were given additional time in technology to work on a special project. The chapter begins with an overview of technology education within New Zealand and outlines information about the school and its technology programme. It then explains the Intermediate school system in New Zealand and more specifically introduces the school featured in this case study. The students in the programme were identified as Gifted and Talented (GATE) learners. A definition of the GATE programme and description of GATE learners at the case-study school are discussed before a brief literature review of authentic learning and guided inquiry. These both are part of the foundational philosophy of the programme described here. The chapter concludes with discussion about the advantages and benefits of the programme for the students and for the wider school community. It also briefly visits some of the teacher's perceived drawbacks of the programme.

Technology Education in New Zealand

Technology first appeared as a part of the New Zealand curriculum when it was included in *The New Zealand Curriculum Framework* (Ministry of Education, 1993a) as one of seven essential learning areas (Jones, 2006). That same year the draft technology curriculum was published (Ministry of Education, 1993b) and trialled in schools through 1994. After significant consultation with relevant sectors, *Technology in the New Zealand Curriculum* (Ministry of Education, 1995) was published for the first time in 1995. Learning was organised into eight levels of achievement from Years 1-13 and incorporated three strands: Technological Capability, Technological Knowledge, and Technology and Society. Within each strand sat a number of achievement objectives, eight in total. Technology was defined as the development of a range of products, systems, and environments aimed at making human existence easier, or to advance the human condition. All technological development was to take place within a social context (Ministry of Education, 1995). This approach was more inclusive of cultural values and beliefs than earlier New Zealand policy and similar policy documents in other nations. Full implementation occurred in February 1999, when technology became part of the compulsory curriculum for Years 1-10 (5 to 14 year olds).

In 2001, a curriculum stocktake was undertaken to review current curricula, teachers' experiences with it, and international trends. This resulted in the development of a revised and refined curriculum. The launch of the New Zealand Curriculum (NZC) (Ministry of Education, 2007) saw significant changes in technology and included the introduction of two new strands (Ministry of Education, 1995, 2007). It is also important to note that when the 1995 technology curriculum was written, it had never been taught in schools. In 2007, technology was redefined as "intervention by design, the use of practical and intellectual resources to develop products and systems [technological outcomes]" (Ministry of Education, 2007, p. 32). The three new (and current) strands of the technology education learning area are: Technological Practice, Technological Knowledge, and The Nature of Technology. They allow for the considered and efficient development of culturally and environmentally situated technological outcomes. The general aim of technology education in NZC is to develop technological literacy through understanding across all three strands (Ministry of Education, 2007, p. 32). NZC (Ministry of Education, 2007) also suggests technological literacy enables students to develop a broader, deeper, and more critical understanding of technology (Compton & Harwood, 2007). Table 1 gives an overview of the 2007 technology strands and lists the key components in each. The technology curriculum incorporates five areas of technology: biotechnology, control, food technology, information and communication technology, and structural technology (Ministry of Education, 2007) and identifies the concept of the transformation, defined as manipulation, storage, transportation, or control of either materials, energy, or information (Compton & France, 2006).

Table 1: *Technology Strand and Components (Ministry of Education, 2007)*

Technological Practice	Nature of Technology	Technological Knowledge
Brief Development	Characteristics of Technology	Technological Modelling
Planning for Practice	Characteristics of Technological Outcomes	Technological Products
Outcome Development and Evaluation		Technological Systems

New Zealand Intermediate Schools

The Intermediate School in New Zealand is a state-funded school for eleven to thirteen year olds covering Years 7 & 8 of their schooling. Typically, these schools are found in urban areas and serve 200-plus students. The largest, Tauranga Intermediate School, caters to approximately 1200 students.

A national education system for New Zealand was first established with the 1877 Education Act. The 1877 Act laid a foundation for universal, state-funded primary education for seven to thirteen year olds, compulsory for half of the year. In the same year, after much debate, provision was also made for secondary schooling, but on a fee-paying basis. This continued until the government introduced a system of free places in secondary schools in 1903 for children able to pass proficiency tests. With an increasing number of children now attending secondary school, there was a concern for how they would transition from primary school into the secondary school system (Dakin, 1973).

This led to the establishment of "intermediate schools," initially in the main urban centres beginning in the early 1920s. Intermediate or middle schools included specialised staff and special facilities such as workshops to help students develop talent beyond what primary schools could offer and to better prepare them for higher education. Students now had an opportunity to experience a wider range of educational opportunities before the highly specialised secondary school years. The intermediate or junior high schools, as they were termed, provided accelerated learning for academic students and terminal education for the non-academic students. Programmes for the latter group were more practically based and provided commercial, industrial, or agricultural education for boys and commercial or domestic programmes for girls. This form of education followed the idea of social efficiency, a poplar educational theory of the era (Phillips, 1989 as cited in Hinchco, n.d.).

The Intermediate School system was formally established by the government on 15 December 1932. It would consist of a two-year period of education for eleven to thirteen year olds with the schools administered, as primary schools were, by regional education boards. It had finally become the unique middle school option long sought after by educationalists in New Zealand, with a set and more balanced curriculum established.

In the mid-1930s Dr. Clarence Beeby led a government-sponsored survey and analysis into the intermediate school system. His report identified some important philosophical tenets for this period of schooling, including beliefs that the schools should provide a socially integrative education, giving future citizens a common basis of experience and knowledge; an introduction to the world of industry, commerce, and the professions; rational choices for future school and occupations; and a "rounding-off" for those students not moving to secondary schooling, including assisting students to find suitable employment (Hinchco, n.d.).

In more recent times the Intermediate School system has continued to hold its favour as a place where students can benefit being away from younger children without the influence of older secondary students. At a developmental period where attitudinal, behavioural, and social problems can escalate, the Intermediate School offers an opportunity for students to re-engage in a different organisational, curriculum, assessment, and pedagogical approach to learning. It is a time where students begin some subject specialisation, particularly in the areas of Technology Education, Arts, and Sciences.

Christchurch South Intermediate School

Christchurch South Intermediate School is a decile 6 middle years school specialising in the education of students in Years 7 and 8 (11 to 13 year olds). All schools in New Zealand are given a decile rating from 1-10 every three years according to the socioeconomic status of the community in which they are situated, with 1 being low and 10 being high. Schools with low decile ratings are funded at higher levels than high decile schools.

Students come from a wide variety of contributing schools. Christchurch South Intermediate is located in the suburbs of Christchurch and the school catchment is bounded by the Port Hills, the Heathcote River, and the city's central business district. The current school roll is approximately 530 students, with 24 teaching staff. The school's motto is "Aim High," and as an intermediate school it targets the needs of Year 7 and 8 students, with a vision that focuses on the very specific needs of this age group, including:

- **developing a passion for learning -** recognising that learning is a lifelong creative process
- **building independence -** helping our young people to take responsibility for themselves and their futures
- **celebrating diversity -** enjoying the wide and varied cultural and socio economic backgrounds we come from and the range of abilities we have to share
- **embracing challenge -** encouraging our students to move out of their comfort zones in order to grow in confidence as they begin to move through the significant and rewarding early adolescent years. (http://www.chchsouth.ac.nz/WebSpace/162/)

The school vision guides what is done in the school, along with a set of shared values that includes self-discipline, common sense, respect, commitment, support, involvement, and honesty. The school's ethnic composition includes New Zealand European 73%, Māori 13%, Samoan 2%, Other Pacific 2%, Asian 4%, and Other 6% (Christchurch South Intermediate School, 2014).

Gifted and Talented Education (GATE)

McAlpine and Reid (1996) identified five key components that need to be addressed and understood in meeting the needs of gifted and talented students. These are: (a) the concept of giftedness and talent, (b) the characteristics of gifted and talented students, (c) how to identify gifted and talented students, (d) programmes for these students, and (e) the on-going self-review that is necessary to ensure that the programme continues to be effective and successful.

Six broad areas of giftedness and talent were identified by Riley et al. (2004), extending what had until then often been a focus more on students with high academic intelligence. They identified these areas:

1. Intellectual/academic
2. Creativity
3. Expression
4. Social/leadership
5. Culture-specific abilities and qualities
6. Expression through physical/sport

The New Zealand education system underwent considerable changes in management and administration in the late 1980s (Gordon, 1992). Following on from this there was a significant shift from the government toward developing a more inclusive system that focused on all students achieving positive outcomes from their education. New Zealand curriculum documents since the 1990s have been outcome-based, maintaining flexibility for teachers to implement programmes that are specific to the level and interests of the student. Teachers have become very adept at student-centred strategies and differentiation for effective teaching and learning that progresses all students toward their potential (Alton-Lee, 2004).

GATE Learners

Gifted and talented students will usually master information quickly, like challenges, be independent and analytical thinkers, find and solve problems, and have a broad knowledge. They will produce original ideas and be creative and imaginative, future-focused, and persistent in their work. In New Zealand schools these children benefit from the ability teachers have to promote differentiated programmes to meet their individual needs. New Zealand teachers are supported by a curriculum that has identified principles, key competencies, values, and learning areas as all contributing to a well-rounded education that ensures citizens can become robust, resilient, responsible, and informed members of society. The curriculum therefore supports the development of a broad range of 21st century skills and allows for gifted and talented students especially to utilise and enhance the special abilities they have.

The Ministry of Education directs schools through the use of National Education Goals (NEGs) (Ministry of Education, 2014b) and National Administration Guidelines (NAGs) (Ministry of Education, 2014a). Both determine the requirements and principles for the way schools will be managed and the desired achievements for their students. There is explicit support for GATE students within these. Since 1997 this government emphasis on GATE education has seen a number of advisory groups and working parties established, handbooks written for schools, and online resources and support systems developed. NAG 1(c)iii states: "On the basis of good quality assessment information, identify students and groups of students who have special needs (including gifted and talented students)" (Ministry of Education, 2014a, p. 1). NEG 1 seeks: "The highest standards of achievement, through programmes which enable all their learning for those with special needs by ensuring that they are identified and receive appropriate support" (Ministry of Education, 2014b, p. 1). To achieve these principles schools must help all students realise their full potential, identify and remove any barriers to their learning, and provide support through the programmes they offer.

Technology GATE Programme at Christchurch South Intermediate

The teacher in charge of the programme described in this chapter, Randall Grenfell, was a recently graduated teacher with a graduate diploma in Secondary Teacher Education. He has a background in engineering and started his career as a tradesman who later studied design at a polytechnic. Until he decided to train as a teacher, Randall owned and ran an engineering business, designing and making automated machinery for factories and the amusement industry.

The school, Christchurch South Intermediate, has a teacher responsible for coordinating their GATE programmes. At time of writing, 2013 and 2014, Technology was the only GATE programme running. This was with Year 8 (12-13 years) students. Randall identified the students when they were in Year 7, three-quarters of the way through the academic year, where he "took them under my wing for two hours a week, giving them lessons on design and problem solving" (Randall Grenfell, personal communication, 8 August 2014). The main reason was to ensure that when they entered Year 8 they were armed with the necessary skills to embark on the major product development project he had planned for them. Randall then formally selected the GATE students based on their capability in Technology, after teaching them in their normal technology rotation of three hours per week. Key factors determining his selections were originality of students' designs, design risks taken, and ability to resolve issues without intervention from the teacher. Interestingly, Randall noted that all but two of the 2014 students were also identified GATE students in literacy and numeracy: "They all typically are good at everything and play two instruments each, Head boy and Head girl, good at sport. They are very busy students, committed to many other activities" (personal communication, 8 August 2014).

Both sets of students in Randall's 2013 and 2014 programmes worked with qualified engineers through the "Futureintech-Neighbourhood Engineering" project. Futureintech is an educational division of the Institute of Professional Engineers of New Zealand (IPENZ), which aims to encourage young New Zealanders into careers in the technology, engineering, and science-based industries. In order to achieve this goal, they employ facilitators to organise a range of experts to work with students in schools. A wide range of experts, including software developers, engineers, surveyors, food technologists, and scientists, visit schools "to share their stories, act as role models and Ambassadors for their industry, and enhance teaching of Maths, Science, Technology and Careers programmes" (Institute of Professional Engineers New Zealand [IPENZ], n.d., para. 2). Futureintech also runs an annual national competition called the Transpower Neighbourhood Engineers Awards.

Once begun, Randall's programme included enrichment classes most nights after school where students selected a project to work on. The two GATE programmes run so far have been quite different. In 2013 the students developed a scooter parking system to solve an authentic problem for their school and within their body of knowledge. They went through a long and convoluted design/modelling process to try all different methods of parking scooters (Figure 1). The students identified the following attributes for their scooter racks. They needed to be: affordable, individually lockable, weather proof, and easy to use. This project was effectively an entirely mechanical project and the students were intimate with the whole process. The project won the Transpower Neighbourhood Engineers Major Award.

Figure 1. "Scooter Rack": The award winning outcome from the programme in 2013, with some modifications for a range of clients. (Photos by author.)

In 2014 the students were given a specific brief of helping the elderly to ensure their projects included a client and end-user other than themselves. "This year the initial brief was immense—'Help the elderly.' The students then decided on the final product development project, based on achievability, research, and advice from the mentors" (personal communication, 8 August 2014). The students went through many different project ideas before settling on the "E-Key" project, based on feedback from engineers after a factory visit and a visit from an occupational therapist who assisted the students' understanding of the needs of the elderly. Figure 2 shows the students working on a mock-up of the E-Key product.

Randall felt that the proposed project was a little out of his field of expertise, so he used an increased number of engineering mentors and the factory visit[1] to facilitate students' momentum. This meant the students had increased contact with professionals from outside the schooling system to guide their learning. According to Randall, the benefits of this were two-fold: (a) it authenticated the learning, and (b) it gave the students contacts and an understanding about real product development. Figure 3 shows an overview of the research undertaken by the students.

In both years it has run, the programme has been funded through two sources. The first was through the school GATE programme. Teachers who organise and take these programmes are able to access limited funds from this area of the school's budget. The second and bigger component came from Randall's workshop consumable budget. The programme is undertaken in the teacher's and students' own time, usually after school and during some lunch times towards the end of the project.

[1]Visit reported in TENZ T News at http://www.techlink.org.nz/stories.cfm?area=7&SID=229

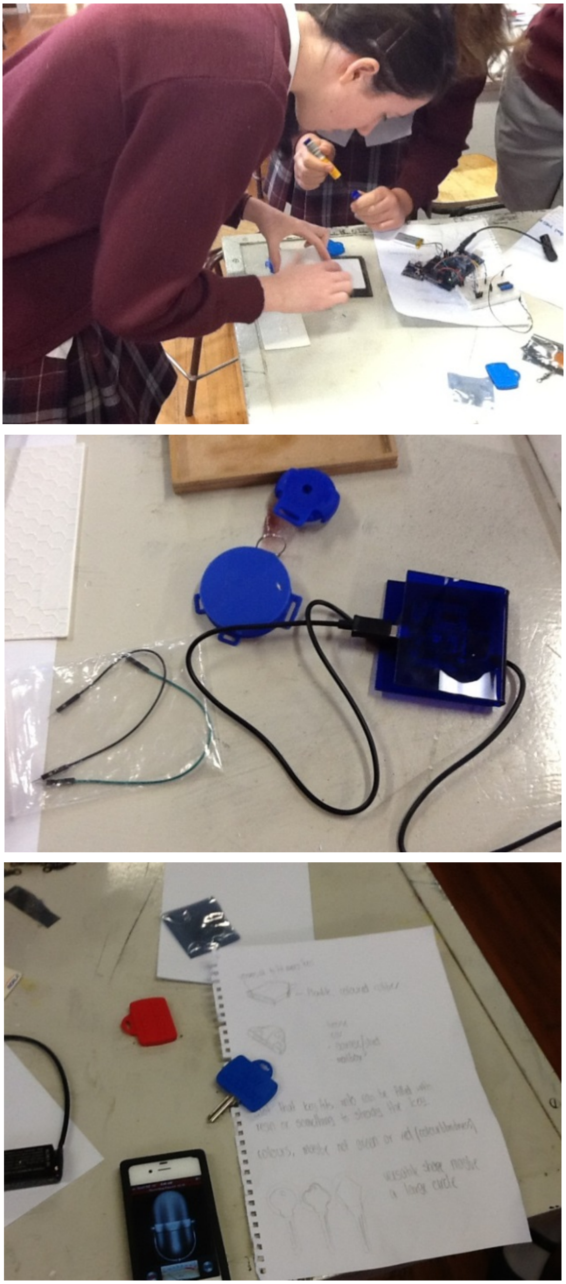

Figure 2. The 2014 project, the "E-Key." (Photos by author; parental and student consent given.)

Figure 3. The students' documentation of their research. (Photos by author.)

The philosophy and values that drive Randall's programme include a belief in learning through authentic problem solving while encouraging and facilitating a need for the demonstration of excellence and resilience in their work. These are the main factors he sees as making a young person employable in a rapidly changing world. He believes this method of learning facilitates leadership through working and managing a team and assists students to develop pathways to tertiary education and/or to owning a business. He commented, "To illustrate, I picked these kids in September last year and the school management in December picked this year's Head Boy/Head Girl, and they were already in my group" (personal communication, 8 August 2014).

Randall undertakes continuous professional development. As an engineer and as a business owner recently trained to be a technology teacher, Randall has had recent professional development experiences focused on Technology Education in the New Zealand Curriculum. He is also actively involved in Technology Education New Zealand (TENZ), a professional association supporting teachers in schools. He is currently a member of the TENZ National Council and of the regional committee. The Canterbury region of New Zealand is in the process of undertaking considerable change in education due to significant population shifts and school rebuilding needs following the Canterbury earthquakes of 2010 and 2011. These changes include a review and reorganisation of the provision of specialist technology teaching and facilities for intermediate-aged students (11-13 years). Randall is very active in the local technology cluster and has input into the proposed changes.

Authenticity and Guided Inquiry

Authentic Learning

"Activity is said to be authentic if it is (i) coherent and personally meaningful, and (ii) purposeful within a social framework—the ordinary practices of culture" (Hennessy &

Murphy, 1999, p.8). An important message about the nature of activities that children undertake is that authentic learning engages children and encourages learning (Hennessy & Murphy, 1999; Hill & Smith, 1998; Rogoff, 1990). A number of theories from different perspectives advocated the placement of learning in authentic practice. The process of enculturation (Brown, Collins, & Duguid, 1989) and the theories of Situated Cognition and Cognitive Apprenticeship (Hennessy, 1993) advocated modelling within context. Bereiter's theory of learning (1992) dealt with the concept of different types of knowledge, including procedural knowledge, which takes place in context and is integral to technological practice. Constructivist theories considered the construction of knowledge within a given framework (Vygotsky, 1978). An authentic framework will directly influence knowledge gained. Expert Knowledge Theory (Bereiter, 1992), Anchored Instruction (Vygotsky, 1978), and Apprenticeship Models (Rogoff, 1990) all advocated the use of experts or experienced practitioners as a key component to learning.

Hennessy and Murphy's definition relates very clearly to the Ministry of Education's vision (2007) for New Zealand's young people to become confident, connected, actively involved, and lifelong learners. Splitter (2008) also made these connections when he discussed what it means to live authentically:

> In so doing (living authentically) we tap into one of the most promising veins in contemporary educational thought, namely, that what lie at the heart of education are not learning, truth and knowledge, but thinking, meaning and understanding. (p. 136)

Dictionaries connect *authentic* to words such as accurate, actual, authoritative, bona fide, genuine, original, true-to-life, and trustworthy. These all seem extremely positive values and understandings for full participation in society.

Authenticity and Technology Education

We believe that Technology Education is the most effective subject area in engaging students in authentic learning. The literature on authentic practice mentioned above supports students undertaking real-world collaborative practice and this is often the norm in Technology Education. These connections can be clearly seen in the definition of Technology in *The New Zealand Curriculum* (Ministry of Education, 2007), which features statements such as:

- technology is intervention by design
- the use of practical and intellectual resources to develop products and systems
- expanding human possibilities by addressing needs and realising opportunities
- quality outcomes result from thinking and practices that are informed, critical, and creative
- it is influenced by and in turn impacts on the cultural, ethical, environmental political, and economic conditions of the day

Technological literacy is developed through the construction and application of three key knowledge types, which include Technological Practice ("know how"), the Nature of Technology ("know why"), and Technological Knowledge ("know that") (Compton & France, 2007; Ministry of Education, 2007). Current literature (Snape & Fox-Turnbull, 2013; Fox-Turnbull, 2007; Hennessy, 1993; Turnbull, 2002) discusses authenticity in technology through specific links to a student's context and real technological practice. Snape & Fox-Turnbull (2013), Turnbull (2002), and Fox-Turnbull (2007) identified and expanded on the role of authenticity within the Technology Education curriculum. Authenticity in technology education is predominantly based on connecting students' understanding to meaningful and real-world situations and on their involvement in technological practice that is similar to practicing technologists while using authentic tools and processes. Hennessey and Murphy (1999) explained that authentic practice involves situations that are real to the student, their lives, and to situations they may encounter in the future workplace. Activity embedded in authentic technological practice is more likely to produce increased student engagement and greater understanding, while providing opportunities for students to identify, simulate, and relate to the tacit knowledge of technologists. One method of learning that assists authenticity in technology is known as Guided Inquiry.

Guided Inquiry Learning

Inquiry learning is set within a socio-constructivist paradigm in which students are encouraged to construct their knowledge and understandings within their own cultural settings. It is a process that enables students to take greater ownership of and responsibility for their learning. It encompasses a wide range of skills and processes in active learning, leading to a much broader understanding of the world the students are part of. This approach is based on the constructivist theoretical foundations of learning (Kuhlthau, Maniotes, & Caspari, 2007).

One inquiry learning strategy that focuses on the facilitation of independent knowledge-based learning is Guided Inquiry (Kuhlthau et al., 2007). In order to stimulate and develop the child's curiosity and thinking, adults need to interact with children at their *potential* level, not at their actual level (Fleer, 1995). The Guided Inquiry approach reflects the belief that, for learners, active involvement in construction of their knowledge is essential for their effective learning (Kuhlthau et al., 2007; Murdoch, 2004). Inquiry is guided and systematic learning that proceeds through a number of teaching/learning phases. It is very different from "open" discovery learning in that the teachers have a major and continuing responsibility to structure a range of activities sequenced to maximize the development of skills and thinking processes of the learners.

Guided Inquiry uses a wide range of teaching approaches, from teachers' exposition to independent student research (Murdoch, 2004). Inquiry methodology and integrated curricula are also supported by Caine and Caine (1990, cited in Murdoch, 2004). They argued that the brain seeks patterns, meaning, and connectedness—methods that move from rote memorization to meaning-centred learning (Murdoch, 2004). Guided Inquiry involves students in developing deep learning through the process of self-motivated inquiry that strives towards development of "big understandings" and "rich concepts" (Kuhlthau et al., 2007; Murdoch, 2004) about the world and how it functions (Blythe, 1998). Like technology education, Guided Inquiry learning is centred on both *process* and *content*, with students taking considerable ownership and responsibility (Murdoch, 2004).

Guided Inquiry is one approach that teachers can use to enable them to plan and implement a constructivist classroom that meets the needs of, and extends learning capacity for, individual students. This process is outlined in Table 1. In the first phase, in most cases the teacher announces a topic of study that requires thorough research, thus *initiating* the inquiry process. During this time the students are prepared for selecting a topic of research through a variety of immersion activities. A range of strategies motivate and engage students; we suggest this phase is more likely to include learning through acquisition than later phases. During this phase it is not unusual for students to feel uncertain and perhaps "bogged down." The second phase involves students in the *selection* of a topic of study and identifying significant questions within the unit they will be working on. Topics come with many parameters or points of interest for the students, including assessment requirements, time available, and resources or information available. During this time students may feel optimistic about the journey ahead. *Exploration*, the third phase, involves sifting through information available to find a focus. Students need to be well informed about the general topic in order to find an area to focus on. This is a most difficult phase, where an abundance of open-ended questions and wonderings abound and confusion and doubt can set in. Students can become easily frustrated and discouraged. At this phase in the project many students drop their projects when they come across inconsistencies within the information and find incompatibilities with what they might already know. The fourth phase is *formulation* and is a time when students identify ways to focus and organise their topic, which provides a degree of clarity. The next phase, *collection*, follows naturally with an extended focus on how to present the new understandings. They now have a sense of direction and increased confidence as they take ownership.

Table 1. *Model of the Information Search Process (*Kuhlthau et al., 2007, p. 19). Reformatted by authors.

Phases	**Feelings** (affective)	**Thoughts** (cognitive)	**Actions** (physical)
Initiative	Uncertainty	Vague	Seeking relevant Information: Exploring
Selection	Optimism		
Exploration	Confusion, Doubt, Frustration		
Formulation	Clarity	Focused	
Collection	Sense of direction/ confidence	Increased self-awareness	Seeking pertinent information: Documenting
Presentation	Satisfaction, Disappointment		
Assessment	Sense of achievement		

Once they have gathered all the required information, students will consider the nature of the presentation they will use to share their findings. Presentation may consider a range of styles from informal to formal outcomes. Often these may become celebrations that can be shared with peers, parents, or other stakeholders in the problem or issue. The *assessment* phase concludes the project as both teachers and students judge what has been learned about content and process. This is a time to critically reflect and evaluate on the inquiry process as a whole. It shouldn't, however, be confused with formative assessment of content and process, which is ongoing throughout the project (Kuhlthau et al., 2007).

Guided Inquiry offers students an opportunity to build on what they already know and to gain new knowledge through active engagement in and reflecting on a learning experience. Students are able to develop and use higher-order thinking skills with teacher guidance at critical points in the learning and development process. It allows for different modes of learning to be catered for and facilitates learning through social interaction with others. Students learn through instruction and experience that aligns with their cognitive development (Kuhlthau et al., 2007). These aspects of Guided Inquiry are critical features of the way Randall encourages and engages his students to think, collaborate, and problem solve as active participants in their projects.

Findings and Discussion

Teacher Randall Grenfell and the students in his 2014 GATE project team (Figure 4) were interviewed by the authors. The students were interviewed in a face-to-face focus group meeting and the teacher via email the same day as the students. The students were also observed working on their project, with photographs of the students taken while they worked. The aim of the interviews was to determine the views and perceptions of students and their teacher about the programme. There were 10 students in the group, four girls and six boys, all in Year 8 (12 years of age).

Figure 4. Some of the 2014 team with their work in front of them. (Photo by author, parental and student consent given.)

From these discussions, three themes emerged regarding the programme. These included perceptions of Technology GATE programme advantages, with an understanding of the reasoning underpinning these advantages, and the specific skills and knowledge learned. Randall identified a number of drawbacks for himself, his students, their parents, and the school.

Advantages with Reasoning

The students identified a number of advantages of participating in the programme. The first major advantage was that they were able to work without distractions. Randall also identified this as an advantage for the students. "The students don't like having to wait for others to catch up to them. There is no upper limit to their learning. They are motivated by possible profit, and they are working with like-minded students" (personal communication, 8 August 2014).

The students also liked that they got to work with other peers (not necessarily their friends). They appreciated being able to assist each other and draw on the different skills and knowledge of their peers. Randall noted in his interview that within the group, "There were no behaviour issues." He felt that working with students in an authentic team environment, and working with students who also learned at an accelerated rate, was beneficial in terms of student learning outcomes. The students stated in their focus group interview that they liked working with other people who also wanted to work.

Kuhlthau and colleagues (2007) suggested that inquiry learning is based on constructivist principles and is student-led. The approach to learning the students undertook was a form of Guided Inquiry, because after the initial immersion stage, when talking to an occupational therapist the students themselves drove the direction of the project. This illustrates that teachers can use this approach to help them plan and implement a constructivist approach to classroom learning that meets the needs of, and extends learning capacity for, individual students.

The students felt they got a better understanding of ideas, skills, and knowledge through visiting and talking to professionals while learning information, knowledge, and skills they could not have learned in the regular classroom. "Learning other stuff that we wouldn't have otherwise known" (focus group interview, 8 August 2014). The students also understood that their learning was relevant to their possible future lives and that it resembled the practice of engineers. One of the things they said they liked about the programme was that "we looked at their product and how they developed the stuff" (focus group interview, 8 August 2014). This aligns with what Hennessey and Murphy (1999) said about authentic practice. These students appreciated the opportunity to be involved in a situation they may encounter in the future workplace. The students also stated that they were "learning stuff we might need in the future" (focus group interview, 8 August 2014). Activity embedded in authentic technological practice is more likely to produce greater understanding and provide opportunities for students to identify, simulate, and relate to the tacit knowledge of technologists (Hennessy & Murphy, 1999).

The students also said that undertaking this project assisted them when thinking about future careers. We asked the students what they would like to do when they grow up. Seven of the ten mentioned technology-related professions, with three wanting to be engineers, three architects, and one a designer. This supports Turnbull (2002) and Fox-Turnbull's (2007) notions of the role of authenticity within Technology as it connected students' understanding to real-world situations. "We were learning stuff we might need in the future," and they learned "how to go through the design process" (focus group interview, 8 August 2014).

Another of the evident benefits that came from the visits the students undertook in the early stages of their project and from interactions with their engineer mentors was that they gained an understanding about the feasibility of their proposed project. They learned "whether our product was able to be made" (focus group interview, 8 August 2014). Randall also noted that the parents took an interest in their children's learning and recognised the importance of learning authentically at an accelerated rate.

Skills and Knowledge Learned

When asked during their focus group interview whether making or learning was more important, the students immediately said "learning." They then suggested that the making was also important and that the two go hand-in-hand, and that therefore both were equally important. One of the factors this year's students said influenced their decision to enter the programme was the success of the previous year's group. This aligns with Fleer's (1995) notions that interaction with students needs to be at their *potential* level, not at their actual level. These students took on a project well beyond their capability but had role models in the previous group of students.

The students also identified that they learned specific collaborative skills. In order to stimulate and develop curiosity the students were taken to an engineering workshop, were visited by an occupational therapist, and worked with mentor engineers on their project. The students felt they learned to "work with different people" (focus group interview, 8 August 2014). The whole group developed its products collaboratively as a team effort. There is also a considerable body of knowledge on understanding how conversations between students can enhance learning (Alexander, 2008; Mercer & Dawes, 2008; Mercer & Littleton, 2007). When working collaboratively and co-operatively with peers, the students needed to seek the opinions of experts and stakeholders from the wider community to enable them to participate successfully. For a group of students to be able to work collaboratively and co-operatively on the development of single technological outcomes, clear communication and, ultimately, consensus is essential. The very nature of developing technological solutions also includes problem solving. Students needed to be able to discuss, debate, disagree, and reason with an open mind to solve the technological problems they encountered.

During their focus group interview the students identified a range of practical skills and knowledge learned. These included sketching and drawing, digital design, wood construction, and 3D printing plastic designs. They also learned about marketing and patent and copyright laws. Expert Knowledge Theory (Bereiter, 1992), Apprenticeship Models (Rogoff, 1990), and Anchored Instruction (Vygotsky 1978) all advocated the use of experts or experienced practitioners as a key component to learning. These students clearly demonstrated this and made the most of the expertise available to them.

Drawbacks of the Technology GATE Program

In his interview, Randall identified a number of drawbacks of the programme. The students did not mention any of these (although they were not specifically asked). From Randall's perspective the project was extremely time consuming, and it required a significant amount of paperwork and time to organise the field trips and mentor visits. This was because none of the work was completed during the students' timetabled technology classes; instead, they came to the programme in the teacher's release time, at lunchtime, after school, and during the school holidays. Randall also felt the programme added to the already busy life of GATE students who were typically engaged in a number of extra-curricular activities. Randall also mentioned that some of the other teachers in the school saw the programme as elitist and didn't like it. Randall felt that one drawback for the parents was that they were frequently asked to sign permission slips for trips and for photographic recording.

Conclusion

This chapter has outlined an exemplary practice in technology education in New Zealand. The programme was offered to a small group of students identified as gifted and talented learners, many so identified in a range of areas. The students and their teacher were motivated and engaged in technological practice, but one cannot help ask the questions "Could this approach work in the mainstream, and if so, what modifications would be required?" In answering the first question, Randall said "Yes, it's called authentic STEM learning" (personal communication, 8 August 2014).

Increased and enhanced student engagement through the student-centred nature of Randall's programme and utilisation of a Guided Inquiry type approach have made teaching and learning more meaningful. The authenticity of the technology contexts he has used and the way that practitioners in the community and their workplaces have been employed has been significant in the success of this GATE programme at Christchurch South Intermediate. Randall's passion for technology education and learning through authentic practice has been a key factor in a programme that makes a significant difference in his students' development.

It seems to us as observers of this programme that it would be possible and extremely exciting for students to be making a difference in their local community. However, the success of such a programme in the mainstream would depend on a number of critical factors, including support from school management, a willingness to allow teachers to take risks within their classroom practice, support through appropriate budgeting, and active community engagement. Also required would be a significant pedagogical shift for teachers, enhanced facilities, and timetabling freedom, to allow students to work on projects across a range of technology areas (food, structural, resistant and soft materials, ICT, control, and biotechnology) and other academic disciplines (English, mathematics, science, and social students).

Figure 5. The winning team with their, certifcates, prizes, and teacher- Randall. (Photo courtesy of Randall Grenfell, parental and student consent given.)

Endnote: In 2014 Randall's students won the "Transpower Neighbourhood Engineers MERIT" Award. Figure 5 shows the winning students (minus one girl). With the $1500 prize money, Randall bought them all toolboxes full of new tools "to encourage future engineering thought processes."

References

Alexander, R. (2008). *Towards dialogic teaching: Rethinking classroom talk* (4th ed.). Cambridge: Dialogos.

Alton-Lee, A. (2004, November). A collaborative knowledge building strategy to improve educational policy and practice: Work-in-progress in the Ministry of Education's Iterative Best Evidence Synthesis Programme. In *A Symposium at the New Zealand Association for Research in Education National Conference*.

Blythe, T. (1998). *The teaching for understanding guide*. San Francisco: Jossey-Bass.

Bereiter, C. (1992). Referent-centered and problem-centred knowledge: Elements of an educational epistemology. *Interchange, 23*(4), 337-361.

Brown, J., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Education Researcher, 18*(1), 32-42.

Christchurch South Intermediate School. (2014). *Christchurch South Intermediate.* Retrieved from http://www.ero.govt.nz/Early-Childhood-School-Reports/School-Reports/Christchurch-South-Intermediate-02-12-2009/About-The-School

Compton, V., & France, B. (2006). *Discussion document: Background information on the new strands*. Wellington, NZ. Retrieved from www.techlink.org.nz

Compton, V., & France, B. (2007). Redefining technological literacy in New Zealand: From concepts to curriculum constructs. In J.R. Dakers, W.J. Dow, & M.J. deVries (Eds.), *PATT 18- Teaching and Learning Technological Literacy in the Classroom* (pp. 259-272). Glasgow, Scotland: University of Glasgow.

Compton, V., & Harwood, C. (2007). *Design ideas for future technology programmes*. Wellington, NZ: New Zealand Ministry of Education.

Dakin, J.C. (1973). *Education in New Zealand.* Auckland, NZ: Fullerton.

Fleer, M. (1995). Staff-child interactions—a Vygotskian perspective. *Canberra: Australian Early Childhood Association, Inc., 1*.

Fox-Turnbull, W. (2007). *Teacher education in technology through a constructivist approach.* In J.R. Dakers, W.J. Dow, & M.J. deVries (Eds.), *PATT 18- Teaching and Learning Technological Literacy in the Classroom* (pp. 63-75). Glasgow, Scotland: University of Glasgow.

Gordon, L. (1992). The New Zealand state and educational reforms: "competing" interests. *Comparative Education*, *28*(3), 281-291.

Hennessy, S. (1993). Situated cognition and cognition apprenticeship: Implications for classroom learning. *Studies in Science Education, 22*, 1-41.

Hennessy, S., & Murphy, P. (1999). The potential for collaborative problem solving in design and technology. *International Journal of Technology and Design Education, 9*(1), 1-36.

Hill, A.M., & Smith, H.A. (1998). Practice meets theory in technology education: A case of authentic learning in a high school setting. *Journal of Technology Education, 9*(2), 29-45.

Hinchco, B. (n.d.). *A history of middle schooling in New Zealand.* Retrieved from http://www.edusearch.co.nz/articles/3/article.htm?pagenum=1

Institution of Professional Engineers New Zealand. (n.d.). *futureintech.* Retrieved from http://schools.futureintech.org.nz/OurServices.cfm

Jones, A. (2006). The developing field of technology education in New Zealand: The last twenty years. In M. de Vries & I. Mottier (Eds.), *International Handbook of technolgy education* (pp. 197-211). Rotterdam: Sense Publishers.

Kuhlthau, C., Maniotes, K., & Caspari, A. (2007). *Guided inquiry: Learning in the 21St century*. Westport CT: Libraries Unlimited, Inc.

McAlpine, D., & Reid, N. (1996). *Teacher observation scales for identiofying children with special abilities.* Wellington, NZ:

New Zealand Council for Educational Research, and Palmerston North: Massey University ERDC Press.

Mercer, N., & Dawes, L. (2008). The value of exploratory talk. In N. Mercer & S. Hodgkinson (Eds.), *Exploring talk in school* (pp. 55-71). London: Sage Publications Ltd.

Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking--a sociocultural approach*. Oxon: Routledge.

Ministry of Education. (1993a). *The New Zealand curriculum framework*. Wellington, NZ: Learning Media.

Ministry of Education. (1993b). *Technology in the New Zealand curriculum - draft for consultation*. Wellington, NZ: Learning Media.

Ministry of Education. (1995). *Technology in the New Zealand curriculum*. Wellington, NZ: Learning Media.

Ministry of Education. (2007). *The New Zealand curriculum*. Wellington, NZ: Learning Media.

Ministry of Education. (2014a). *The national administration guidelines (NAGs).* Retrieved from http://www.minedu.govt.nz/theMinistry/EducationInNewZealand/EducationLegislation/TheNationalAdministrationGuidelinesNAGs.aspx

Ministry of Education. (2014b). *The national education guidelines (NEGs).* Retrieved from http://www.minedu.govt.nz/theMinistry/EducationInNewZealand/EducationLegislation/TheNationalEducationGuidelinesNEGs.aspx

Murdoch, K. (2004). *Classroom connections – strategies for integrated learning.* South Yarra: Eleanor Curtain Publishing.

Riley, T., Bevan-Brown, J., Bicknell, B., Carroll-Lind, J., & Kearney, A. (2004). *The extent, nature and effectiveness of planned approaches in New Zealand schools for providing for gifted and talented students.* Final report. Wellington, NZ: Ministry of Education. Retrieved from www.educationcounts.govt.nz/publications/schooling/5451

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York, NY: Oxford University Press.

Snape, P., & Fox-Turnbull, W. (2013). Perspectives of authenticity: Implementation in technology education. *International Journal of Technology and Design Education,23*(1), 51-68.

Splitter, L. (2009). Authenticity and constructivism in education. *Studies in Philosophy and Education, 28*(2), 135-151.

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. *International Journal of Technology and Design Education, 12*(1), 23-40.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), *Mind in Society* (pp. 19-119). Cambridge, MA: Harvard University Press. (Original work published in 1930.)

Using Curricular and Co-Curricular Activities in a Technology and Engineering Education Program at a STEM Magnet Middle School

Chapter 6

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The School Setting: Hanes Magnet Middle School

Hanes Magnet Middle School is part of the Winston-Salem/ Forsyth County School system in North Carolina. Located in the heart of downtown Winston-Salem, Hanes Magnet is home to just over 1,000 sixth to eighth grade students who travel across the county to attend this nationally-recognized magnet school. Hanes Magnet is part of the North Carolina Public School's STEM Initiative and is recognized as a STEM School of Distinction.

According to Magnet Schools of America,

> Magnet schools are free public elementary and secondary schools of choice that are operated by school districts or a consortium of districts. Magnet schools have a focused theme and aligned curricula in Science, Technology, Engineering, and Mathematics (STEM), Fine and Performing Arts, International Baccalaureate, International Studies, MicroSociety, Career and Technical Education (CTE), World Languages (immersion and non-immersion) and many others. Magnet schools are typically more "hands on – minds on" and use an approach to learning that is inquiry or performance/project based. They use state, district, or Common Core standards in all subject areas; however, they are taught within the

> overall theme of the school. (Magnet Schools of America, 2013, para. 1.)

At Hanes Magnet, the focus is on STEM, with an emphasis on engineering in the Technology, Engineering and Design (TED) Education program. Their mission, "Educating and inspiring future engineers, innovators, and thinkers....people who will change the world" (Hanes Magnet School, 2015a), highlights this emphasis on STEM education. The TED program consists of three teachers and utilizes the Project Lead the Way™ curriculum. Hanes Magnet is also the proud sponsor of more than a dozen STEM student organizations, including the Technology Student Association (TSA), First Lego League, Math Counts, Science Olympiad, Sea Perch, Team America Rocketry Club (TARC), Odyssey of the Mind, and Future City. These co-curricular and extra-curricular organizations provide the students at Hanes Magnet with the opportunity to increase their knowledge through "hands on, minds on" activities, and they provide meaningful connections to the real world. In an article for the *Winston-Salem Journal*, Melita Wise, Principal of Hanes Magnet, said that approximately one-third of Hanes students participate in at least one of the STEM-related after-school clubs (Herron, 2013). In 2013, Hanes Magnet Middle School was named the top magnet school in the country at the non-profit Magnet Schools of America national conference. This award recognizes a school for innovative programming, academic achievement, and promoting diversity.

Hanes Magnet's innovative approach to instructional programming is centered on inquiry and problem-based learning (PBL). Both of these approaches are student-centered and allow the students to dive deeper into their learning experience by asking questions and solving problems. STEM is celebrated at Hanes through showcase events, guest speakers (see Figures 1 to 3), publicity, an Engineer's Week, and student recognition. The teachers at Hanes Magnet are intentional in their efforts to identify interdisciplinary connections. Teachers offer quarterly design challenges at each grade level and in each content area.

Figure 1. Lunch and Learn with business and industry partners: Jeff Stallings is a LEED certified engineer. (https://twitter.com/HanesMagnetScho/media)

They strengthen and enrich their students' classroom experiences through the use of learning teams and the integration of STEM content and processes in all academic areas and exploratory subjects. Summer programs related to STEM and robotics are also provided as enrichment for the students. As a result of these efforts, STEM education has greatly increased in Winston-Salem/Forsyth County Schools and now includes five schools. This expansion provides support for programming and enables the county to create a much needed K-12 continuum related to STEM education.

Figure 2. Lunch and Learn with business and industry partners. (https://twitter.com/HanesMagnetScho/media)

The teachers at Hanes Magnet are focused on continuous student development as well as on professional development. Through the support of their administration, the Winston-Salem/Forsyth County magnet schools director, and the on-site STEM coordinator, teachers are able to engage in discussions and site visits that strengthen industry and postsecondary partnerships. The teachers are also involved in monthly professional development sessions related to problem-based learning. This training occurs through The Center for Excellence in Research, Teaching and Learning (CERTL) at Wake Forest School of Medicine. CERTL's professional development offerings meet the individual needs of the teachers and also focus on "assisting them to integrate the National Science Education Standards and National Council of Teachers of Mathematics Standards with problem-based learning" (Wake Forest School of

Medicine, 2014, para. 1). Through these intensive hands-on sessions, teachers learn about PBL management, problem-case development, and assessment. Teachers at Hanes also engage in professional development related to academic and intellectually gifted (AIG) learners and differentiated instruction. Natalie Norman, TED teacher and the school's STEM coordinator, believes that the PBL training has made a huge impact on the teaching in her classroom.

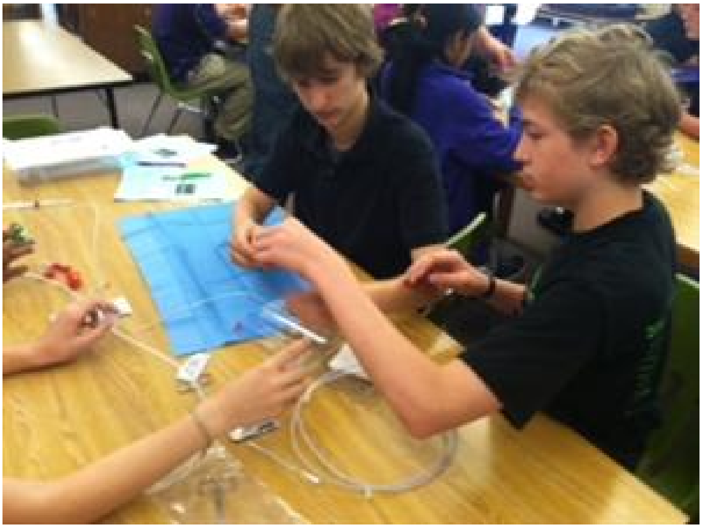

Figure 3. Students working on a project involving medical feeding devices during a visit from two local bioengineers. (http://www.wsfcs.k12.nc.us/Page/87037).

According to Natalie, PBL allows her to structure the projects in her classroom to be focused around a problem:

> By doing this the students are able to search to find their own answers and be more creative in their solutions. PBL also allows students to work in cooperative learning groups to develop a certain skill set for collaborative problem solving. It incorporates brain mapping and the use of Know, Want to know,

> Learn [K-W-L] charts so you can see what direction each student/group is heading and why. It also allows the students to become more confident in their learning and their own ability to solve a problem by understanding that there is no wrong answer, as long as they can justify the fact.

Material provided on the National Education Association website describes K-W-L charts as follows:

> K-W-L (Ogle, 1986) is an instructional reading strategy that is used to guide students through a text. Students begin by brainstorming everything they **Know** about a topic. This information is recorded in the K column of a K-W-L chart. Students then generate a list of questions about what they **Want to Know** about the topic. These questions are listed in the W column of the chart. During or after reading, students answer the questions that are in the W column. This new information that they have **Learned** is recorded in the L column of the K-W-L chart. (National Education Association [NEA], 2015, para. 1)

K-W-L charts promote active learning and comprehension by providing a visual depiction of content for the learner. K-W-L also provides a useful strategy for built-in assessment and planning (Figure 4).

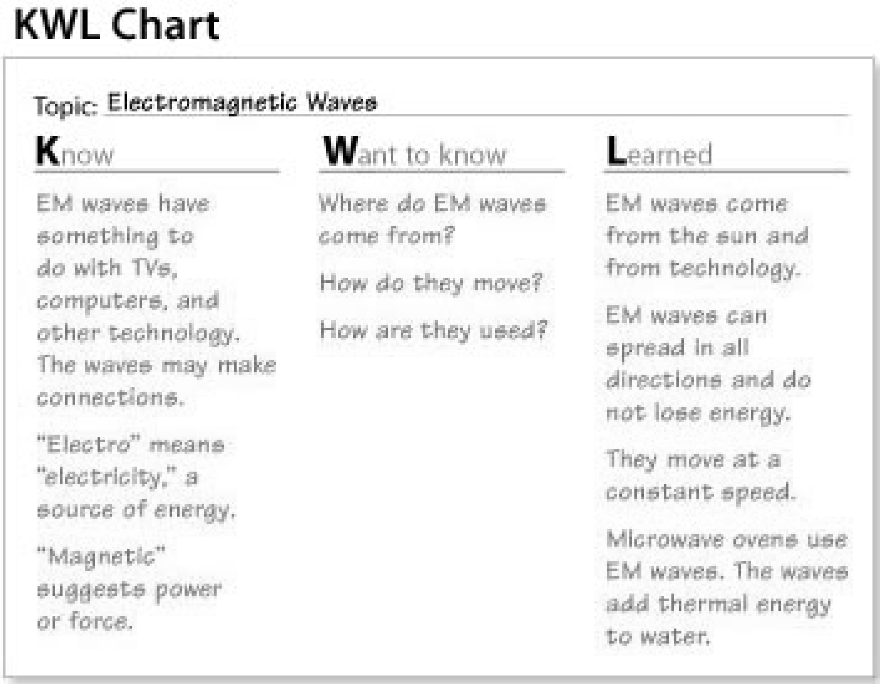

Figure 4. Sample K-W-L chart (Thoughtful Learning, 2014).

Engineering at Hanes Magnet Middle School is defined as "the application of creativity in partnership with math, science, social studies, language arts and fine arts to search for quicker, better and less expensive ways to use the forces and materials of nature to meet today's challenges" (Hanes Magnet School, 2015b, para. 1). Teachers and students view engineers as "problem solvers who use every resource possible to bring into existence things and ideas that they imagine" (Hanes Magnet School, 2015b, para. 1). Providing students with this solid foundation in STEM education is critical to the mission of the school. Teachers create and implement student learning experiences that articulate with what they have identified as the "four key elements of engineering: Engineering Habits of Mind, Engineering Design Process, Systems Thinking and Problem Solving" (Hanes Magnet

School, 2015b, para. 2). In keeping with the recommendations of the National Academy of Engineering (Katehi, Pearson, & Feder, 2008), teachers at Hanes Magnet School work to create learning environments that align with 21st century learning skills such as collaboration, communication, and creativity, along with habits of mind such as optimism about the ability of technology and engineering to solve problems and attention to the ethical considerations that must accompany these solutions. These learning experiences include in-class experiences, co-curricular, and extracurricular activities.

In the TED classes at Hanes Magnet Middle School, it is easy to see PBL in action on a daily basis through the use of the Project Lead the Way™ curriculum. Each TED teacher has received specialized training from PLTW to teach its curriculum. They also meet regularly as a team to receive updates and discuss best practices for each unit. According to Natalie,

> 70% of the students take one or more of the Technology, Engineering and Design classes over the course of their three years at Hanes Magnet. Students involved in the performing arts are often unable to get into the TED classes due to scheduling conflicts. Sixth grade students can take Design and Modeling and Automation and Robotics. In the seventh grade, students can take the Science of Technology and Flight and Space. Finally, in the eighth grade, students can take the Magic of Electrons and Energy and the Environment.

Each of the courses is a semester long, and all classes are part of the PLTW curriculum. One of Natalie's favorite examples of PBL is in the 6th grade course, Design and Modeling. Students are given a problem where they have to interview a person with a disability (physical or age-related), then design an assistive device to meet the interviewee's specific needs. Over the years, students have designed and modified numerous things as a result of this assignment. Some examples include wheelchairs and crutches to meet specific needs. One student even designed a diabetic shoe that had a special insole that monitored the circulation in the foot.

In seventh and eighth grade, students are able to build bridges and begin working with robotics. These initial experiences serve as feeders for the various STEM organizations at Hanes Magnet School, and specifically for its Technology Student Association (TSA) chapter. Natalie and the other TED teachers watch for students to "find their niche" in class, then encourage the students to get involved in the student organizations after school. Getting the students "hooked" on engineering in the sixth grade is one of the fundamental techniques for success, according to Natalie.

The PLTW curriculum has several lessons that align nicely to the TSA's competitive events, as well as other organizations' competitive events. TSA is a national organization of students engaged in science, technology, engineering, and mathematics (STEM) and is open to students enrolled in, or who have completed, technology education courses (Technology Student Association [TSA], 2011, para. 3). Further investigation shows just how similar activities and approaches within PLTW and TSA are. Both promote teaching leadership. In addition, TSA provides an opportunity for state and national recognition through its leadership competitions at the middle and high school level. Both utilize the VEX robotics platform for curricular and competitive events. Both PLTW and TSA provide scholarship opportunities and have been demonstrated to increase the likelihood of college attendance (Project Lead the Way [PLTW], 2014, para. 6; TSA, 2011, para. 2). Anecdotal evidence suggests that both TSA and PLTW increase student test scores in core subjects and their overall knowledge of STEM (PLTW, 2014, para. 4; Taylor, 2006, para. 28). In addition, both align with national science, mathematics, and technology standards. Similarities between PLTW and TSA also include use of the engineering design process and inclusion of the latest technologies.

TSA's competitive events are best utilized when delivered through a co-curricular method, which is one key difference between PLTW and TSA. PLTW professional development training focuses on teaching the curriculum exactly the way it was designed by the vendor. TSA's overall nature and philosophy, as a Career and Technical Student Organization (CTSO), focuses on integrating the competitive events into the curriculum, in addition to providing extra-curricular experiences. This, however, does not mean that the two entities cannot exist and work together. TSA has seen growth in its membership as a result of PLTW adoption in middle and high schools (Roseanne White, personal communication, October 26, 2015). In North Carolina, TSA serves as the primary CTSO for PLTW programs.

Table 1 shows which TSA activities align well with which PLTW courses for the middle grades. In North Carolina, PLTW teachers are also encouraged to show the integration of the competitive events in the curriculum (Brian Moye, personal communication, October 26, 2015). These competitive events complement and are easily substituted into the PLTW curriculum in order for students to have the competitive edge through various TSA competitions.

Hanes Magnet Middle School's "game plan" for mastering TSA competitive events at the regional (Figures 5 and 6), state, and even national levels is often what it is most known for. Under Natalie's leadership, the students have been recognized for the past five years as the middle school chapter of the year in North Carolina. Students have earned countless awards at the regional, state, and national levels over the years due to the approach outlined in Table 2.

Table 1. *PLTW Alignment to TSA Competitive Events* (Hogan & Taylor, 2015, p. 1)

Project Lead The Way (PLTW) Middle School Courses	**Technology Student Association (TSA) Competitive Events**
Design and Modeling	Mass Production Inventions and Innovations Construction Challenge Catapult Design CAD Foundations
Automation and Robotics	Microcontroller Design System Control Technology VEX Robotics
Energy and Environment	Environmental Engineering
Magic of Electrons	Electrical Applications
Flight and Space	Flight
Medical Detectives	Forensics Technology
All Courses	Challenging Technology Issues Communication Challenge Problem Solving Technical Design

Figure 5. Hanes Magnet School student preparing to compete at the western region NCTSA conference. (http://www.wsfcs.k12.nc.us/Page/87037)

Table 2. *Hanes Magnet Middle School's TSA "Game Plan"*

Academic Year Timing	TSA Chapter Activity
Week One – Meet with 6th grade only	• *Review events and all chapter requirements*
Week Two – Meet with 7th and 8th Grade	• *Review events and all chapter requirements*
Week Three - 6th Grade only	• *Review and sign up for group events only*
Week Four – 7th and 8th grade only	• *Sign up and make groups for team events*
Week Five – First meeting as a full chapter	• *Introduce chapter officers* • *Combine like group event topics* • *Create hard deadlines for all group events*
October through first meeting in December -- Group events only	• *All project notebooks due at first meeting in December* • *Review non-traditional presentation boards* • *Review small group and individual events (must have group events complete to qualify for small group, on site or individual event)*
January – February	• *Work on small group, individual, on-site events* • *Finalize presentation boards*
February	• *Peer review of events before regionals*
March	• *Modify events after regionals feedback*
April – June	• *Modify events after state conference feedback and results and prepare for nationals*

Figure 6. Hanes Middle School students competing in the Problem Solving event at the western region NCTSA conference (http://www.wsfcs.k12.nc.us/Page/87037).

Although a top-three finish at the TSA National Conference is never a guarantee as a result of following these types of procedures, Hanes Magnet Middle School and other schools in the state of North Carolina contribute their success at the TSA Nationals to their organized approach (Figure 7). Therefore, one would have to question if it is not definitely worth a try.

Figure 7. Hanes Magnet School teachers Natalie Norman and Brian Mendellson holding their NCTSA Chapter of the Year trophy (http://www.wsfcs.k12.nc.us/Page/87037).

The Teacher: Natalie Norman

Natalie Norman is a young and energetic STEM teacher. A graduate of East Carolina University, her original career plans included teaching middle grades math and science. After a serendipitous encounter with a former CTE director and family friend, Natalie quickly moved into the ranks of becoming a TED teacher at Hanes Magnet Middle School, where she has been teaching for over five years. With the support of her county, she has worked to transform Hanes Magnet's TED program by using the PLTW™ curriculum in her classes and by allowing the TSA's competitive events to serve as an extension of her class (Figure 8).

In 2014, Hanes Magnet was recognized as the Program of the Year for North Carolina by the International Technology and Engineering Educators Association (ITEEA). Hanes Magnet also received the TSA Chapter of the Year from National TSA in 2011. Natalie received the TSA Advisor of the Year for North Carolina from National TSA in 2013. Most recently, Natalie was recognized by the North Carolina Technology, Engineering and Design Educators' Association as the Young Educator of the Year. It is clear that Natalie's efforts and her students' successes are making an impact.

Figure 8. Hanes Magnet School students competing at the western region NCTSA conference (http://www.wsfcs.k12.nc.us/Page/87037).

Natalie believes that students learn best through problem solving. She encourages them to create a personal investment in their learning. This personal connection enables them to retain knowledge and apply it to future problems in their life. Students leave her class with basic engineering skills, as well as a systematic way to solve problems, whether education-related or not. She feels that the application of the steps of the engineering process can easily be incorporated into students' daily lives.

Natalie encourages her students to define the problem, generate concepts and possible solutions to the problem, develop a solution to the problem, construct and test their solution, evaluate, and then implement that solution. She emphasizes to students that this method can be incorporated into any problem in their life. "If students can synthesize the design process in this way, they can take a truly systematic approach to solving every problem in their life," according to Natalie. Natalie also expects students to leave her classroom with a certain set of skills, such as being able to complete basic tasks using a 3-D modeling program (specifically, Autodesk Inventor); using tools such as a dial and digital caliper; and understanding the purpose of, and how to use, everyday hand tools. Many of Natalie's students plan to go into managerial or engineering careers later in life. She also feels it is important that they understand the levels of engineering from the ground up. The various activities that Natalie incorporates into her classes foster self-motivation through problem solving and inquiry-based learning.

Natalie's teaching philosophy represents a combination of pragmatic and constructivist learning theories. She allows students to solve real-world problems through case studies and design briefs. She emphasizes brainstorming and the fact that more than one answer can be right. She wants students to know it is okay to not know the answer, and that not knowing means they have the chance to learn something new. Natalie also wants her students to understand that it is okay to fail. Through failure, students have an opportunity to design and innovate. According to Natalie, these are all attributes that will benefit them later in life.

Problem-Based Learning

Problem-based learning (PBL) originated in the 1950s in medical education. It is an instructional method that initiates student learning by creating a need to solve an authentic problem (Center for Innovation in Research and Teaching, n.d.). During the PBL process, students build content knowledge and develop problem-solving skills, along with self-directed learning skills, while working toward a solution to the problem (Hung, Jonassen, & Liu, 2008). Hanes Magnet Middle School's affiliation with the Center for Excellence in Research, Teaching and Learning (CERTL) at Wake Forest School of Medicine provides a natural tie to the origins of PBL, and also the needed professional development for academic and TED teachers.

Thomas (2000) used five criteria to define PBL: (a) "Projects are central, not peripheral to, the curriculum;" (b) "projects are focused on questions or problems that 'drive' students to encounter (and struggle with) the central concepts and principles of the discipline;" (c) "projects involve students in a constructive investigation;" (d) "projects are student-driven to some significant degree;" and (e) "projects are realistic, not school-like" (p. 3-4). Collaboration is also included as a sixth criterion of PBL.

The use of the PLTW curriculum, TSA, and numerous other extracurricular activities at Hanes Magnet provides students with many opportunities to be engaged in projects and to investigate and focus on real world problems. Most, if not all, of the projects and TSA competitive events have collaborative elements. These experiences allow the students to work together and to learn the importance of teamwork (Figure 9).

The characteristics of PBL were summarized by Hung, Jonassen, & Liu (2008) as follows:

- It is problem focused, such that learners begin learning by addressing simulations of an authentic, ill-structured problem. The content and skills to be learned are organized around problems, rather than as a hierarchical list of topics, so a reciprocal relationship exists between knowledge and the problem. Knowledge building is stimulated by the problem and applied back to the problem.
- It is student centered, so that faculty do not dictate learning or drive student outcomes.

- It is self-directed, such that students individually and collaboratively assume responsibility for generating learning issues and processes through self-assessment and peer assessment and access their own learning materials. Required assignments are rarely made.
- It is self-reflective, such that learners monitor their understanding and learn to adjust strategies for learning.
- Tutors are facilitators…who support and model reasoning processes, facilitate group processes and interpersonal dynamics, probe students' knowledge deeply, and never interject content or provide direct answers to questions. (pp. 488-489)

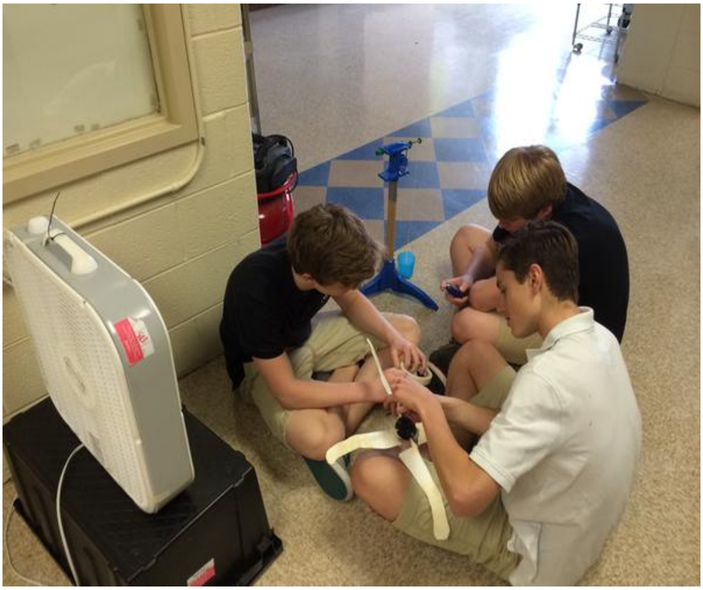

Figure 9. Students testing and adjusting a model wind turbine (http://www.wsfcs.k12.nc.us/Page/87037).

Hung et al. (2008) also cited research that suggests students learning through PBL retain content longer, have a deeper understanding of what they are learning, demonstrate better problem-solving skills, and are better able to apply what they learn to real-life situations. Hung et al. cited additional research that suggests students engaged in PBL show improved critical thinking and improved ability to work collaboratively and to resolve conflicts. The academic and competitive event successes seen at Hanes Magnet Middle School support this research (Figure 10).

Figure 10. Hanes Magnet School students placed second at a recent Future City Competition (http://www.wsfcs.k12.nc.us/Page/87037).

Project Lead the Way™

Project Lead the Way™ is one of many STEM-based curriculum models in the United States. Its endorsement by governors, state superintendents, principals, and teachers has enabled it to gain much popularity over the years. Currently, it is implemented in over 6500 schools in the United States. Project Lead the Way™ is a US non-profit organization that develops STEM curriculum for the elementary, middle, and secondary levels. In addition to its relevant but rigorous curriculum, it also provides intensive training for its teachers. PLTW is currently implemented in 40 counties and in over 150 schools in North Carolina. Research conducted by PLTW suggests that the program contributes to a strong, positive impact on mathematics and science achievement. Students completing PLTW courses were more likely to complete at least four years of mathematics (PLTW, 2014, para. 3). The PLTW web site claims:

- PLTW has a positive influence on students' career interest and likelihood to continue their education
- PLTW offers a pathway to prepare and motivate students to enter careers in science and engineering. (PLTW, 2014, para. 8).

Figure 11: Students working on their design challenges at STEM night at Hanes Magnet Middle School. http://www.wsfcs.k12.nc.us/Page/87037).

Tai (2012) examined research literature related to PLTW and its impact. Tai highlighted, among other studies, research that compared problem-solving behavior among PLTW students and students in a different program. This research found the PLTW students spent more time defining and analyzing problems than the control group, but less time generating solutions, which was described as more closely mirroring how engineers carry out their work. Tai also reported on the findings from three dissertations that had focused on PLTW. These found, respectively, "positive outcomes with respect to self-efficacy among PLTW black students," increased levels of "interest and achievement among middle school girls," and "academic resilience among technical college transfers going on to earn baccalaureate degrees" (Tai, 2012, p. 4). In addition, Tai referenced a study that incorporated multiple case studies of teacher professional development across five high school level engineering-focused curricular programs. PLTW was found to "be among the most comprehensive programs focused on instructor training, background, and follow-up support during the school year" (Tai, 2012, pp. 5-6).

Summary

Hanes Magnet Middle School's TED program provides an excellent example of best practices related to curricular and co-curricular engineering education at the middle school level. Through the use of problem-based learning, a structured curriculum related to engineering, business and industry partnerships, and the use of co-curricular and extra-curricular enrichment, one is able to understand why the school is recognized as a Model Magnet Middle School and a recipient of ITEEA's Program Excellence Award. However, it is equally important to emphasize that each of these attributes are carried out and expanded upon on a day-to-day basis by a teacher, Natalie Norman, who genuinely cares about her students and their well-being. Model schools are built by model teachers. Natalie is just one of the many teachers who make learning about engineering fun and effective at the middle school level.

References

Center for Innovation in Research and Teaching (CIRT). (n.d.). *Problem based learning in the classroom*. Retrieved from https://cirt.gcu.edu/teaching3/tips/pbl

Hanes Magnet School. (2015a). *About us: STEM education*. Retrieved from http://wsfcs.k12.nc.us/domain/6780

Hanes Magnet School. (2015b). The "E" in STEM. Retrieved from http://wsfcs.k12.nc.us/Page/67517

Herron, A. (2013, May 8). Hanes earns recognition as top magnet school in the nation. *Winston-Salem Journal*. Retrieved from http://www.journalnow.com/news/local/hanes-earns-recognition-as-top-magnet-school-in-nation/article_9c41a59e-b846-11e2-a989-001a4bcf6878.html

Hogan, J., & Taylor, J. S. (2015). *Table B: PLTW alignment to TSA competitive events*. Unpublished manuscript. Jefferson City, MO: Missouri Department of Elementary and Secondary Education.

Hung, W., Jonassen D., & Liu, R. (2008). In J.M. Spector, M.D. Merrill, J. Merrienboer, & M.P. Driscoll (Eds.). *Handbook of research on educational communications and technology* (3rd ed.), pp. 486 -500. London, England: Routledge.

Katehi, L., Pearson, G., & Feder, M. (2009). The status and nature of K-12 engineering education in the United States. *The Bridge: Linking Engineering and Society, 39*(3), 5-10. Retrieved from http://www.nae.edu/File.aspx?id=16147

Magnet Schools of America. (2013). *What are magnet schools?* Retrieved from http://www.magnet.edu/about/what-are-magnet-schools

National Education Association (NEA). (2015). *K-W-L (Know, Want to Know, Learned)*. Retrieved from http://www.nea.org/tools/k-w-l-know-want-to-know- learned.html

Ogle, D.M. (1986). K-W-L: A teaching model that develops active reading of expository text. *Reading Teacher, 39*(6), *564-570.*

Project Lead the Way™ (PLTW). (2014). *The impact of Project Lead the Way.* Retrieved from https://www.pltw.org/about-us/our-impact

Tai, R. H. (2012). *An examination of research literature on PLTW.* Retrieved from http://pltwmichigan.org/pdf/PLTW%20DR.TAI%20-%20brochure_0.pdf

Taylor, J. S. (2006) Student perceptions of selected Technology Student Association activities. *Journal of Technology Education.* 17 (2), 57-72. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v17n2/taylor.html

Technology Student Association (TSA). (2011). *Our story*. Retrieved from http://tsaweb.org/Our-Story

Thomas, J. W. (2000). *A review of research on project-based learning*. Retrieved from http://www.bobpearlman.org/BestPractices/PBL_Research.pdf

Thoughtful Learning. (2014). *Bring out the teacher in your students.* Retrieved from https://k12.thoughtfullearning.com/blogpost/bring-out-teacher-your-students

Wake Forest School of Medicine. (2015). *What is problem based learning?* Retrieved from http://www.wakehealth.edu/Research/CERTL/Problem-Based-Learning.htm

Wake Forest School of Medicine. (2014). *Professional development for K-12 teachers*. Retrieved from http://www.wakehealth.edu/Research/CERTL/Professional-Development-for-K-12-Teachers.htm

Helping Secondary Technology and Engineering Students Succeed

Chapter 7

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Introduction

The call for this collection of work was to highlight exemplary teachers in the field of engineering and technology education. This chapter provides an overview of one such teacher and a description of his teaching beliefs and practices. This chapter emphasizes various factors—past and present—that have influenced this individual's teaching. Due to the variety and complexity of this teacher's professional experiences, it is difficult to focus on a single element. Instead, an assortment of characteristics has been provided in an attempt to illustrate a wider range of educator concerns. Specific items of note include (but are not limited to) this teacher's non-traditional paths to teaching, student development, student motivation, and alternative funding sources. Each section is followed by a brief reflection focused toward prospective and experienced teachers alike.

I was initially introduced to Mr. Steve Marionneaux during a Science, Technology, Engineering, Mathematics, and Nursing (STEMN) outreach program sponsored by Berea College for the benefit of Madison County Schools in Kentucky. It was at this meeting that Mr. Marionneaux's strong focus on student learning and success was evident. Following the outreach program, he was placed on a short list of model/cooperating teachers for education majors within Berea College's Engineering and Technology Education concentration. It wasn't until I began this case study process that it became clear how valuable Steve's story would be for other professionals in the field.

I contacted Steve Marionneaux about this project in early Fall, 2014. Once he committed to the project, we scheduled a series of interviews and observations. The appointments varied in time of day and day of week in order to collect a complete picture of Mr. Marionneaux and his learning environment. The school at which he taught at the time, Woodford County High School in Versailles, Kentucky, maintained a block schedule though which class times averaged 95 minutes, depending upon the day and other scheduled events. During certain visits, other faculty and staff were asked questions about the school, the program, and Steve's approach to teaching.

The Teacher

Steve is currently a pre-engineering and robotics teacher at the high school level. At the time of my interviews with Steve he worked at Woodford County High School, and examples provided here to highlight his teaching are drawn from that school. However, he subsequently moved to the same position at another high school within Madison County, Kentucky, Madison Central High School.

Steve had an extensive career prior to entering into the classroom teaching profession. He spent more than two decades serving in the United States Army, both in active and reserve duty. While in the military, Steve did occupy a variety of instructional positions that would later direct him toward a career in education. During his enlistment, he was assigned to operational planning and training. Some of his responsibilities included tasking and coordinating military personnel. Prior to enlisting in the military, Steve considered a teaching career, but opted for the Army due to the experience he felt it would provide him and because of the financial prospects that were available at that time.

After retiring from the Army in 2000, Steve was still compelled toward a teaching career. He enrolled in the Troops to Teachers (TTT) program. The purpose of TTT "is to assist eligible military personnel to transition to a new career as public school teachers" (Troops to Teachers [TTT], 2014, para. 1). This program provides retired military personnel with an alternate route to certification. It was established by the Department of Defense in 1994 and is currently funded by the US Department of Education. To date, more than 17,000 teachers have been trained and employed through this program, nationally (TTT, 2014). It was this program that provided Steve provisional certification to teach while he completed his master's degree in education.

When he began classroom teaching, Steve took on the responsibility of serving as the teacher representative for the School/Site-Based Decision Making (SBDM) Council at his school. The SBDM is a shared leadership council that is comprised of teachers, parents, and an administrator of the school. The council is primarily responsible for establishing school policy in the interest of student achievement. The SBDM Council grew out of the 1990 Kentucky Education Reform Act (KERA) arranged by the state's Department of Education. A key function of this act was to shift the face of education, including school governance, mandating establishment of school-based decision-making bodies that would set policies to enhance student achievement and promote the schools' educational goals (Kentucky Department of Education, 2013a).

The timing of this act aligned with the recommendations by the Southwest Educational Development Laboratory (SEDL) and its emphasis aligned with the works of Harrison, Killion, and Mitchell (1989) and of Malen, Ogawa, and Kranz (1990). To achieve a functional council requires the support and investment of all involved. Harrison et al. were very clear about the challenges that such a process requires and cautioned against making the change until a series of questions and concerns are addressed (see Table 1). When Steve was asked why he took part in such a council—especially so early in his teaching career—his response was candid: He wanted to learn about the school system and its operations. He felt that working as a part of this council would provide him with detailed information about the school, the school system, curricular directions, and funding opportunities. The latter two were especially important to him due to his interest in improving engineering/technology education in the system, as well as in obtaining specific equipment for his classroom, clubs, and athletic activities.

Table 1. *Implementing Site-Based Management* (Harrison et al., 1989, p. 57)

Questions Districts Should Ask Before Implementing Site-Based Management
• What do we mean by site-based management?
• What roles need to be redefined, and how will we provide the necessary training and support?
• What are the parameters, expectations, or limitations of local site-based decision making?
• What do we know about the change process, and how does this apply to our situation?
• To what degree will variations and differences among schools within the district be accommodated?
• What underlying conditions must be present for site-based management to work? How can we clarify and communicate them?
• What can we learn from other organizations in the public and private sector about making the transition?

Steve also participated in the Student Technology Leadership Program (STLP) as a coordinator. STLP is a Kentucky Department of Education initiative that seeks to utilize "project-based learning principles to empower student learning and achievement through the utilization (and creation) of technology to solve school and community needs" (Kentucky Department of Education, 2014, para. 1). Steve participated in this program to improve the quality of the educational environment for his students while also attempting to give something back to the community. This goal is also reflected in his strong commitment to students outside the classroom, a topic to be discussed in greater detail later in this chapter.

The Teacher: Take-Away

Steve Marionneaux's story is not necessarily unique, but it does highlight what could be critical elements for becoming an involved teacher. His military experience surely provided him some foundational skills, both technical and social. However, it is the availability of, and access to, alternative pathways to teacher certification for individuals like Steve that provide the greatest promise. There is a wealth of knowledgeable and capable individuals in society who have collected amazing experiences that could be shared in our classrooms. However, alternate routes to teacher certification, including Troops to Teachers, are not widely publicized. In the state of Kentucky, there are at least eight options for teacher certification (not including emergency certification). They are:

Option 1: Exceptional Work Experience Certification
Option 2: Local District Training Program Certification
Option 3: College Faculty Certification
Option 4: Adjunct Instructor Certification
Option 5: Veterans of the Armed Forces
Option 6: University-Based Alternative Route to Certification
Option 7: Institute Alternative Route to Certification
Option 8: Teach for America Alternative Route to Certification (Kentucky Department of Education, 2013b).

Potential teachers (and teacher educators) should be made aware of the variety of certification options that exist within their state and/or districts.

Steve's participation in the SBDM was a large undertaking for a new teacher. The reason it is highlighted here is because it serves as an example of the potential gains in knowledge (and possible influence) acting as a member of such a group can present for new as well as for experienced teachers. Specifically for new teachers, participating in councils or committees will allow them access to information and colleagues that may take years to gain otherwise. On the other hand, such commitment requires more time out of the teacher's day, and time management will always be a concern. However, time could be better utilized if additional commitments like these are dedicated to those opportunities that possess the greatest potential for the teacher and his or her program. The SBDM model is also highlighted to illustrate that school districts around the country function under different sets of procedures. Teachers should be aware of these operating principles so that they may best function as part of their learning community.

Lastly, even though Steve was relatively new to the field, he was already looking for ways to improve upon his teaching. This is an admirable and valuable use of time for a teacher seeking ways to best benefit the students. Education (in all disciplines) is progressive. A teacher must attempt to remain active in the field to assure that he or she is providing a contemporary learning environment. This is not to suggest that teachers should change how they teach every time a new idea is publicized. Rather, teachers should be aware of the changes that are occurring in education and be responsive to those that they believe will benefit their students.

Middle School to High School

After spending almost fourteen years teaching at the middle school level, Steve decided to take an open position at a high school, Woodford County High School (WCHS). WCHS is a comprehensive high school located in Versailles, Kentucky, northwest of Lexington in central Kentucky. It is comprised of just over 1250 students between the ninth and twelfth grades. The school prides itself on providing "all students a rigorous and comprehensive program of studies in a safe and caring environment, preparing them to pursue their life ambitions and contribute to society" (Woodford County High School, 2014). WCHS was recognized as a Kentucky School of Distinction for the 2013-2014 academic term, ranking in the 97th percentile for the state of Kentucky.

Teaching at the middle or high school level requires a flexible approach to education. A teacher must be aware of the evolving characteristics of the students as they transition from childhood through adolescence and into young adulthood. "Besides the biological, environmental, and social factors influencing development, there is an array of life events including the tempo of social changes, race, family behaviors, and religion" (Hurd, 2000, p. 3). When shifting from the middle school into the high school realm, a teacher is literally moving with students along this developmental gradient. Although certain developmental concerns will extend bi-directionally into both middle and high school, most students in high school will be progressing toward adulthood. Until making this shift to teach at WCHS, Steve had only worked with adults or with middle school students. Other than raising his own children, this was his first experience teaching students at this developmental level.

When asked why he chose to make the shift to WCHS, Steve explained that he welcomed the change so that he could have a greater influence on students and their futures. While teaching at the middle school level, Steve felt the guidance he was offering his students (above and beyond his classroom instruction) was not having the long-term influence he desired. He didn't think the students were "taking it with them" to high school or thinking seriously about their future opportunities. Steve emphasized another component of his personal philosophy: the importance of building confidence and providing motivation—even serving as a role model—for certain "at risk" students. His words resonated in this case study.

A report issued by the United Nations noted that adolescents struggle with confidence, especially decision making. The same report also noted that a lack of confidence can manifest in many forms, such as avoiding conversations, refusing offers of assistance, declining favors, and not requesting that borrowed items be returned (United Nations, 2009). Another reality to be faced is that although children are physically maturing at younger ages, the transition to adulthood is taking longer to achieve (Rumbaut, Furstenberg, & Settersten, 2005; Waters, 2011). This shift has increased the reliance of adolescents and young adults on others—peers, parents, role models, and so on. Steve used his understanding of children's developmental levels at the middle school level, and has maintained this awareness while working with his high school students.

Middle School to High School: Take-Away

When entering into middle school or high school teaching, it is important to consider the developmental state that students are experiencing. Students will vary greatly along this gradient. However, acknowledging and understanding the potential implications of this gradient could help teachers adjust the learning experience to better meet their students' development needs. Of particular concern is the emotional state of the students and how they are coping with the constant changes and expectations that seemingly consume their existence. For example, at the high school level:

> Due to the evolving nature of college admissions, many students are now pressured by their parents to be excellent students, be active in sports, and perform community service. Their hectic schedules rival the busy lives of their parents. Thus, they may not receive appropriate support for emotional development. (Frydenberg & Reevy, 2011, p. xi)

Because of these pressures, students' experiences in school may be a more important foundation for them to build upon than teachers may at first acknowledge. Successful "adjustment to the school setting is likely to provide a strong foundation for successful adaptation during the transition out of secondary school to new roles and contexts" (O'Connor, Sanson, & Frydenberg, 2011, p. 112).

When Steve took on the high school teaching position he had to reconsider the majority of his classroom engagement and management techniques to reflect the new population of students and their emotional position. His desire to provide students greater amounts of confidence aligns with their developmental stage and needs. As he progresses in his role as a high school-level teacher, Steve must continue to help students develop a foundation from which they may draw elements of their adult identities.

WCHS maintains a strong position on student expectations, and this position was one that varied greatly from the schools at which Steve had taught previously. School culture presents another piece to this already complex puzzle. A teacher can—to his or her credit—implement an environment that is conducive to student development. However, if the school supports and embodies such environments, the chance for student success may increase exponentially across the school's population. Without question, a school's culture and expectations is something to consider when looking for a new teaching position.

Helping Students Succeed

Steve's own motivation for teaching is almost transparent. Anyone who has ever been fortunate enough to work with him can attest to that fact. He cares for his students and their futures—he wants them to succeed. This personal objective that Steve displays is not limited to his classroom or his subject. He has established a reputation for going above and beyond for students, assuring they receive available assistance when needed. This desire to promote student success appears to be heavily driven by Steve's life experiences: personal, spiritual, military, and professional.

Toward this goal, Steve spends a great deal of time working with his students, especially outside of the classroom. For example, he coaches sport teams and teams working on robotics, and serves as a club advisor, among other commitments. When asked why he does so many activities with his students outside of scheduled class time, he explained that the various activities allowed him access to his students in ways that may not be available during school hours. He believes that access, in this sense, does not simply refer to time, but to consideration of developing a student's full range of skills—their foundation for the future. Steve explained that allowing students to see you (the teacher) in a context other than your "defined" role may disarm the students from their preconceived notions and allow for greater connections to the students. These connections may open doors to student learning and success in ways that are not otherwise possible. He dedicates an inordinate amount of time to this effort, while also attempting to impart specific skills and life lessons.

This form of mentoring aligns well with the Vygotsky model of Zone of Proximal Development (ZPD) (Kozulin, 2003; Murphy, Mufti, & Kassem, 2009). The ZPD model looks at learning beyond the concept of basic knowledge transfer. It takes into account the emotional connection between two (or more) persons while building upon the cognitive (Murphy et al., 2009). The experience in the classroom could be the same as it is in the club room or on the field. The difficult part is to make the initial, vital emotional connection. It is not a connection that is exclusive to a student/teacher dynamic and is, therefore, available in a variety of contexts. Identifying and establishing these connections is a purposeful underpinning of Steve's teaching, mentoring, and coaching.

Helping Students Succeed: Take-Away

This section is simply an extension of the previous section, but also is an attempt to elucidate this example of how helping students achieve may be accomplished. Steve views this extracurricular mentoring as "getting to know [his] students and their needs." However, the literature on this topic takes a much stronger stance. It is estimated that over seven million school-age children in the U.S. are without adult supervision for some period of time once school lets out. This unsupervised allotment of time increases the likelihood of negative influences on students, while also increasing the threats to student development and achievement (Durlak & Weissberg, 2007; Weisman & Gottfredson, 2001). Many teachers have been open to spending time with students outside of scheduled class time, or have done so during their careers. It is important to consider how vital that time may be to student progression and success, in both the short and long term.

"Young people benefit when they spend time engaged in structured pursuits that offer opportunities for positive interactions with adults and peers, [that] encourage them to contribute and take initiative, and [that] contain challenging and engaging tasks that help them develop and apply new skills and personal talents" (Durlak & Weissberg, 2007, p. 10; see also American Youth Policy Forum, 2006; Carnegie Corporation, 1992; Larson & Verma, 1999; National Research Council & Institute of Medicine, 2002)

The suggested "emotional connection" may be found in the form of developed trust between two or more individuals. Trust can be defined in many ways. Deutsch (1973) defined trust as "confidence that one will find what is desired from another, rather than what is feared" (p. 148). Adams and Christenson (1998) applied this concept to the family-school relationship. They defined trust as "confidence that another person will act in a way to benefit or sustain the relationship, or the implicit or explicit goals of the relationship, to achieve positive outcomes for students" (p. 480; see also Adams & Christenson, 1998). In order to develop trust, certain features must be addressed. Table 2 is an excerpt from Steven Covey's *The Speed of Trust: The One Thing that Changes Everything* (2006). This table may serve as a model for those interested in establishing such connections with their students.

These concepts of emotional connection and trust are not meant to be prescriptive, because each experience and connection will vary. It should also be said that when attempting to establish emotional connections, clear objectives and limitations should be shared and documented, whether between students, parents, faculty, staff, or any combination thereof. This is for the safety of the student as well as of others involved. For example, Figure 1 depicts a template from the Education World website for a "contract" that defines the values and expectations for students, parents, and teachers to enhance the overall learning experience. Although this example does not represent the full spectrum of behaviors previously depicted, it provides a foundation for participants to cooperate toward a beneficial learning environment.

Making it Work

Time is a valuable commodity to any teacher. Many teachers allocate tremendous amounts of time to their work so that their students may succeed, and Steve is no exception. In all honesty, Steve may not be the best model for time management. However, he does address another area very well: resources. Like most teachers, Steve has grown accustomed to allocating and stretching available resources. Examples of stretching include recycling materials, adjusting projects to reflect available materials, and sharing equipment as needed. When he accepted his position at WCHS, he was developing and implementing a new robotics program. Prior to the beginning of the Fall term, Steve attended the Carnegie Mellon University Robotics Academy to prepare specifically for this task.

Table 2. *Trust and Distrust Behaviors (Adapted from Covey, 2006)*

Behavior		**Opposite**
Character	Talk straight	Lie, spin, and tell half-truths, flatter
	Demonstrate respect	Show disrespect or show respect only to those who can do something for you
	Create transparency	Withhold information, keep secrets, create illusions, and pretend
	Right wrongs	Don't admit or repair mistakes; cover up mistakes
	Show loyalty	Sell others out; take the credit yourself; sweet talk people to their faces and bad-mouth them behind their backs
Competence	Deliver results	Fail to deliver; deliver on activities, no results
	Get better	Deteriorate; don't invest effort in improvement; force every problem into your one solution
	Confront reality	Avoidance; focus on busywork while skirting the real issues
	Clarify expectations	Assume expectations or don't disclose them; create vague and shifting expectations
	Practice accountability	Don't take responsibility; "it's not my fault"; don't hold others accountable
Both	Listen first	Don't listen; speak first, listen last; pretend to listen; listen without understanding
	Keep commitments	Break commitments and promises; make vague and elusive commitments or don't make any commitments at all
	Extend Trust	Withhold trust; fake trust; give responsibility without authority

A PARENT/STUDENT/TEACHER CONTRACT

As a parent/guardian, I will:

- Show respect and support for my child, the teachers, and the school.
- Support the school's discipline policy.
- Provide a quiet, well-lit place for study and supervise homework.
- Attend parent-teacher conferences.
- Talk with my child each day about his or her school activities.
- Monitor my child's TV viewing.
- Assist with at least one school or classroom activity.
- Read with my child for at least 10 minutes each day and let my child see me read.

As a student, I will:

- Always try to do my best work.
- Be kind and helpful to my classmates.
- Show respect for myself, my school, and other people.
- Obey classroom, school, and bus rules.
- Show respect for property by not stealing or vandalizing.
- Come to school prepared with my homework and my supplies.
- Believe that I can and will learn.
- Spend at least 15 minutes each day studying or reading at home.
- Talk with my parents each day about my school activities.

As a teacher, I will:

- Show respect for each child and for his or her family.
- Make efficient use of learning time.
- Provide a safe and comfortable environment that's conducive to learning.
- Help each child grow to his or her fullest potential.
- Provide meaningful and appropriate homework activities.
- Provide necessary assistance to parents so they can help with assignments.
- Enforce school and classroom rules fairly and consistently.
- Supply students and parents with clear evaluations of progress and achievement.
- Use special activities in the classroom to make learning enjoyable.
- Demonstrate professional behavior and a positive attitude.

Now, hand in hand, we will work together to carry out this contract.

____________________ __________
Parent signature/date

____________________ __________
Student signature/date

____________________ __________
Teacher signature/date

Figure 1. Parent/student/teacher contract (Education World, 2015).

The Carnegie Mellon Robotics Academy is supported by the National Science Foundation (NSF), Department of Education (DoE), Department of Defense (DoD), and the Lego Group. It is also aligned with the University of Pittsburgh's Learning Research and Development Center (LRDC) for assessment of the academy and its influence on mathematics education (Carnegie Mellon University Robotics Academy [CMURA], 2014a). The academy provided a collection of curriculum materials (presentations, projects, rubrics) to help Steve get started. These materials are tailored toward robotics education at the elementary, middle, or high school levels. (In other words, depending on the grade level, a different curriculum set is provided.) The high school-specific curriculum is geared toward specialization, which in this context is described as follows:

> At the high school level the focus can be either on introductory or a deeper understanding of a specific skill set; i.e., programming or mechanical design. All robotic programs should include the development of 21st century skills: teamwork, problem solving, ideation, project management, communication. The type of hardware you choose will be dependent on what you choose to teach. Many teachers choose robotics to teach specialized concepts like programming, parametric solid modeling, electronics, advanced machining, etc. (CMURA, 2014b, para. 1)

Attending the academy allowed Steve to obtain a series of virtual software packages (Virtual NXT), which are marketed to be compatible with LEGO products. Each package costs between $220 and $270 for classroom licenses. The academy offers other software packages for different robotics applications.

When Steve started at WCHS, school administrators provided a budget for his classroom and laboratory. Because he was establishing a new program, the needs were great and the funds didn't extend as far as required. Steve subsequently applied for additional funding from the school board. This also prompted Steve to look elsewhere for funds to help provide his students with the equipment he sought for their learning. Steve tapped into his LinkedIn and Facebook communities, asking for support for equipment purchases from friends, family, and colleagues. Steve's experience is one shared by many teachers: available funding may simply be insufficient to cover needs, and other strategies must be tried. For example, the New Jersey Education Association recently posted a list of five fundraising tips for classroom projects. They are provided in Table 3.

Table 3. *Alternative Funding for Classroom Projects (New Jersey Education Association, 2014)*

Five Fundraising Tips for Classroom Projects	
Start Early	You may be conducting fundraising that is seasonal (candle sales) or weather dependent (car wash), or that needs collaboration or coordination before you can start.
Do what works	Talking to other schools that have conducted similar fundraisers will give you an idea of what might work and what won't.
Don't give away your profit	Be wary of sites or products that ask for upfront fees or extraordinary percentage of the profits.
Know what you're fundraising for	Funders need to know how much you're asking for, what percentage of the overall budget that is, and what that will buy.
Only ask once	Coordinate the campaign so that you know who is asking whom for what. For instance, you wouldn't want all members of your team asking that local sports shop for t-shirt donations for the same project. Have a sign up form or make assignments to avoid embarrassing duplication of effort.

With the advent of online crowdfunding platforms like Kickstarter, it was only a matter of time for the education community, and teachers like Steve, to take notice. Kickstarter does include some educational projects, but other crowdfunding platforms focus specifically on education support. These include DonorsChoose.org, Incited.org, Peerbackers.com, Wishbone.org, Indiegogo.com, and others. During my observations of his program, Steve was in the process of setting up accounts through a selection of these sites to try to obtain funding for the purchase of additional equipment, primarily in the area of robotics. At the time of my observations, Steve had received a donation from a family member for the purchase of specific classroom equipment.

Making it Work: Take-Away

School budgets are limited and the number of technology/ engineering programs is dwindling nationally, in part due to a lack of teachers and funding (Brown, 2012; Crawford, 2009).

School districts continue to face a so-called triple whammy of economic factors. First are the dwindling local revenues from property taxes and the continued slow recovery in real estate values in many locations. Second, there have been severe reductions in state budgets along with increased costs of mandated services such as Medicaid, resulting in less state funding for education. Third, there are cuts in federal funding to local school districts (Education Funding Partners, 2012, p. 3).

Being able to find alternative sources of funding and resources may become a common device for educators in the near future. Steve purposefully seeks alternative funding opportunities to purchase the materials that he believes his students need for their education. Some of that funding comes from his personal resources. This is not a fair expectation of teachers, but it is far too often a reality. Looking beyond district budget limitations to a world that is interested in innovation, creativity, design, engineering, and production may produce resource availabilities not previously imagined.

This trend has expanded the avenues for educational funding beyond local resources. Corporations are investing heavily in educational programs to aid in the development of the next generation of educated, innovative, future consumers and employees.

Cash-strapped schools are turning to partnerships with corporate America to increase available funds. One recent example surfaced in a brief news item about the Winston-Salem/Forsyth County, North Carolina school district's decision to add a Target logo to elementary school supply lists in return for $9,000 (Molnar, 2013, para. 1). This is just one example. Several corporations have been partnering with school districts and special projects by providing financial support and curricular development (see Table 4 for additional examples). Certain educational entities are becoming increasingly open to these opportunities and have purposefully engaged in forming such relationships.

The National School Foundation Association encourages K-12 schools to follow the model set by public colleges and universities, which garner large gifts through partnerships with corporations and alumni (Jordan, 2014).

Although these opportunities are varied and seemingly plentiful, caution should be taken when attempting to supplement regular funding with gifts, endowments, and grants. Securing some of the available funds may be beyond the reach of a typical classroom teacher, requiring the full involvement of a teacher's school or district to be considered. Certain funding entities may have specific requirements regarding the use of the allocated funds. These requirements can have direct and immediate impacts on curricular and learning objectives that may or may not align with the school's, the teacher's, or the students' needs (Barkan, 2011; Ravitch, 2014; Woodward, 2013).

Table 4. *Examples of Corporate Funding for K-12 Education*

American Honda Foundation (Honda Motor Company, 2015)		
Building Educated Leaders for Life (BELL) Summer STEM Education	Dorchester, MA	$75,000
Oregon Museum of Science and Industry: Rosa Parks Tech Challenge	Portland, OR	$55,905
Chicago Pre-College Science and Engineering Program, Inc. Science, Engineering and Technology for Students, Educators and Parents (SETSEP)	Chicago, IL	$50,000
Classroom Central STEM Initiative	Charlotte, NC	$60,000
Google Rise (Google for Education, 2015)		
LA Makerspace	Los Angeles, CA	$15,000 - $50,000
National Center for Women and Information Technology (NCWIT): AspireIT K-12 Outreach Program	Boulder, CO	$15,000 - $50,000
Toyota U.S.A. Foundation (Toyota Motor Sales, 2011)		
Breakthrough STEM Initiative	San Francisco, CA	$225,000
Groundwork Inc. – Middle School Educational Support	Brooklyn, NY	$375,000

Conclusion

The goal of this yearbook is to highlight exemplary technology and engineering education teachers. Steve Marionneaux was selected for this chapter due to his work at the middle school level and the early success of his programs at the high school level. The chapter examined Steve’s professional development and discussed how this ultimately led to his current teaching career.

The chapter also reviewed purposeful decisions Steve has made to improve his understanding of his position, his school, and his district. Steve has dedicated significant time and effort to maintaining proficiency in his subject and to advancing his teaching, while allocating time to engage students on an individual level. He is driven—professionally and personally—by his dedication to student learning and development.

This chapter is intended to provide a form of guidance to teachers and teacher educators. The review of current research and current concerns in education in relation to Steve's work and professional decisions was provided so that readers can gain a contextual understanding of these decisions. Although the concepts presented are open to discussion and are not meant in any way to be prescriptive, it is my hope that educators may learn from, and even be inspired by, the information provided.

References

Adams, K.S., & Christenson, S.L. (1998). Differences in parent and teacher trust levels: Implications for creating collaborative family-school relationships. *Special Services in the Schools, 14(1/2),* 1-22.

Adams, K.S., & Christenson, S.L. (2000). Trust and the family-school relationship: Examination of parent-teacher differences in elementary and secondary grades. *Journal of School Psychology, 38(5),* 477-497.

American Youth Policy Forum. (2006). *Helping youth succeed through out-of-school time programs*. Retrieved from www.aypf.org/publications/HelpingYouthOST2006.pdf

Barkan, J. (2011). Got dough? How billionaires rule our schools. *Dissent Magazine*. Retrieved from https://www.dissentmagazine.org/article/got-dough-how-billionaires-rule-our-schools

Brown, T.T. (2012). The death of shop class and America's skilled workforce. Retrieved from http://www.forbes.com/sites/tarabrown/2012/05/30/the-death-of-shop-class-and-americas-high-skilled-workforce/

Carnegie Corporation (1992). *A matter of time: Risk and opportunities in the out-of-school hours.* New York, NY: Carnegie Corporation.

Carnegie Mellon University Robotics Academy (2014a). *Educators – Get started*. Retrieved from http://www.education.rec.ri.cmu.edu/content/educators/start/index.htm

Carnegie Mellon University Robotics Academy (2014b). *High school curriculum*. Retrieved from http://education.rec.ri.cmu.edu/content/curriculum/high_school/high_school.htm

Covey, S. (2006). *The speed of trust: The one thing that changes everything*. New York, NY: Free Press.

Crawford, M. (2009). *Shop class as soulcraft*. New York, NY: The Penguin Press.

Deutsch, M. (1973). *The resolution of conflict: Constructive and destructive processes*. New Haven, CT: Yale University Press.

Durlak, J. A., & Weissberg, R. P. (2007). *The impact of after-school programs that promote personal and social skills*. Chicago, IL: Collaborative for Academic, Social, and Emotional Learning (CASEL).

Education Funding Partners. (2012). *Evolved thinking: Putting brands to work to advance public school education.* Golden, CO: Education Funding Partners. Retrieved from http://www.edufundingpartners.com/wp-content/uploads/2013/12/EFP-White-Paper-Putting-Brands-to-Work-5-12-Final.pdf

Education World. (2015). *A parent/student/teacher contract*. Retrieved from http://www.educationworld.com/tools_templates/parent_student_teacher_contract.pdf

Frydenberg, E., & Reevy, G. (2011). *Personality, stress, and coping: Implications for education.* Charlotte, NC: Information Age Publishing.

Google for Education. (2015). *Google RISE awards*. Retrieved from https://www.google.com/edu/resources/programs/google-rise-awards/index.html#!overview

Harrison, C. R., Killion, J. P., & Mitchell, J. E. (1989). Site-based management: The realities of implementation. *Educational Leadership, 46(8),* 55-58.

Honda Motor Company, Inc. (2015). *American Honda Foundation*. Retrieved from http://corporate.honda.com/america/philanthropy.aspx?id=ahf

Hurd, P. D. (2000). *Transforming middle school science education.* New York, NY: Teachers College Press.

Jordan, E. (2014). Public schools turning to private financial sources. *The Gazette*. Retrieved from http://www.thegazette.com/2012/02/05/public-schools-turning-to-private-financial-sources

Kentucky Department of Education (2013a). *District/School support - School based decision making.* Retrieved from http://education.ky.gov/districts/SBDM/Pages/default.aspx

Kentucky Department of Education (2013b). *Alternative routes to teacher certification*. Retrieved from http://www.epsb.ky.gov/certification/certaltroutes.asp

Kentucky Department of Education (2014). *Student technology leadership program (STLP) - About.* Retrieved from http://stlp.education.ky.gov/

Kozulin, A. (2003). *Vygotsky's educational theory in cultural context*. UK: Cambridge University Press.

Larson, R.W., & Verma, S. (1999). How children and adolescents spend time across the world: Work, play, and developmental opportunities. *Psychological Bulletin, 125,* 701-736.

Malen, B., Ogawa, R. T., & Kranza, J. (1990). What do we know about school-based management? A case study of the literature - A call for research. In W. H. Clune & J. F. Witte (Eds.), *Choice and control in American education, Volume 2: The practice of choice, decentralization and school restructuring* (pp. 289-342). London: Falmer Press.

Molnar, M. (2013, August 12). Back-to-school time brings new corporate sponsorships. *Education Week*. Retrieved from http://blogs.edweek.org/edweek/marketplacek12/2013/08/back-to-school_time_brings_new_corporate_sponsorships.html

Murphy, L., Mufti, E., & Kassem, D. (2009). *Education studies: An introduction.* Maidenhead, England: Open University Press.

National Research Council and Institute of Medicine. (2002). *Community programs to promote youth development.* Washington, DC: National Academy Press.

New Jersey Education Association. (2014). *Alternative funding for classroom projects.* Retrieved from http://www.njea.org/news-and-publications/njea-review/october-2013/alternate-funding-for-classroom-projects

O'Connor, M., Sanson, A., & Frydenberg, E. (2011). The relationship between positive development during the transition to adulthood and education, temperament, and personality. In E. Frydenberg & G. Reevy (Eds.) *Personality, stress, and coping: Implications for education* (pp. 111 – 132). Charlotte, NC: Information Age Publishing.

Ravitch, D. (2014). *Reign of error: The hoax of the privatization movement and the danger to America's public schools.* New York, NY: Vintage Books.

Rumbaut, R. G., Furstenberg, F. F., & Settersten, R. A. (2005). *On the frontier of adulthood: Theory, research, and public policy.* Chicago, IL: University of Chicago Press.

Toyota Motor Sales, Inc. (2011, March 15). *Toyota USA foundation announces $5.2 million in new grants*. Retrieved from http://pressroom.toyota.com/releases/toyota-usa-foundation-announces-5-million-new-grants.htm

Troops to Teachers. (2014). *About the program – Overview.* Retrieved from http://troopstoteachers.net/AbouttheProgram/Overview.aspx

United Nations. (2009). *Strengthening life skills for positive youth health behaviour: An overview and discussion paper*. Bangkok, Thailand: United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).

Waters, M. C. (2011). *Coming of age in America: The transition to adulthood in the twenty-first century.* Berkeley, CA: University of California Press.

Weisman, S.A., & Gottfredson, D.C. (2001). Attrition from after school programs: Characteristics of students who drop out. *Prevention Science, 2,* 201-205.

Woodford County High School. (2014). *About our school*. Retrieved from http://www.woodford.k12.ky.us/1/Content/108\

Woodward, D. (2013). The corporate takeover of public education. *Huffington Post - Politics*. Retrieved from http://www.huffingtonpost.com/diann-woodard/the-corporate-takeover_b_3397091.html

A Non-Traditional High School Technology and Engineering Education Setting

Chapter 8

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A technology and engineering education high school curriculum consisting of *Foundations of Technology*, *Game Art Design*, and *Engineering Design*—courses developed by the International Technology and Engineering Educators Association's (ITEEA) STEM Center for Teaching and Learning™—coupled with courses relating to computer-aided design (CAD) and materials science and technology may be typical curricular offerings for high schools across the United States. What is not typical, however, are high school programs like the one featured in this chapter. The technology and engineering education program where this curriculum takes place features two year-long courses and ten semester-based courses, and is implemented by a single teacher. Timothy Christian High School (TCHS), founded in 1911 and located in Elmhurst, Illinois (approximately 43 minutes from downtown Chicago), is the setting for this chapter, and the exemplary teacher to be highlighted is Mr. Troy Blunier. Mr. Blunier was chosen as an exemplary teacher for this chapter for four reasons: He (a) teaches in a non-traditional high school that offers technology and engineering education, (b) displays a high degree of self-efficacy, (c) is highly effective as a teacher, and (d) regularly engages in professional development activities.

The Setting

Like other high schools across the United States, TCHS is accredited through a state board of education (Illinois State Board of Education) and athletics association (Illinois High School Association), but additionally maintains accreditations through the North Central Association Commission and through Christian Schools International. The mission statement for the Timothy Christian Schools reads: "Serving God and His people, Timothy Christian Schools develop academically prepared Christian disciples who embrace Christ's call to transform the world" (Timothy Christian Schools, n.d., "Mission & Vision," para. 1). Twenty-two Carnegie credits are required for graduation at TCHS, but technology and engineering education courses are not required, and serve as electives within the school's curriculum, which is typical of most high schools in the United States. TCHS's 2014-2015 population consisted of 351 students, with an 11:1 student to teacher ratio. Seventy-four percent of the students were Caucasian, 15% African American, 6% Hispanic American, 2% Asian American, and 3% international students (Timothy Christian Schools, n.d., "Demographics/Diversity"). During the 2014-2015 school year, 100% of eligible students completed the American College Test (ACT), where the composite score was 24.6; the composite score for the State of Illinois was 20.7, and the composite score for the rest of the United States was 21.0 (Timothy Christian Schools, n.d., "Timothy at a Glance").

The classroom and laboratory facilities at TCHS are typical of other high schools in the United States, especially those with only one teacher and with a small student enrollment. Two spaces are used within TCHS for technology and engineering education coursework. The first space is a classroom setting that doubles as the laboratory used for CAD, rendering and animation, 3D printing, and so on. The second space is a laboratory that houses material fabrication tools and machines and that includes a storage area.

The Teacher

Troy Blunier has been teaching at Timothy Christian High School since 2006. Troy has both Bachelor of Science and Master of Science degrees in Technology and Engineering Education. His motivation to teach technology and engineering (T&E) education at TCHS is two-fold: Troy is passionate about technology and engineering and about STEM education, and he is passionate about his faith. What is further intriguing about Troy is that he came to find T&E education somewhat non-traditionally. Initially, Troy started his undergraduate studies as an engineering major, but decided that he could do better Christian work as a teacher of technology and engineering education (personal communication, December 30, 2014). According to Troy's profile, located on the Timothy Christian website, his philosophy is that as Christians:

> We need to educate our students and children to be prepared to be ministers to the world; in both their word and their walk of life. Therefore, as educators we need to model for them the correct attributes of a Christian, stressing values like honesty, integrity, purity, faith, and above all, love. We need to show them how to express these attributes toward their elders and parents, peers, friends, and even their enemies or opponents. On top of this foundation should come the ideas, information, and content that are essential to our children's future.

What Troy is explaining is servant leadership. In research conducted in 2013, Msila contends that (a) servant leadership is focused on the society one lives in, (b) there is an importance to serving first, and (c) servant leaders are selfless.

Self-Efficacy

Through personal communication with Troy, I learned that although he felt prepared to be a teacher after completing his

Bachelor of Science degree, he also felt he was a bit naïve when it came to being the single teacher in charge of an entire program (including facilities, equipment/laboratories, and curriculum). Upon starting his teaching career in 2006, Troy inherited a program that was teetering between industrial arts and technology education. Over the course of his time at TCHS, Troy transformed the program to T&E education, modeled after the ITEEA's STEM Center for Teaching and Learning™. In addition to curricular changes and facilities upgrades, Troy believes that programs like VEX Robotics and the Technology Student Association (TSA), coupled with his own professional development in the STEM disciplines, were also required in order to have a successful program that leads students toward technological literacy, post-secondary endeavors, and career attainment. Simply put, Troy had the self-efficacy to transform a program based upon his moral convictions, the school's philosophy, and the profession's view of T&E education. As noted by the Committee on Integrated STEM Education, in their text *STEM Integration in K-12 Education* (2014), "A teacher's self-efficacy depends on adequate background in the STEM subject(s) being taught, [and] the ability to effectively transfer that knowledge and understanding to students" (p. 119).

Teaching Effectiveness

At minimum, as noted by Marzano (2007), there are three components to effective classroom pedagogy: (a) use of effective instructional strategies, (b) use of effective management strategies, and (c) use of effective classroom curriculum design strategies. Additionally, as Stronge (2007) pointed out, an effective teacher cares deeply, recognizes complexity, communicates clearly, and serves conscientiously. Troy is an effective teacher who exemplifies the characteristics noted by Marzano and Stronge, but additionally has vision regarding his students, the school's mission, and T&E education.

In our conversation, Troy noted that technology and engineering education, coupled with the emphasis on STEM education, are moving targets—as a teacher, he must grow and stay up to date with the profession. Troy discussed that one of the key items that has helped his effectiveness as a teacher is his involvement with the curriculum created by the ITEEA's STEM Center for Teaching and Learning™. Troy feels that because there is a clear connection between and among the STEM disciplines within the curriculum, he is better able to focus on teaching and learning, which he said is not necessarily the case with other curricula that he either has created, adapted, or is utilizing.

As for instructional and assessment strategies, Troy has found that the most effective instructional strategy to help his students understand information, concepts, and processes is to employ a learner-centered approach. "Teachers who are learner centered recognize the importance of building on the conceptual and cultural knowledge that students bring with them to the classroom" (Bransford, Brown, & Cocking, 2000, p. 134). For example, Troy uses demonstrations as his key instructional strategy, but not in the sense where his students simply watch what he is doing and then mimic his actions. Rather, he focuses on the use of demonstration *with student interaction*, where students can ask questions and practice the action alongside him. Troy recognizes that tactile manipulation, oral discussion, and building upon what students currently know and are able to do is an effective way to promote learning. His assessment strategies are also focused on the learner. Troy uses rubrics in his curriculum to assess student work, but the rubrics are not finalized until his students (the learners) have input. He challenges his students to think about their learning and what they feel is expected of them to know and be able to do regarding the content. As noted in in the National Research Council's *How People Learn*, "effective teachers continually attempt to learn about their students' thinking and understanding" (Bransford et al., 2000, p. 140).

Professional Development

As stated in the ITEEA (2005a) book *Developing Professionals: Preparing Technology Teachers*, "professional development is the continuous process of lifelong learning and growth that begins early in life, continues through the undergraduate, pre-service experience, and extends through in-service years" (p. 2). Troy's professional development has included:

- Attending regional, state, and international professional conferences;
- Participating as a teacher in the National Science Foundation-funded *National Center for Engineering and Technology Education* and *Project Probase* projects, where he implemented curricular models;
- Completing a Master of Science degree;
- Becoming a designated ITEEA *Engineering byDesign*™ Coach;
- Serving as the Region 2 Director for the ITEEA; and
- Serving as the Technology Education Association of Illinois/Illinois Career and Technical Education Association Liaison.

Exemplar Curricular Activities

Raku Pottery Lab

One of the lessons and lab projects that Troy's students get excited about takes place in the materials science course when students learn how ceramic objects are designed, formed, kiln fired, and glazed. Troy uses a firing technique called Raku, which is based on traditional Japanese pottery. Using an inquiry-based approach, students learn about pottery shape, design, and the material characteristics of clay; about the history of pottery making, including its social and cultural constructs; and how the chemical processing of firing actually works. Through the Raku firing technique, students are able to visually see the chemical processing that takes place in the clay and glaze because of a process called oxidation reduction. The content and hands-on experience with this lab allows students to connect STEM-based concepts together, and contextualizes history and social studies concepts.

Vehicle Design Challenge

In this engineering design challenge that takes place in his introductory technology course, Troy's students design a vehicle that must move down an inclined plane and stop short of a fixed barrier. There are several constraints to this challenge that students must adhere to while competing for the closest distance to the barrier (the constraints are beyond the scope of this chapter). The intent of the engineering design challenge is for students to: (a) realize that all systems have an input, process, output, and feedback mechanism; (b) work as members of a collaborative group that also maintains individual accountability; and (c) base all modifications of their vehicle on statistical data, not on trial and error.

Independent Studies

Technology and engineering teachers know that some of the richest student learning happens when students complete their own independent study projects. Although independent study projects present their own challenges for teachers, Troy is excited that he has the ability at his school to offer students the opportunity to learn about technological problems of their choosing, and he is willing to load time into student-developed challenges. Troy highlighted two specific independent studies that his students have completed in recent years that showcase student learning. In the first example, one student designed and fabricated a 500-gallon aquaponics system to raise fish (tilapia) and to grow and harvest flowers, herbs, vegetables, and bananas. The second independent project that Troy highlighted was a student who produced consumer-level ethanol, but more importantly, developed the production system to make large quantities of the fuel.

The Program

In describing the elements of model T&E programs, the ITEEA said:

> The technology [and engineering] program includes everything that affects student learning, including content, professional development, curricula, instruction, student assessment, and the learning environment, implemented across grade levels as a core subject of inherent value. (ITEA/ITEEA, 2005b, p. 5)

As previously stated, the technology and engineering education program at Timothy Christian School consists of two year-long courses (Foundations of Technology and Material Science) and ten semester-based courses (mechanical drawing, architectural drawing, woods technology, applied technology, advanced woods, introduction to computer programming, animation and rendering, engineering design, game art design, and an independent study). In order to offer such a wide array of courses with only one teacher, the coursework is offered on a rotational basis. Within the program, Troy also serves as the VEX Robotics project director, the school's TSA chapter advisor, the Worldwide Youth in Science and Engineering (WYSE) advisor, director of the school's Gaming Club, and as a grant writer. Outside the T&E program, Troy serves as the school play sets coordinator/builder, men's track assistant coach, and intramural director (flag football, volleyball, etc.).

Mr. Blunier's involvement in all aspects of the school setting follows the model suggested by Stronge (2007), where:

> Effective teachers invest in their own education. They model to their students that education and learning are valuable by taking classes and participating in professional development, conferences, and in-service training. Additionally, they discuss their participation in these activities with students in a positive manner. Effective

> teachers learn and grow as they expect their students to learn and grow. (p. 29)

One of the unique features of TCHS is a new program called Renew, which has recently been implemented. Renew is a nine-day term that occurs between the Fall and Spring semesters, during which students and teachers complete coursework, internships, and service experiences. Starting in 2018, students will have to complete one Renew credit each academic year, in addition to their normal graduation requirements (Timothy Christian Schools, n.d.). Mr. Blunier has developed a Renew service experience that will require students to become certified in scuba diving and then travel to Florida to work on reef repair; this is a two-year process to complete, so it will not be fully implemented until 2016.

Discussion

Timothy Christian High School is a unique, non-traditional setting for an exemplary T&E program. The program is founded on both Christian beliefs and technological literacy. Mr. Blunier is an exceptional teacher because of his sense of self-efficacy, his effectiveness in the classroom, and his commitment to professional development endeavors. It is rare, however, to be an effective teacher without an effective school system. As Reeves (2010) pointed out,

> Although teachers have an undeniably large influence on student results, they are able to maximize that influence only when they are supported by school and system leaders who give them the time, the professional learning opportunities, and the respect that are essential for effective teaching. (p. 70)

Troy would not be able to conduct exemplary teaching and learning or continue his professional development activities without the established school-based leadership, which should not be overlooked. Msila (2013), based on research conducted on leadership and teacher commitment, wrote: "Effective instruction in schools needs shared vision and shared perceptions" (p. 98). It is evident that members of the school's leadership team and Troy share complimentary visions for their school and, by extension, for his T&E program—to serve as educators whose focus is based on faith that engages students in learning and serving, including in technology and engineering education.

References

Bransford, J.D., Brown, A.L., & Cocking, R.R. (Eds.). (2000). *How people learn: Brain, mind, experience, and the school*. Washington, D.C.: National Academy Press.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research.* Washington, D.C.: National Academies Press.

International Technology Education Association (ITEA/ITEEA). (2005a). *Developing professionals: Preparing technology teachers*. Reston, VA: Author.

International Technology Education Association (ITEA/ITEEA). (2005b). *Planning learning: Developing technology curricula*. Reston, VA: Author.

Marzano, R.J. (2007). *The art and science of teaching: A comprehensive framework for effective instruction*. Alexandria, VA: Association for Supervision and Curriculum Development.

Msila, V. (2013). In search of a liberating practice: Leadership, teacher commitment and the struggle for effective schools. *International Studies in Educational Administration, 41*(3), 95-105.

Reeves, D.B. (2010). *Transforming professional development into student results*. Alexandria, VA: Association for Supervision and Curriculum Development.

Stronge, J.H. (2007). *Qualities of effective teachers* (2nd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.

Timothy Christian Schools. (n.d.). Retrieved from http://www.timothychristian.com/index.php

Utilizing Problem-Based Experiential Learning in the Center of Applied Learning at Pittsburg High School

Chapter 9

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After 44 years of teaching within the Technology and Engineering Education field, Larry Dunekack still arrives at work at six-thirty in the morning to prepare for the day ahead. Larry has taught at both the middle and high school levels and has also assumed administrator duties during his career. A master teacher by all measures, Larry assumes full responsibility for his students' achievement through his lesson planning and classroom management techniques. Within this chapter, Larry's approach to helping students learn will be explained and presented as a viable teaching strategy for other high school instructors teaching in pre-engineering or STEM-based programs.

Why Pittsburg Kansas: A Unique Place for Innovation in Technology & Engineering Education

Pittsburg, Kansas has a rich history of innovation in the field of Technology and Engineering Education, fueled by educators in the local USD 250 Pittsburg, Kansas School District, by Pittsburg State University, and by education entrepreneurs in the community. A few examples are highlighted in the following narrative.

In the summer of 1971, the Kansas State College of Pittsburg (now Pittsburg State University) received funding for Dr. Victor F. Sullivan and Dr. Harvey Dean to develop the Secondary Explorations of Technology project (known as the S.E.T. Project), which "was designed to change industrial education curriculum for grades seven through twelve" (Dean, 1997). The program development team produced curriculum guides and implemented programs for grades nine and ten in three areas: *Power Conversion and Transmission Systems*, *Materials and Analysis Processing Systems*, and *Industrial Communication Systems*.

The 1985 AIAA (now ITEEA) conference in San Diego, California, at which the professional field changed its name from Industrial Arts to Technology Education, served as the impetus for Max Lundquest and Michael Neden to develop Pittsburg Middle School's *Explorations in Technology* program. This seventh and eighth grade program consisted of 16 technology-related instructional areas, and paired two students working together in self-directed instructional modules (Iley, 1987). In 1987, Larry Dunekack left Topeka, Kansas and came to Pittsburg to work with Neden and Lundquest, where he later developed the course *Introduction to Technology* for sixth graders (Iley, 1989). These two programs became the foundation of many technology education modular-based programs popularized throughout the United States, including Synergistic Learning Systems, which is headquartered in Pittsburg, Kansas.

In addition to the university and the school district, Pittsburg is home to two major Technology & Engineering Education companies—Pitsco and Depco—that provide resources for lab and curriculum development. These companies have benefitted greatly from working with regional school districts and with the university, and the benefits are mutual.

A uniqueness of Pittsburg is the cooperative and collaborative spirit that exists between the community and the university, whether on brick and mortar projects, at athletic events or art activities, or on education projects. With Pittsburg State University (PSU) possessing one of the nation's leading Technology and Engineering Education teacher preparation programs, and the school district supportive of joint innovative education projects, Pittsburg High School (PHS) and PSU have developed a lasting partnership in the development of technology and engineering teachers and projects that serve the region. In 2010, PHS and PSU collaborated to develop the *Center for Applied Learning* that serves as the facility for delivering the high school Technology and Engineering Education instructional programs and that hosts PSU student teachers. Throughout this paper, you will see how these education partners are committed to not only developing future teachers, but to developing a first-class educational program at the high school level to better meet the needs of today's youth.

Demographically, Pittsburg is representative of an average rural Midwestern town or small city. Data from the Kansas State Department of Education website (Kansas State Department of Education [KSDE], 2014) for 2014 noted that PHS had 904 students, graduating 90.8% of its students, based on the *No Child Left Behind* formula. Among the students, 57.7% were on free and reduced lunch, which was slightly higher than the state-wide average of 50% (Kids Count Data Center [KCDC], 2014). Gender differences were minimal, with 456 male and 448 female students. Ethnically, the school had a predominantly white population of 57.7%. Hispanics comprised 12.3%, and African American, Asian, and multi-ethnic students made up the rest of the student population. The special education population for the school was approximately 11%.

Although some schools in suburban and urban areas may have demographic differences in population, it would be fair to infer schools of similar or smaller size in Kansas would provide similar data. For instance, in reviewing Hutchinson (KS) High

School's demographics, that school had very similar numbers based on KSDE information (KSDE, 2014).

The Center of Applied Learning

To better understand Larry Dunekack's approach to teaching high school students, a brief description of the facilities and listing of the program's curricular scope and sequence is necessary. It is imperative to understand the necessity of having a facility that is equipped with the software, hardware, equipment, and tools to adequately support the curriculum. Prior to changing the Center's facility, Larry spent a semester on sabbatical to develop the curriculum with Pittsburg State University faculty to ensure the Technology Education model of technological literacy was being fulfilled, after which he added necessary components to complete the model lab. A full description of equipment and space needed to create a similar facility can be found in the ITEEA's *Facilities Planning Guide* (International Technology and Engineering Educators Association [ITEEA], 2010). The guide also shows how a smaller facility can be outfitted to perform the same functions as Pittsburg's Center of Applied Learning. Figure 1 shows the Pittsburg High School Center of Applied Learning facility layout, with approximately 6800 square feet in overall size. With one teacher, the facility can support three foundations courses with 24 students in each class. The other periods support the Investigations and Application level classes. According to Dunekack, "If I could teach more Foundations of Technology, I would. Kids are turned away all the time. Obviously because [there] are just not enough places for them" (Larry Dunekack, personal communication, November 17, 2014). The original plan was to have two team teachers, but limited funds only allowed for funding one position and therefore limited potential enrollments.

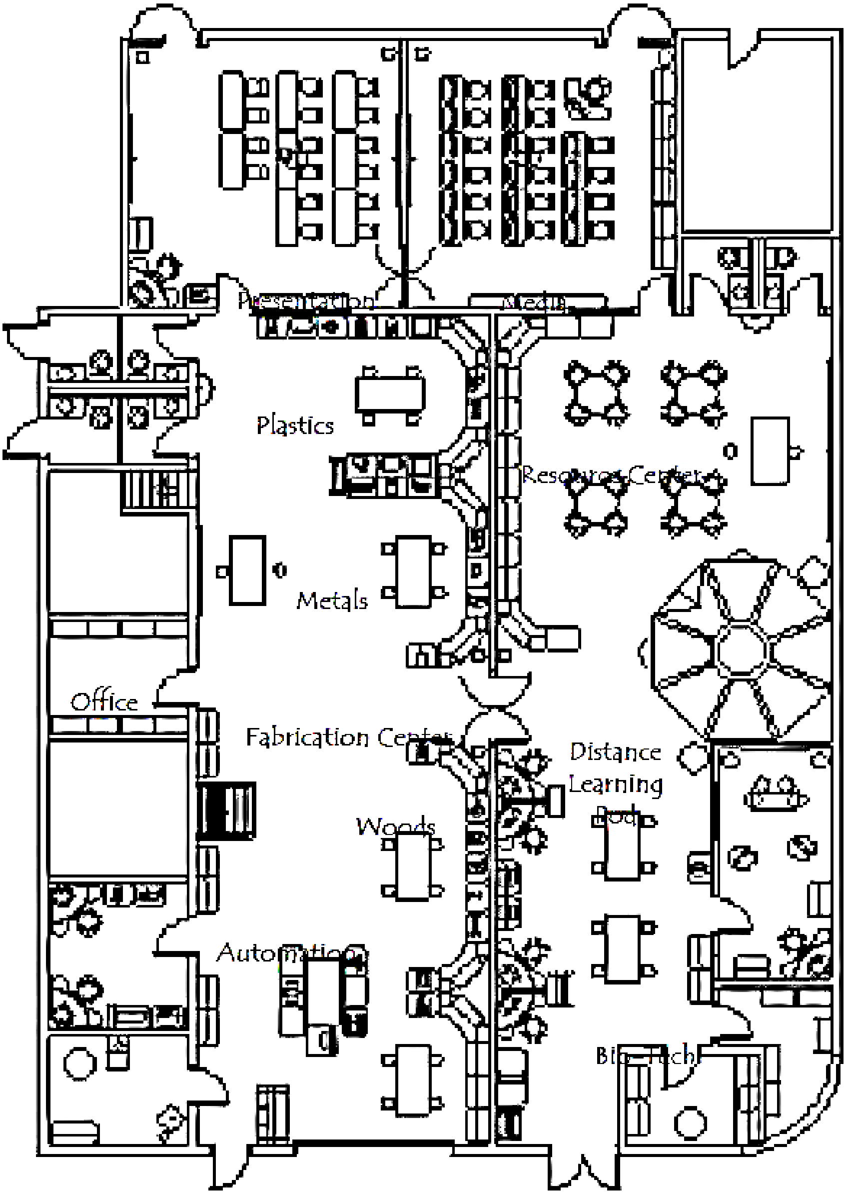

Figure 1. Floor plan for the Center of Applied Learning at Pittsburg (KS) High School.

The functional aspects of the Center of Applied Learning facility are essential to problem-based experiential learning. The facility's space previously housed a communications lab and manufacturing lab that were very underutilized and had deteriorating student enrollments. It was inevitable that the school either change what was being done, or close the programs completely. Visitors now often comment about how nice the lab looks, and ask about its development. A favorite question is in regard to funding sources used to create the center. Dunekack responds:

> The University [Technology & Engineering Education faculty] and I came together to develop a proposal to our district for a curriculum that would meet the needs of all kids. Whether the students are University bound, going into the job market, or going into a two-year program, we were going to try to put in a program that would meet the needs of all kids in a modern high school. That was our goal, and the proposal we made was for [the Center of Applied Learning], the curriculum, this [classroom] facility, and the lab. I gave the proposal to the school board. I presented them with the documentation, the floor plan, and curriculum. The proposal for the cost and everything. The board voted to do it, and they voted to do it without grant money. They voted to do it with money they had. (personal communication, November 17, 2014)

This powerful statement validates the district's commitment to student learning, specifically in the area of technological literacy. Since the program's opening in 2010, Dunekack has secured VE-2 funding from the state (a mechanism used in Kansas for distributing Perkins money) by demonstrating his curriculum qualifies as Pre-Engineering/STEM learning under the state's career clusters model.

The Curriculum Model

Developing a curriculum model around problem-based experiential learning has always been the focal point of the Pittsburg program. Also important to Dunekack and the Pittsburg State University faculty was to ensure the content was standards-based.

> I definitely believe in education centered on the kids. In other words, I don't think it should be a teacher-centered approach. The most you could ever hope for is to put in a program and curriculum to give students opportunities. I believe in hands-on learning, project-based learning. I believe in integration [of the curriculum]. (personal communication, November 17, 2014)

The curriculum model for the program is fairly simple and provides many more opportunities for students than conventional programs do. As depicted in Figure 2, students begin by taking the *Foundations of Technology* course, which provides the students with opportunities to develop cognitive technological literacy as well as correlated hands-on applications.

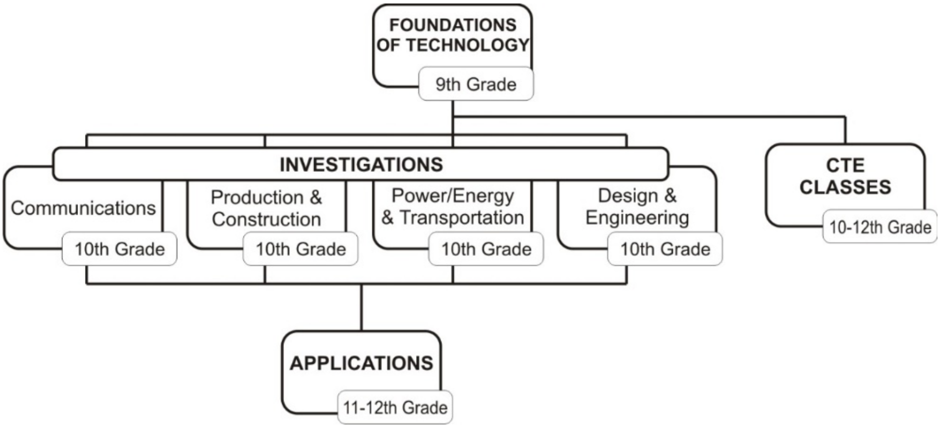

Figure 2. A scope and sequence map for the T&EE program at Pittsburg High School.

The Educational Approach

When asked about teaching styles used in the classroom, Larry would say "ALL," referring to the demand on teachers to use multiple teaching approaches to keep all the students engaged. After touring the classroom, viewing examples of assignments, and discussing student interaction, it is evident that Larry believes in variety. Larry noted, "I'm not relying on one style. It is not effective for all kids." Larry Dunekack could be likened to the educational philosopher John Dewey, whose learning by doing mantra has guided many educators. In Larry's classroom a combination of individual and group activities mixed with research, experimentation, problem-solving, and role-playing keeps the students engaged and the class fresh. The students are also allowed to drive the direction of the instruction, with the teacher functioning as a facilitator of learning. For example, a student may decide to further study electronics and in doing so, identifies a design problem, lists what he or she expects to learn, researches the topic, creates drawings, builds a prototype, writes a lesson(s) for other students, and concludes by presenting the project to the instructor and peers. Of course, there are specific goals and objectives for the course that must be reached by the end of the lesson, unit, quarter, or semester, but Larry believes in letting the students be who they are and achieve competencies in their own individual way. He directs them with gentle nudges to guide the learning of key concepts and to meet the course objectives. He doesn't necessarily give a student a pat answer to his or her question, but helps the student find the answer through inquiry and, in the process, learn how to learn. All of these features can be summed up as Larry's effective implementation of project-based experiential learning (PBEL).

Although the definitions vary greatly depending on content area and sources cited, generally handbooks for teachers identify PBEL as using thought-provoking questions or problems, resulting in complex tasks that encompass design, problem-solving, decision making, and investigative activities. These activities give students the opportunity to work relatively independently on long- or short-term projects that culminate in realistic outputs (Hmelo-Silver & Barrows, 2006; Jones, Rasmussen, & Moffitt, 1997; Mergendollar, 2006; Savery, 2006; Thomas, Mergendollar, & Michaelson, 1999; Thomas, 2000). Additional key features of a PBEL program or activity typically include:

- Authentic, open-ended problems
- Student progression through stages or phases
- Group collaboration
- Self-directed, student initiated research
- Student reflection (self & peer assessment)
- Teacher facilitation

The overall approach to PBEL is really a flip of the traditional use of Bloom's Taxonomy. Typically, Bloom's hierarchy of learning starts with the more basic conceptual levels, then students progress upward to the higher levels of learning (Anderson, Krathwohl, & Bloom, 2001). When utilizing PBEL, the focus is learning the basic skills *alongside* the application, analysis, and evaluation (higher levels) aspects of the project (Sams & Bergmann, 2013).

Benefits of Project-Based Experiential Learning

The benefits of a PBEL approach include enhancing several 21st century skills, when these skills are identified as targeted educational goals or objectives (Hughes, 2012). More specifically, students who participate in this educational approach enhance their problem-solving skills (Gultekin, 2005) and creativity (Gultekin, 2005; Pisanu & Menapace, 2014). These students also experience increased motivation to complete projects (Pisanu & Menapace, 2014) and their overall perceptions regarding education are improved (Geier et al., 2008).

Improved performance on standardized tests is also a benefit when using PBEL (Boaler 1999; Catalfamo, 2014; Geier et al., 2008). Unfortunately, standardized tests typically do not measure the important 21st century skills; however, gains in the tested subjects (e.g., math and science) still provide additional support for utilizing the PBEL approach. Assessment of student progress can be done through the use of rubrics, but must also include student “self-reflection and reflection” (Bell, 2011, p. 43). It is this process which allows students to learn from the process instead of just reciting answers from a textbook.

Gains are also experienced regardless of special population membership. Mussman (2012) found that at-risk students experienced enhanced motivation, improved grades, and increased graduation rates. Hampton (2014) found that “when time was not a constraint on learning, all students, regardless of ethnicity, cultural background, or language learned the content” (pp. 178-179).

Although many students experience benefits from PBEL, it is vital to note the importance of the teacher in successful facilitation of the approach. Without the teacher effectively maneuvering the classroom and questioning the students or groups, the effectiveness of PBEL may be minimal. As opposed to providing the students with the “answer,” the teacher must provide “nudges” to help students progress so they “don’t get too frustrated” (Pecore & Bohan, 2012, p. 31). In situations where there is really no predetermined solution, the role of the effective teacher is to ask students questions that are open-ended, complex, and that link to specific concepts (Gehrki, 2014). The teacher’s rapport with, and trust in, students allows them to share control of the learning environment (Ertmer & Simons, 2005).

Classroom Examples of Project-Based Experiential Learning

There are many ways to approach PBEL; some are longer-termed projects (e.g., senior/capstone projects or problem-based activities), while others may be short-term or even components of a larger project. The ability of the classroom teacher to guide students through the learning process without being heavyhanded or forcing the situation is vital to the success of the approach.

Typically, senior/capstone projects are individualized and student driven. Teacher approval is required prior to the student starting the project, but the student can propose a project based on a desire to enhance prior knowledge or to address identified deficiencies. In Larry's classroom there are various examples of student-designed and built projects. One particular student wanted to learn about wiring a house, so he designed and began building a classroom model that could be rolled around, stored, and used in future classes. During the construction process the student realized he did not have enough knowledge to complete the project. Instead of the teacher telling the student what to do or how to do it, Larry allowed the student to make mistakes, develop a new plan, and try again.

An example of a short-term application of PBEL was a test review. Instead of standing in front of the classroom and listing all of the review information for the test, it was presented as a problem the students needed to solve. Each student was provided one test question for a "pop test" that was open book. After each question was answered and graded, the next step was to get all of the information to all of the students. Instead of the teacher instructing the students on how to share the information, the teacher facilitated an impromptu brainstorming session. One suggestion was for each student to stand in front of the room and tell the other students the answers. Another idea was to write the answers down on a card and pass the cards around. Yet another idea was to write down the page numbers so the individual students would know where to find the answers. Instead of the instructor telling to students which option to select, Larry allowed the group to discuss and decide which option was best. The group was emotionally involved and into the task. Students were invested and wanted to make sure the cards got back to the right person. "I was just having fun with kids. Let them be kids." With a goal in mind—students needed to know the same information—the teacher facilitated the activity instead of directing it.

Sometimes during the educational process new content needs to be presented. These times may require the teacher to lead instruction, but Larry believes it is vital for students to experience technology, especially those tools, equipment, or programs with which they may not have prior hands-on experience. In one example in Larry's classroom, after instruction and demonstration the entire group of students was taken to the laboratory area where a variety of nail guns was displayed. Under his supervision, each student was required to select a nail gun and fire it into a board. Larry provides opportunities for experiencing technology instead of just discussing or observing it.

The PHS/PSU Connection

When developing the Pittsburg High School lab, both Dunekack and the PSU faculty found it imperative to ensure there was consistency between the two programs. Having similar technologies in the two facilities proved beneficial for several reasons. First, lesson development could transfer from one facility to the other seamlessly. According to Larry, "Lessons or projects I was doing in this lab migrated to PSU and, likewise, things the university was doing could migrate here." Secondly, Larry has played a significant role in the development of future teachers for decades as a supervising teacher. In fact, when asked about his career highlights, he cites "having students exit his program and become technology and engineering teachers."

When talking about the partnership between Pittsburg State University and Pittsburg High School, Larry is emphatic about its importance. "PSU is supportive in terms of being able to answer questions. I believe the manpower from the student teachers has been an asset to this program. The university faculty bring leadership, credibility, expertise, and ideas to this program." When asked to give an example of PBEL projects developed with the university, Larry was quick to point out mass production projects, problem-solving projects, and other collaborative activities done together by PHS and PSU students or in competitions between them. One noteworthy STEM integration activity he elaborated on was the "Aeromax at Gorilla Gulch" project (named for PSU's mascot, Gus the Gorilla), which was enthusiastically embraced by not only the students but also by the teachers who participated in it (Figure 3).

Figure 3. The "Aeromax at Gorilla Gulch" competition between students at PHS and PSU.

In describing the project, Larry noted: "Pitt State helped put together a PHS STEM team: a science teacher, math teacher, and me. Along with PSU students and Mike Neden [a faculty member at PSU], we developed the integrated project. Pitt State motivated me to do it. . . . they were supportive all the way, brought the project here, and we did it together." Instead of separate classes teaching components of the project, 60 students were brought together into the lab at the same time, in teams comprised of math, science, and technology students and their teachers. The students worked on the project together while the teachers collaborated on integration of the subject matter. The result was students understanding the relationship between theoretical and hands-on application. PSU faculty member Mike Neden and his students developed the project apparatus and assisted with the culminating event held at Pittsburg High School. The event demonstrated the impact integrated STEM project-based experiences can have on student learning.

According to student Stuart Perez of Pittsburg High School, " 'When you look at the different subjects that went together in this project, you can see in all of them how they applied and why they were needed,' " he said. " 'It truly does benefit the students when they can see why they are learning what they're learning' " (Pittsburg State University [PSU], 2013, para. 13). A PHS junior added, " 'This was a pretty cool activity, because it got us out of the regular classroom setting, it was hands-on, fun and we can see how these things apply in the real world. We were using science, technology, and math to solve a real problem that was put in front of us' " (PSU, 2013, para. 9).

The AeroMax project embodied the idea of integrated STEM learning with collaboration between university faculty and students. More information on the activity can be found by going to Pittsburg State University's website and searching for *Gorilla Gulch* or *AeroMax*.

Conclusion

Although it may be said that project-based experiential learning is new to the educational classroom, it could also be stated that we are simply continuing an approach we have always used in technology education. If we look to the past, our history shows we built projects and solved problems within the era of industrial arts. Even then, the importance of using your hands to understand how things worked based on mathematical principles was understood (Foster, 1997).

Dunekack admits that students have changed in having so many more challenges personally than when he first started teaching. Likewise, subject matter in technology and engineering education is changing dramatically, no longer focused on industrial classes like woods, metals, and auto mechanics but now encompassing a vast range of technologies and processes. However, enabling students to learn in a variety of ways has not changed. Having a lab like the Center of Applied Learning is undoubtedly one of the keys to successfully implementing PBEL programs like the one at Pittsburg High School. Engaging the mind with the hands to solve problems, and building on each student's experience and knowledge base, has worked for Larry Dunekack for over four decades of teaching.

References

Anderson, L.W., Krathwohl, D. R., & Bloom, B. S. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York, NY: Pearson Education.

Bell, S. (2010). Project-based learning for the 21st Century: Skills for the future. *Clearing House, 83*(2), 39-43.

Boaler, J. (1999). Mathematics for the moment, or the millennium? *Education Week 17*(29), 30–34.

Dean, H. R. (1975). Career awareness developed by "Systems of Industry," *Industrial Technology, 64*(1), 21-23.

Dean, H. R. (1997). *Changing education - a success story*. Dallas, TX: Arete Publishing.

Ertmer, P. A., & Simons, K. D. (2005). Scaffolding teachers' efforts to implement problem-based learning. *International Journal of Learning*, *12*(4), 319-328.

Foster, P.N. (1997). Lessons from history: Industrial arts/ technology education as a case. In K. Swortzel (Ed.), *Journal of Vocational and Technical Education*, *13*.

Gehrki, K. (2014). Using PBL to reach and teach. *Techniques*, *89*(1), 8.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E. & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching, 45*(8), 922–939.

Gultekin, M. (2005). The effect of project based learning on learning outcomes in the 5th grade social studies course in primary education. *Educational Sciences: Theory and Practice, 5*(2), 548–556.

Hampton, P. D. (2014). *Effective instructional practices in science for Latino students* (Doctoral dissertation, Lewis & Clark College). Available from ProQuest Dissertations & Theses A&I (1551228846).

Hmelo-Silver, C. E., & Barrows, H. (2006). Goals and strategies of a problem-based learning facilitator. *Interdisciplinary Journal of Problem-Based Learning, 1*(1), 21-39.

Holm, M. (2011). Project-based instruction: A review of the literature on effectiveness in prekindergarten through 12th grade classrooms. *InSight: River Academic Journal, 7*(2), 1-13.

Hughes, S. R. (2012). *Exploring the 21st century skills used during a project-based learning experience at the secondary level* (Doctoral dissertation, Walden University). Available from ProQuest Dissertations & Theses A&I. (1115148990).

Iley, J. (1987). Technology program - Pittsburg, Kansas. *The Technology Teacher*. Reston, VA: International Technology Education Association.

Iley, J. (1989). Technology program - Pittsburg, Kansas - Revisited. *Technology in Action - Outstanding Programs*. Reston, VA: International Technology Education Association.

International Technology & Engineering Educator's Association (ITEEA). (2010). *Facilities planning guide (CD)*. Retrieved from https://www.iteea.org/Publications/STEMProducts/77052.aspx?source=generalSearch

Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1997). *Real-life problem solving: A collaborative approach to interdisciplinary learning*. Washington, DC: American Psychological Association.

Kids Count Data Center. (2014). *Free and reduced lunch*. Retrieved from http://datacenter.kidscount.org/data/tables/1277-free-and-reduced-lunch#detailed/2/any/false/869,36,868,867,133/any/2761

Kansas State Department of Education (KSDE). (2014). *Kansas K-12 reports*. Retrieved from http://svapp15586.ksde.org/k12/CountyStatics.aspx?org_no=D0250

Mergendollar, J. R., (2006). *Project based learning handbook* (2nd ed). Novato, CA: Buck Institute for Education.

Mussman, B. A. (2012). *At-risk student experiences with project-based learning: A phenomenological study* (Doctoral dissertation, Capella University). Available from ProQuest Dissertations & Theses A&I. (1013836714).

Pecore, J. L., & Haeussler Bohan, C. (2012). Problem-based learning: Teachers who flourish and flounder. *Curriculum and Teaching Dialogue*, *14*, 1-2.

Pittsburg State University. (2013, May 7). *PSU, PHS team in i-STEM Project, Pittsburg, KS*. Retrieved from http://www.pittstate.edu/news/psu-phs-team-in-i-stem-project

Sams, A., & Bergman, J. (2013). Flip your students' learning. *Educational Leadership, 70*(6), 16-20.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1), 1-13.

Thomas, J. W., Mergendollar, J. R., & Michaelson, A. (1999). *Project-based learning: A handbook for middle and high school teachers.* Novato, CA: The Buck Institute for Education.

Thomas, J. W. (2000). *A review of research on project-based learning*. Retrieved from http://bie.org/object/document/a_review_of_research_on_project_based_learning

Implications for Technology and Engineering Teacher Education

Chapter 10

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The goal of this yearbook was to provide descriptive analyses of exemplary teaching practice in K-12 technology and engineering education. To that end, fourteen colleagues were asked to identify, observe, and write about classroom teachers whom they believe serve as exemplars within their schools, states, or countries. The result is this yearbook, which highlights the work of eight classroom teachers.

These teachers work at different grade levels: two are elementary teachers, three are middle school teachers, and three are high school teachers. Among them are three women and five men. Six are based in the U.S., representing states including Maryland, Illinois, Kentucky, North Carolina, South Carolina, and Kansas; one teacher is based in New Zealand, and another in Thailand. The paths these teachers traveled toward becoming K-12 technology and engineering classroom teachers are diverse. Nevertheless, some common elements are evident between these teachers, no matter their location or grade level.

In this final chapter of the CTETE Yearbook *Exemplary Teaching Practices in Technology and Engineering Education,* I summarize those common elements, explore some of the divergent elements, and discuss what lessons might be learned from these case studies by technology and engineering education teacher educators and classroom teachers alike.

Characteristics of Teacher Dispositions

In Chapter 1 and throughout this yearbook examples are cited of authors who acknowledge the integral role played by teacher attitudes, beliefs, emotions, and so on in the success of their teaching and of the students in their classrooms (e.g., Alsop, 2005; Barber, 2015; Bybee, 2013; and others). These attributes have been broadly referred to by some as teacher *dispositions*. This language became embedded in the teacher preparation literature as a result of its inclusion in teacher accreditation standards, most prominently NCATE/CAEP, which defined “professional dispositions” as follows:

> Professional attitudes, values, and beliefs demonstrated through both verbal and non-verbal behaviors as educators interact with students, families, colleagues, and communities. These positive behaviors support student learning and development. NCATE expects institutions to assess professional dispositions based on observable behaviors in educational settings. The two professional dispositions that NCATE expects institutions to assess are *fairness* and the belief that all students can learn. Based on their mission and conceptual framework, professional education units can identify, define, and operationalize additional professional dispositions. (National Council for Accreditation of Teacher Education [NCATE], 2010-2014).

The notion of assessing dispositions has had its detractors, in part due to the potential politicization of defining what attitudes and beliefs are desired (e.g., Borko, Liston, & Whitcomb, 2007). However, considering the acknowledged influence of teacher attitudes and beliefs on their effectiveness as teachers, efforts should be made to “operationalize” positive dispositions by identifying specific actions that reflect these positive attributes. The practices of the teachers highlighted in this book offer some examples.

Willingness to Contribute Extra-curricular Time

Perhaps the most prominent characteristic of the teachers highlighted in this yearbook was their willingness to spend time with students outside the classroom, providing students opportunities to apply their learning through engagement in organizations such as the Technology Student Association (TSA), participation in competitive events like VEX Robotics and Future City, and through local challenges such as the "Aeromax" in Pittsburg, Kansas or the development of tools to aid members of the community in Christchurch, New Zealand. In every case, student involvement in these events required teachers who were willing to go above and beyond their primary efforts in the classroom setting, signaling their commitment to the development of their students. This can demand time, energy, and other resources, yet clearly these teachers believe the payoff is worth the personal investment.

Engagement in Professional Development

Multiple examples were provided of these teachers' efforts to seek out and participate in continuous professional development (PD). Among these teachers the PD took many forms, from pursuing advanced university degrees, to attending week-long summer robotics workshops, to working with university-based colleagues, and much more. These teachers worked to expand their disciplinary content knowledge; re-tooled their pedagogical knowledge to learn more about STEM integration; and made efforts to understand their students' developmental needs. All of this adds up to teacher practitioners who show exemplary understanding of both the content they are teaching and the instructional approaches being used.

Professional development is a two-way process; in addition to *receiving* PD training, many of these teachers also engage in *delivering* professional development to others. This can offer reciprocal benefits that extend beyond the classroom, as will be discussed in more detail later in this chapter.

Purposeful Teaching

Much has been written about "reflective teaching" and how to be a reflective practitioner (e.g., Zeichner & Liston, 2014), so much so that the phrase has perhaps lost some of its meaning. Yet of all the positive professional behaviors one might identify for teachers, the willingness to engage in reflection on practice is perhaps the most important in assuring student success. The first step toward making purposeful decisions about our teaching is to think deeply about what we do in the classroom, and why.

In these chapters, several of the teachers were quoted as saying that it's important to teach students to learn from mistakes, particularly when using inquiry and problem-based learning—approaches where there are often no single, correct solutions. The same can of course be said for teaching, and the capacity to try, possibly fail, reflect on the outcome, and make changes is imperative for teachers who desire to improve classroom outcomes.

Enjoyment of Teaching and Working with Students

The word "joyful" showed up in at least one chapter in this yearbook, but the sentiment that word expresses was evident in many more of these stories. From Teacher Becky (Chapter 3), who uses simple and sometimes improvised activities to challenge students' creativity; to Larry Dunekack (Chapter 9), who in the spirit of "just having fun with the kids" allowed them to decide how to prepare for a test; to Steve Marionneaux (Chapter 7), who strives to connect with his students by providing them many extracurricular opportunities; each of these teachers, in his or her own way, exhibits enjoyment in their work and in their students' successes.

Characteristics of Teaching Practice

The teaching practices elucidated in this yearbook fall into two categories: those that refer to the specific activities or instructional approaches used by the teachers, and those that refer to how the teachers have structured their classrooms to impact student learning. At least eight notable teaching practices used by these exemplary teachers emerged from these narratives.

Incorporating Problem- and Project-Based Learning

As I noted in Chapter 1, project-based learning has historically been, and remains, a dominant instructional approach in technology education classrooms. Along with problem-based learning, it has been championed by those interested in promoting STEM learning, particularly as endorsed in documents like the *Next Generation Science Standards* (NGSS Lead States, 2013) that feature use of the "engineering design" process. Problem-based and project-based learning share similarities but have some key differences, as outlined by Banks and Barlex (2014) and described more fully in Chapter 1 of this yearbook. Both approaches emphasize activities that are student-centered, interdisciplinary, and that incorporate hands-on elements. The challenge for teachers is to identify problems or design tasks that are both appropriate and engaging (Denson & Lammi, 2014) and that don't strain available resources, including time (Banks & Barlex, 2014).

Technology and engineering education is well-positioned to provide meaningful problem- and project-based learning, and many of the examples provided of projects used by these teachers support this claim. There are, however, some related instructional strategies that might be seen as necessary corollaries of successful problem- and project-based learning. They are exhibited by all of the teachers highlighted in Chapters 2 through 9, and are briefly outlined below.

Using questioning. When giving students opportunities to engage in open-ended design or problem-based activities, the students' work must be guided by the use of questioning to encourage students to think their way through information gathering, design decisions, and assumptions, and to test their understanding. This is well-illustrated in the example of Korbin Shoemaker (Chapter 4), who as a student himself gained from the power of teacher questioning, and who now employs questioning with his own students to engage them in thinking critically about, and learning from, their work. A study conducted by Smart and Marshall (2013) on the use of questioning within science classrooms showed a direct relationship between questioning levels, question complexity, and what they called "questioning ecology" (p. 260) and students' cognitive level. "When teachers utilize higher levels of questioning with more complexity, students have the opportunity to explain, justify, and rationalize" their work (p. 264).

Giving students autonomy. One of the most powerful aspects of teaching via open-ended problems and projects is that they can mirror so-called real-life activity, are seen as more authentic, and allow students to feel more invested in their learning because they are given opportunities to guide the educational experience. These are all phrases we see used in relation to problem- and project-based learning; the examples provided in this yearbook illustrate what these things look like in actual classrooms. For example, Troy Blunier (Chapter 8) guided students through independent projects in which one built an aquaponics system and another an ethanol production system.

Addressing the standards. A successful teacher is one who is able to maintain a focus on the expected outcomes of the curriculum even in the face of open-ended educational experiences like the ones described above. This means knowing the applicable educational standards—and, in the case of elementary teachers, this means "all of them" (Chapters 2 and 3); being purposeful in the selection of activities and design challenges to ensure that they provide opportunities for learning desired knowledge and skills (Chapter 4); using co-curricular activities that support the kinds of learning desired (Chapter 6); and finding *and modifying* curricular resources that best support the desired learning outcomes (all chapters).

Requiring Student Portfolios

Having students maintain some type of journal or portfolio can assist learning in a variety of ways. Depending on how they are structured, portfolios can serve as tools for asking students to elaborate on the thinking processes they used for a project, as records of design ideas explored, as places to record new vocabulary and ideas, and more. Rebecca Petersen (Chapter 2) requires her bilingual Thai students to maintain STEM journals in which they record what they learned and track vocabulary words in both languages. Korbin Shoemaker (Chapter 4) requires his students to use process portfolios that document their design work. Using prompts that students address within their portfolios is a way that Korbin can monitor student progress and learning at key checkpoints in a project.

Bringing the Outside World Into the Classroom

In at least two of these schools, the teachers make very deliberate efforts to connect their students to outside experts or partners who can provide additional mentoring or provide information and insights that are helpful to the work the students have been tasked to complete. For example, Natalie Norman (Chapter 6) and colleagues regularly invite business and industry partners to their school for "lunch and learn" sessions. She also requires students in one of her classes to interview individuals with disabilities and then to design assistive devices for them. In a similar project, Randall Grenfell's (Chapter 5) students designed a tool to help the elderly (the "E-Key") after making a factory visit and inviting an occupational therapist in to speak in their classroom.

Integrating Other Subjects

Notable among the two elementary teachers highlighted (Chapters 2 and 3) are the very explicit efforts they make to fully integrate the STEM disciplines in their programs, along with language acquisition and even cultural elements. In both cases, these teachers are seen as STEM resource teachers and leaders, who work closely with the other teachers in their schools to identify opportunities for integrative lessons that address standards from multiple disciplines. The ability of both Melida Reeves (Chapter 2) and Rebecca Petersen (Chapter 3) to holistically view and plan for seamless integration within student learning experiences illustrates why elementary schools may provide unique opportunities for STEM integration that are less readily available in middle and high schools.

Restructuring Use of the School Day

As mentioned earlier, one important teaching practice that is more of a structural adjustment than a specific instructional strategy is the use of alternative scheduling to accommodate more involved projects with significant hands-on components. Fox-Turnbull and Snape (Chapter 5) mentioned the importance of "timetabling" freedom to allow students to work on projects across a range of subjects. Rebecca Petersen (Chapter 3) effectively "renamed the timetable" of the students' day by combining the times set aside for individual subjects into a single, extended STEM class period. The message from these two examples is that to fully take advantage of the learning opportunities contained within open-ended projects and design problems requires extended work sessions to accommodate group work, hands-on work, and investigations.

Characteristics of Classrooms, Curricula, and Schools

It is clear from these narratives that the individuals who are highlighted owe at least part of their success as teachers to elements beyond themselves: namely, their teaching facilities, their colleagues, and their communities. Many of the teachers were quick to point toward factors that contribute to their programs' success, including the following.

The Importance of Facility Design and Placement

In a teaching field long dominated by hands-on learning, the central role played by facilities in technology education has been well understood. The importance of facilities to technology and engineering education has perhaps been downplayed in recent decades as programs have moved away from skill development and have become more dependent on computer technologies. However, several of these chapter authors emphasized the significance of their facilities to the success of the overall technology and engineering education program. For example, both elementary teachers (Chapters 2 and 3) oversee dedicated STEM or engineering labs housing tools and equipment to support hands-on activities. Integral to the success of their labs, which accommodate students from throughout their schools, is the fact that these teachers both serve as designated coordinators of these labs—in other words, their schools made the decision to support the STEM integration efforts by allocating a teaching position for that supporting role.

Effective implementation of technology and engineering education programs, some of these authors suggested, requires laboratory spaces that can fully support the breadth of the curriculum. Most prominent among the examples provided is the Center of Applied Learning at Pittsburg (KS) High School (Chapter 9) which, at 6800 square feet, and with spaces for fabrication, research, and group work was very specifically planned for maximum utility. Another important consideration highlighted in Chapter 4 is the importance of T&E lab placement within the flow of the main school building, signaling its role as being integral to the other school subjects. Just as critical, as noted in Chapter 4, is the content and organization of materials and tools in the lab/classroom.

A Culture of Support

Many of the teachers featured in this yearbook readily acknowledged the importance of having supportive school administrators and colleagues. In some cases this culture of support extended into the community, with community members sharing their expertise with teachers and students in the school (Chapters 5 and 6), providing monetary support for T&E program initiatives (Chapter 7), and remaining informed about initiatives within the program (Chapter 4). In some districts, school administrators provided significant, essential funding to make programs (and facilities) possible (e.g., Chapters 2, 3, and 9), signaling their belief in the benefits of these STEM and technology and engineering programs.

For their part, teachers facilitated this culture of support in a variety of ways, including by being active members of school-based planning teams; by preparing clear proposals detailing the resources they needed, and why; and by making use of web sites, social media, and other tools to communicate about their programs and their students' successes. At least one of the teachers, Steve Marionneaux (Chapter 7), has also actively sought funding for his program via outside sources, including through LinkedIn connections.

Shared Governance and Collaborative Planning

A final notable characteristic evident in some of these schools is the prominent role played by school-wide planning teams, collaborative planning within teacher teams, and fruitful collaborations with outside entities, including local universities. Some of the teachers purposefully sought out participation on school or district planning committees (e.g., Chapter 7) as a means of becoming more knowledgeable about and connected with school functions. Others play central roles in school-wide planning efforts to promote STEM integration (e.g., Chapters 2 and 3), or to promote student engagement in co-curricular activities like TSA (Chapter 6). These efforts to become connected within their school communities yield many benefits, including enhanced recognition for their academic programs, increased administrative support, better integration within the curriculum, and greater levels of teacher empowerment through shared decision making. There is evidence that high quality collaboration also has measurable, positive impacts on student achievement (Ronfeldt, Farmer, McQueen, & Grissom, 2015).

Implications for T&E Teacher Education

The characteristics of exemplary teachers and programs that were drawn from these case studies help to illustrate the kinds of attributes that should be promoted more broadly across the technology and engineering education landscape. They also carry implications for T&E teacher educators and how they structure their own programs for maximum success of their graduates.

Supporting Non-traditional Pathways to T&E Teaching

Not yet mentioned, but common to at least half of the teachers highlighted in these pages, is the fact that they came to the classroom via non-traditional paths and often after having held careers in other areas, including military service, engineering, as a school resource officer, and as a paralegal. Particularly for career changers, but also for individuals who came through traditional routes but seek advanced degrees to further their professional development, models for providing teacher training must be accessible and have a degree of flexibility.

The problem of T&E teacher shortages is widespread and well-documented. In response to these shortages, most states have adopted alternative licensure pathways for teachers. These can vary widely in terms of their scope and rigor, and not all of them involve T&E teacher education programs (Hoepfl, 2001). Initiatives such as Troops to Teachers (mentioned in Chapter 7) provide conduits for recruiting potential T&E teacher candidates. A number of T&E teacher education programs across the U.S. have adopted online delivery models in efforts to accommodate working professionals for whom travel to university sites is impractical or impossible.

Although a variety of non-traditional pathways to licensure have existed for some time, T&E teacher educators should re-examine their programs to determine if there are additional steps they can take to recruit, prepare, and support teachers. Considerations include:

- Can the faculty become more active in working with the state department of education to develop meaningful licensure pathways for T&E teachers? Are there other ways that the teacher preparation program(s) in the state can be involved in delivery of alternative licensure trainings?
- Do the non-traditional pathways available (whether state-sponsored, university-based, or online) contain sufficient pedagogical content rigor to lead to teacher success and retention? If not, what changes can be made?
- Should program delivery structures (including course scheduling, availability of online offerings, and so on) be modified to better address both professional development needs *and* the constraints of program participants?
- Are there state-wide or national recruitment initiatives that the program can participate in more actively?
- Can we engage with other teacher prep programs in the university to promote complementary licensure initiatives, particularly across the STEM disciplines?

Re-evaluation of Program Content and Rigor

As became evident when reading the accounts of these exemplary teachers, all displayed solid disciplinary expertise relating to both the content and to the processes of technology and engineering (and in some cases other disciplines). Gaining the necessary breadth and depth of content expertise requires adequate preparation and continual professional development, and is critical for successfully managing, and for maximizing the benefits from, problem- and project-based learning. The level of knowledge needed in a time when integration of content across the STEM disciplines is seen as essential (Rose, Shumway, Carter,

& Brown, 2015; Honey, Pearson, & Schweingruber, 2014; Katehi, Pearson, & Feder, 2009) makes sufficient teacher preparation even more challenging.

To ensure that teachers emerging from T&E teacher education programs are gaining the knowledge and skills needed, teacher educators should re-evaluate their programs of study to consider the following:

- What additional science, mathematics, and engineering coursework should be required of teacher candidates?
- Where within the program's existing required courses can STEM integration be more effectively modeled?
- Are there courses that are no longer adequately addressing new curricular models, and that should be updated?
- How is the teacher candidates' pedagogical content knowledge being assessed (besides the Praxis), and is information from those assessments being used to make changes to the program of study?

Preparation of Teacher Candidates as Participatory Leaders

Willingness to contribute as members of participatory teams within their schools and beyond was a characteristic displayed by most of these teachers. Although this orientation toward professional engagement falls within the realm of a "disposition," there are nevertheless specific actions that can be promoted to encourage this type of involvement. When considering how T&E teacher education programs can contribute to this development, the following questions might be asked:

- Are extra-curricular and co-curricular opportunities (e.g., TEECA) made available to the teacher candidates? What steps are taken to encourage and facilitate candidates' involvement in these?
- Does the program have an advisory board, and are students invited to take part in board meetings?

- Do program faculty serve as role models of participatory leadership within their institutions and their professional organizations?
- Are teacher candidates exposed via field experiences to classroom teachers who display, and school models that promote, participatory leadership?

Continuing Attention to Skill Development

With the move in many states toward more academically-oriented T&E curricula (as compared to traditional industrial arts approaches) and the push toward increased levels of science and math integration, some T&E teacher preparation programs have made the decision to include fewer technical skill-building courses. This has resulted from too–little room within crowded university programs of study, from dissociation from engineering technology programs with which they were once housed, from the increased prevalence of online course offerings, and more. Yet many would argue that a key contribution of technology and engineering to broader STEM capabilities and to the overall development of students is the hands-on element these disciplines bring (e.g., Stewart, 2014; Halverson & Sheridan, 2014; Martin, 2014; Christensen, Knezek, & Tyler-Wood, 2015). It was evident in many of these case narratives that the teachers possess skills in the appropriate and safe use of tools, equipment, materials, and software, and that they wish to impart this type of knowledge to their students. Thus, as T&E teacher educators consider their own programs, they may pose questions such as:

- What technical skills are necessary to effectively teach the T&E curricula used in the state? Has the program updated its labs, equipment, and faculty expertise in ways that are consistent with these curricula?
- Are teacher candidates provided explicit instruction in the safe use of a range of tools, materials, and equipment, and do they have access to this equipment outside of the regular course meeting patterns?

- Is sufficient attention paid to how to teach others about the safe use of tools, materials, and equipment, as well as how to manage laboratories that incorporate these elements?

Discussion

Barber (2015), in her case study of four master teachers in Ontario, Canada, characterized these teachers as people who trusted their intuition, valued mistakes as learning opportunities, saw teaching as their vocation, and had a passion for quality, among other traits. She also suggested that the best teachers share qualities with individuals who excel in any profession. This raises the question of whether the kinds of dispositions, qualities, and abilities described in this yearbook can, in fact, be "taught" to teacher candidates (Cummins & Asempapa, 2013; Nelsen, 2015). However, this should not deter T&E teacher educators from attempting to move beyond "recognizing excellence when we see it" toward a more systematic effort to operationalize that excellence.

A caution posed by Barber (2015) is the potential for burnout among excellent teachers due to their high levels of emotional commitment to their craft:

> School leaders must be aware that their best teachers, or those with the potential to be their best, are also at high risk for stress and burnout.… Maintaining a personal life, keeping a healthy lifestyle, balancing commitment to work and to self are all habits that must be nurtured in young teachers to prevent burnout….Excellence requires an emotional, intellectual and spiritual intensity on the part of the individual which must be managed and balanced with care. (p. 2546)

Based on the descriptions of the teachers highlighted in this yearbook one can readily see their passion for quality, but one also questions the sustainability of their levels of engagement, particularly in providing extracurricular opportunities for students.

As interest in the use of open-ended, integrated, project- and problem-based learning, and guided inquiry—particularly in the STEM context—continues to grow, it is even more imperative to further define what effective T&E teaching looks like in practice. This means fully articulating how a teacher behaves when acting as a successful "facilitator" of these kinds of activities: How are the lessons structured? What kinds of supports are needed to ensure student success, and when are these employed? How can material be scaffolded for better learning? How is questioning used? Simplistic descriptions of activities may inspire, but do little to inform teacher candidates and other teachers about specific, successful strategies that can be replicated in their own classrooms. Implementing teacher study groups (see, for example, Cayuso, Fegan, & McAlister, 2013); borrowing the case study approach used in MBA and medical programs to analyze classroom examples; and developing narrated videos showing excellent teachers in action are three ways that deeper understanding of teaching and learning can be developed.

Improving teaching skills requires a long-term commitment to reflection on practice. Morrison (2012) found, in her study of exemplary teachers' implementation of inquiry science, that teachers felt "they had only come to understand inquiry through years of teaching and trying different strategies" (p. 579). One teacher described the inquiry approach as requiring the teacher to give up some control, and to give the students more freedom; in the process, the students take control of their learning.

In closing, I hope that others have gained from reading these narratives about exemplary T&E teachers, and that this yearbook serves as a spark to encourage future research and collaboration. Much has been written in the education literature about communities of practice, and a clear message from these highly regarded teachers and programs is that they benefit from being part of such communities. As educators, we must remember that our students are key partners in those communities.

References

Banks, F., & Barlex, D. (2014). *Teaching STEM in the secondary school.* London: Routledge.

Barber, W. (2015). Developing high performance teachers in 21 century schools: A case study of beliefs and behaviours of master teachers. *International Journal for Cross-Disciplinary Subjects in Education, 5*(2), 2538-2546.

Borko, H., Liston, D., & Whitcomb, J. (2007). Apples and fishes: The debate over dispositions in teacher education. *Journal of Teacher Education*, *58*(5), 359-364.

Cayuso, E., Fegan, C., and McAlister, D. (2013). *Designing teacher study groups.* Gainesville, FL: Maupin House.

Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. *Journal of Science Education and Technology, 24*(6), 898-909.

Cummins, L., & Asempapa, B. (2013). Fostering teacher candidate dispositions in teacher education programs. *Journal of the Scholarship of Teaching and Learning, 13*(3), 99-119.

Denson, C., & Lammi, M. (2014). Building a framework for engineering design experiences in high school. *Journal of Technology Education, 26*(1), 75-87.

Halverson, E.R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review, 84*(4), 495-504.

Hoepfl, M. (2001). Alternative routes to certification of technology education teachers. *Journal of Technology Studies, 27*(2), 14-23.

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integraton in K-12 education: Status, prospects, and an agenda for research.* Washington, DC: National Academies Press.

Katehi, L., Pearson, G., & Feder, M. (2009). The status and nature of K–12 engineering education in the United States. *The Bridge: Linking Engineering and Society, 39*(3), 5-10.

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research, 5*(1), 30-39.

Morrison, J.A. (2013). Exploring exemplary elementary teachers' conceptions and implementation of inquiry science. *Journal of Science Teacher Education, 24,* 573-588.

National Council for Accreditation of Teacher Education (NCATE). (2010-2014). *NCATE glossary.* Retrieved from http://www.ncate.org/Standards/UnitStandards/Glossary/tabid/477/Default.aspx#D

Nelsen, P.J. (2015). Intelligent dispositions: Dewey, habits and inquiry in teacher education. *Journal of Teacher Education, 66*(1), 86-97.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Ronfeldt, M., Farmer, S.O., McQueen, K., & Grissom, J.A. (2015). Teacher collaboration in instructional teams and student achievement. *American Educational Research Journal, 52*(3), 475-514.

Rose, M.A., Shumway, S., Carter, V., & Brown, J. (2015). Identifying characteristics of technology and engineering teachers striving for excellence using a modified Delphi. *Journal of Technology Education, 26*(2), 2-21.

Smart, J.B., & Marshall, J.C. (2013). Interactions between classroom discourse, teacher questioning, and student cognitive engagement in middle school science. *Journal of Science Teacher Education, 24*, 249-267.

Stewart, L. (2014). Maker movement reinvents education. *Newsweek.* Retrieved from http://www.newsweek.com/2014/09/19/maker-movement-reinvents-education-268739.html

Zeichner, K.M., & Liston, D. P. (2014). *Reflective teaching: An introduction* (2nd ed.). New York: Routledge.