Contents

From the Editor

Musings about Technology and Engineering Education

P. John Williams

I recently attended a Technological Learning and Thinking Conference in Vancouver, British Columbia after which I was privileged to spend some time touring through the Canadian Rocky Mountain area. It was summer (or so the calendar said) so the countryside was green, the rivers were gushing, and there seemed to be a lot of snow, at least to an Australian. This is the context that shaped the thoughts which follow.

As I travel in new areas, I am always interested in the schools that I pass. They are generally recognizable because schools look like schools regardless of the country you are in. I recall this was particularly the case when I traveled through Zimbabwe soon after that country achieved independence when there was a massive increase in state funded education to achieve the goal of primary education for all. There was no time to design schools to suit their environment, so all the hundreds of schools that were built in the first few years of independence in the early 1980's were exactly the same.

I wonder what type of technology education goes on in the schools that I pass. I try and see an indication of technology activities and usually find it near the rear of the school; sometimes the evidence is in the form of dust extraction hoppers or wire fences full of vehicles in various states of deconstruction. As I passed schools in the Canadian Rockies, I wondered what type of technology programs might be offered that would be relevant to the students in those schools. Given the context, I thought of technologies surrounding the sports of rafting, fishing, skiing, and snowboarding, or those related to resource conservation and depletion of the currently vast coniferous forests.

A number of presentations at the Vancouver conference had touched on the importance of context when designing technological activities for children; it is the context that makes experiences relevant to students and so enhances their learning capacity. I thought of technology curricula with which I had been involved where the context is reflected in the curriculum content. In Seychelles,

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for example, one of the technology curriculum content areas is fishing. This is relevant because of the large commercial fishing industry which runs out of Seychelles, but also at the personal level many individuals enjoy fishing, and fish comprise a significant aspect of Seychellois diet. Many of the schools in the country are within a couple of hundred meters of the ocean, so it is avery familiar aspect of life to students.

In Botswana, mud brick construction and traditional building were part of the technology curriculum. Many students lived in mud brick houses, the design of which had evolved over many years to be particularly appropriate to the environment – the bricks come from the earth and eventually return to it.

The notion of relevant context also applies to national curriculum design. The technology curriculum of any country is a product of the history of that country and reflects the prevailing social attitudes toward education and technology. Diversity in technology education across the world is therefore inevitable. I think of the audacity of the Jackson's Mill curriculum project to proclaim the universality of the 'grand narrative' curriculum organizers that were developed at that time (communication, production, and transportation). In the current post-modern climate of respect for situational developments and local contexts, such declarations would probably not be made. However, it is clear that curricular developments in some countries are strongly influenced by other countries. For example, the history of technology education in Australia can be quite clearly linked to developments in the United Kingdom, as is the case with a number of other Commonwealth countries.

The Standards for Technological Literacy are a case in point. No claims are made anywhere in the Standards documentation that they might be appropriate for use anywhere other than the USA. Despite this they have been translated for local use in Germany, Finland, and Taiwan, but have not had a major impact in those countries. They have also been used in limited ways in Chile, Spain, and Cyprus. Such limited influence of the Standards on international technology education curriculum is appropriate at a time when the significance of the local context is recognized.

The current thrust of technology education toward engineering in the US is an interesting case in this context. One would not expect this development to have a significant influence on other technology education systems around the world, except that the STEM movement is concurrently developing momentum in a number of countries. In both the UK and the USA, the overall thrust of STEM is the coordination and alignment of previously disparate initiatives in the four areas of science, technology, engineering and mathematics.

Back to the Rockies, and my musings moved to consider the implications for school technology programs if they were called engineering and not technology. Could students still study snowboards for example, develop an understanding of the properties of materials and their application to this context, and then design and produce one that matched their conditions and needs? Or could they do a project on forest conservation and examine the effects of the mountain pine beetle on the timber industry? Probably, but not as logically as if it was a technology program.

What about those aspects of national curricula that are seen to be important areas of study in developing students' technological literacy? Could students still study fishing in Seychelles, both from national and personal perspectives, if the subject was engineering and not technology? Fishing would be difficult to justify as engineering, despite being a technologically rich area of study.

It would also be difficult to include mud brick construction as part of an engineering course in Botswana. Superficially, construction engineering is a significant branch of the engineering profession, within which a study of brick-making could be considered. However, the nature of this specific application, mud bricks, seems to be technology rather than engineering. The current state of this art of mud brick construction is the result of years of trial and error which eventually produced an efficient and effective design – this is technology. Engineering would do all the quantitative analysis and testing prior to production, and so ensure that the first batch of bricks worked as was intended.

The bricks could be deconstructed as part of engineering and analysed to explain the design/process/product in engineering terms, but this would be after the event, and would not constitute design nor the consequent development of new knowledge through design.

My traveling companion in the Rockies was a lady from South Africa who had just completed her doctorate on Indigenous Technology, which is a part of the technology education curriculum in South Africa. In discussing the implications for a study of indigenous technology in the context of a subject called engineering, her feeling was that it would be a lot more limiting. One of the areas she explored as a significant indigenous technology was fermentation, which is studied as part of the technology curriculum, but would be difficult to incorporate in a subject called engineering.

Of course, after having expressed the need to respect localized history and developments in the design of new curriculum, these musings have little to do with the change from technology to engineering in the US, However, they may provide a hint that a more narrow type of technological literacy could be the outcome of studies in engineering when compared to technology.

I have some concerns about the move to engineering, particularly in a STEM context. Being currently involved in the battle in Australia to ensure the place of technology education in the new national curriculum, I empathize with the desire for credibility, recognition, and understanding. However, let me outline a couple of my concerns.

The Rationale

The rationales for the engineering agenda are various but limited, and related mainly to vocational and economic goals which arise from shifts in workforce patterns and downward trends in economic indicators—it is not uncommon for curricular development in technology education to be promoted in periods of economic downturn. Such rationales are not uncommon in technology education, though they have more recently been marginalized as technology education in many countries has established its place more securely as a component of general education. Traditional technology education had a strong vocational emphasis and consequently the link with workforce needs and the economy was quite explicit. Technology as a component of general education has a less direct link with economic development, but nevertheless it remains a rationale which is often invoked.

The current rationales for engineering include:

- Increase interest, improve competence, and demonstrate the usefulness of mathematics and science.
- Improve technological literacy which promotes economic advancement.
- Provide a career pathway to an engineering profession.
- Improve the quality of student learning experiences.
- Prepare for university engineering courses.
- Elevate technology education to a higher academic and technological level.

There is a disconcerting lack of rationale related to the promotion of the individual's personal development as a technologically informed member of society. A useful type of technological literacy would essentially be broad, encompassing many aspects of technology, not just engineering, and this may be why there are few engineering rationales which focus on the development of the individual.

The Confused Acronym

My assumption in this discussion is that the scope of technology is broader than that of engineering, If it is accepted that engineering is a subset of technology, and there are many technology areas that are not engineering (architecture, industrial design, biotechnology, computing), this would seem to be a plausible assumption. So if technology education potentially dealt with the breadth of technology, then engineering as a subject would be essentially more limited. Given that one of the virtues of technology is that teachers can choose to teach aspects that are of interest to them and relevant to their students, it would seem that limiting this scope would be a disadvantage.

STEM is a confused acronym: engineering has a different type of relationship to technology than does science or mathematics because it is actually a subset of the broad area of technology. The science equivalent would be to link science, biology and mathematics, for example. While some apologists have developed rationales for the consideration of technology as a discipline, it really is interdisciplinary and relates to engineering, along with a range of other disciplines in both the sciences and the arts.

Inequitable Emphasis.

When technology is aligned with another curriculum area in schools, it invariably gets undervalued. Science and technology as a subject in primary schools results in the prioritization of science. Science and technology offerings in secondary schools tend to be quite academic rather than practical. Numerous science, technology and mathematics (STM, SMT or TSM) projects that have been developed around the world produce interestingly integrated curriculum ideas and projects, but rarely translate into embedded state or national curriculum approaches. This is partly because the school and curriculum emphasis on science, technology and mathematics is not equivalent across these areas. Even the earliest integrated approaches involving these subjects served the need for reform in science and mathematics rather than the goals of technology. History and research indicate that technology will be undervalued when aligned with science and mathematics (and maybe engineering as well).

The Process

There seems to be a developing consensus that the fundamental difference between the design processes in engineering and technology is the absence of mathematical rigor and analysis in technology that precludes the development of predictive results and consequent repeatability, although this is being questioned in recent research. This thinking has led a number of authors to categorize design into conceptual design and analytical design, the former being common in technology education and the latter a part of engineering.

The process of engineering design involves problem factor analysis which is dependent on an understanding of applicable science and mathematics. Analytic design may be utilized to ensure functionality and endurance and involves static and dynamic loads, and consequent stresses and deflections. Conceptual design is less predictive. Success in technology is determined by what "works," which is initially defined by a range of criteria, and through a process of research and idea development, a solution is produced and then judgments are made about its success. In technology, it is not possible to predict what will work with certainty because of the manifold qualitative variables involved. It is a process of experimentation and modeling that leads to a solution. In engineering, experimentation and modelling lead to the verification of a solution, prior to its development. This confidence in a predetermined solution is obviously essential, given the nature of engineering projects. So in engineering, the design criteria are more deterministic, implying that a more limited range of outcomes are possible and there is less opportunity for divergent and creative ideas to develop. In technology, the design criteria are more open, permitting a broader range of acceptable outcomes. My concern here, therefore, is that engineering design provides less scope for the achievement of the general goals related to creativity and lateral thinking because it is more constrained.

Vocational and General Education.

Engineering as a school subject has a pre-engineering or vocational goal, and will necessarily employ a design process that is aligned with the nature of engineering design—one that is more analytic and based on a defined body of knowledge. However, some authors and curriculum development projects promote engineering design in lower secondary and even primary schools, which at this level should not be vocational but general. A design process at these lower levels of education which prioritizes analytic design and is preceded by the mastery of a body of knowledge, and consequently limits creativity and divergent thinking, is inappropriate. Projects such as “Primary Engineer” are really engaging in Design and Technology for general education purposes and presumably use the engineering label for reasons related to status or recognition.

There is an explicit vocational approach in the STEM agenda, mainly in terms of science and engineering. While the government paints a broad approach to vocational goals and refers to increasing the flow of qualified people into the STEM workforce, it’s more specific concern is the large number of engineering graduates from developing countries and the concurrent decline in the number of domestic engineering graduates. Project Lead the Way represents an integrated approach to STEM education and specifies one goal of preparing students for university engineering courses. A number of researchers also see STEM education as providing a career pathway to an engineering profession. In this context, the validity of such a strong vocational bias is questionable, and it is reasonable to question the morality of exposing all learners to STEM when only a few of them will go on to STEM based careers.

STEM education is also being proposed as a component of general education, by endeavoring to improve the level of STEM literacy in the population and increase STEM skills overall for everybody. The basic incompatibility of general and vocational approaches in one course has been well established: the goals of each are different, as are the assessment methods and the fundamental teaching methodologies.

The Place of Knowledge.

What knowledge is relevant in the study of engineering and technology? If a particular context area of engineering is being taught, such as civil or automotive, then there is a defined and acceptable body of knowledge related to that area that forms the parameters for the development of design projects. However, this is not the case with technology as there is no defined body of knowledge. So the question arises, what knowledge is relevant?

The answer to this question defines a difference between engineering and technology. In technology, the relevance of technological knowledge to a problem or design brief is defined by the nature of the problem. The information that is needed to progress toward a solution of a technological problem becomes the body of relevant knowledge, which of course cannot be defined prior to the analysis of the problem. This, therefore, also specifies the accompanying pedagogy and that content cannot be taught in the absence of a design problem. The design problem is analyzed, possible pathways to a solution are projected, and then the solution is pursued. These determine the knowledge that is relevant.

In engineering studies, the context, which defines the relevant body of knowledge, is predetermined, be it chemical, marine, automotive, etc. Because the context determines relevant knowledge, it is not dependent on the nature of the design problem. Thus the task for the student is different in engineering than it is in technology.

The knowledge needed to solve a technology problem is ill-defined until the nature of the problem is fully explored and the design process is underway. The knowledge needed to solve an engineering problem is pre-defined by the type of engineering that is being studied, so there is less scope for the student to explore and, consequently, to define relevant knowledge.

Curriculum Clarity

At the moment there seems to be little clarity about what STEM education might look like in schools. It would require a very radical curriculum approach to take out all the time in the school day that is now occupied by science, technology, and mathematics and replace it with a sequence of learning activities that would represent an integrated approach to achieving the essential skills and knowledge of these three subjects, plus engineering. This ambiguity extends to how it can be taught in schools, whether it needs to be taught as a discrete subject or whether it should be an approach to teaching the component subjects, what progression in STEM education is, and how STEM learning can be assessed.

Even if an integrated curriculum was possible, it is probably quite unrealistic to expect such an approach to be successful in the short term in secondary schools because of the staffing implications. Primary school teachers generally already teach all subjects to one class of students, so an integrative approach is not such a radical approach at this level. Individual secondary teachers, however, would not be able to develop the expertise required in all the STEM subject areas to enable just one teacher to provide an integrated approach. Therefore a system of team teaching would be necessary, along with all the accompanying school organization and timetable implications. Teachers would need to be trained for this type of approach.

One of the goals promoted by the STEM agenda is “STEM literacy.” As a vague idea this is laudable, but as an educational outcome it is problematic. Scientific literacy, technological literacy, and particularly numeracy are reasonably well researched and defined, but something that is an amalgam of the three has neither been developed nor trialed and tested. Consequently, it is difficult to develop an academic program (STEM) when the goals are not defined.

One implied definition is provided by Sesame Street’s Early STEM Literacy Initiative which has a major focus on mathematics in the early years, and is formally a part of a two year science initiative related to developing an understanding of the natural world. If this approach, that prioritizes mathematics and science, represents STEM literacy, then the goals of engineering and technology are ill considered.

As with many curriculum developments, the curriculum changes are made before the rationales are explored and verified. The trend from technology toward engineering in the US is well established and cannot be reversed even if there was a will to do so. Therefore my concerns are not pleas to desist but rather a call for needed research to ensure that this significant curriculum change is successful by initiating informed argument, highlighting the need for a sound philosophical rationale, and conducting carefully structured investigations.

Editor's Note

John Williams has been a member of the JTE Editorial Board since 1994. In addition to his distinguished service to this publication, he has provided an international perspective to our work and has mentored several international authors in publishing between these covers. He is serving as honorary editor for this issue.

JEL

Articles

The Problem in Technology Education (A Definite Article)

Jim Flowers

As with any field, technology education and its close relatives have numerous strengths and weaknesses. One of these weaknesses has too long been overlooked, and it is the subject of this article. We might think of technology education as empowering students, divergently fostering their own creativity. An abundance of design briefs shows that this field seems to encourage students to develop diverse and creative solutions to technological problems. It is ironic, therefore, that dogmatism is prevalent in the curriculum, literature, and research in technology education. In this sense, *dogmatism* refers to "a positive, arrogant assertion of opinion" (Neufeldt, 1997, p. 404) (if you'll pardon my arrogant assertion of this claim.)

This article focuses not on larger, overt examples of dogmatism that can easily be spotted, but on small and subtle ones, taking a very narrow approach to attempt to identify some instances of dogmatism in technology education literature by focusing on dogmatic uses of a single English word *the* to falsely imply uniqueness. Illustrative examples are examined with the hope of beginning recognition of this problem by our field. There was no intention to review the corpus of literature in technology education according the classifications of definite articles, though the classification systems can inform the analysis.

Linguistic Classifications of *The*

There are several approaches among linguists in classifying different usage of definite articles. Quirk, Greenbaum, Leech and Svartvik (1985) mention a generic use, as in "The tiger can be dangerous" (p. 265). They additionally suggest the eight categories of non-generic usage of definite articles (pp. 266-270) seen in Table 1. Chesterman's (1991) approach includes the *sporadic* and *logical* categories within a *non-referential use* category, eliminating the *body parts* category and adding a category of *unfamiliar,* which seems to include

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much of the *cataphoric* category. Epstein (2002) forwarded a framework, suggesting that "familiarity, discourse prominence, role/value/status, and point-of-view shifts" (p. 333) may be fruitful in understanding definite article function, rather than looking at the categories previously mentioned.

Table 1
A definite article classification scheme for non-generic usage from Quirk, Greenbaum, Leech and Svartvik (1985, pp 266-270)

Category	Description	Example
Immediate situation	the listener is in the same context	"Have you fed the cat?" [said to a housemate]
Larger situation	a shared understanding of context	"the last war" [said to a compatriot]
Direct anaphoric reference	previous reference had been made	"John bought a TV and a video recorder, but he returned the video recorder."
Indirect anaphoric reference	an association to a previous reference	"John bought a bicycle, but when he rode it one of the wheels came off."
Cataphoric reference	later information provides the meaning	"The president of Mexico"
Sporadic reference	reference to an "institution of human society"	"My sister goes to the theatre every month."
"Logical" use of "the"	a logical interpretation due to uniqueness	"When is the first flight to Chicago tomorrow?"
Use of "the" with reference to body parts		"Everyone gave us a pat on the back."

Note: descriptions are paraphrased.

One sense of uniqueness is not that the referent is the only example, but that it is the only important example. This is connected with an *emphatic usage* of *the* noted by Christopherson (1930), where a long vowel sound is sometimes, although not always, emphasized to provide contrast to indefinite article usage; "it means not merely 'the X you know,' but 'the only X worth knowing'" (p. 111). There are examples outside the field of technology education, such as the name of *The* Ohio State University. Within technology education, emphatic usage of *the*, possibly without the long vowel sound, is seen in the title and subtitle for a journal of the International Technology Education Association, *The Technology Teacher: The Voice of Technology Education.* Such usage seems quite appropriate from a marketing stance where a money-making entity suggests that whatever competition may be offered is not worthy of attention. Not far behind was the crafting of the name, *Project Lead The Way*, which carries a different connotation than would *Project Lead One of Many Ways*, *Project Lead Some Way*, or *Project Lead a Way*. Were crafters of these titles aware of subtle implications in using *the*? One would suppose. As we move from marketing and manipulating the consumer to instead focus on teaching and learning, we again find instances of an emphatic *the* effectively and appropriately used by MacDonald & Gustafson (2004), for example, when they state: "Smith (2001) suggests that too much emphasis on representation, i.e., the perfect drawing, could restrict opportunities for discovering new ideas" (p. 56). It is ironic that the title of their work was "The role of design drawing among children engaged in a parachute building activity," implying that there was only one role and their research would uncover it. But this moves us from a discussion of an emphatic usage to a notion of unique identifiability.

Some usage of *the X* connotes: *There exists an X; this X is the one and only X. The* is used effectively and appropriately to convey uniqueness in statements such as "The committee chair casts a vote only to break a tie." Sometimes we use *the* without conveying uniqueness: "Don't mar your wood, Roberta; the nailset is used to set a finish nail," but of concern here are uses that do convey uniqueness, but maybe should not. Richard Epstein (2002) suggested that definite article usage is not a simple matter of reference, but instead that "speakers/writers frequently manipulate the meanings of words like 'the' in order to achieve all sorts of rhetorical effects" (personal communication, September 19, 2009), and that they "commonly construct discourse referents under distinct conceptual guises for various communicative and rhetorical purposes – through, amongst other things, their choices of articles – rather than introducing referents into the discourse in a neutral, homogeneous fashion" (Epstein, 2002, p. 335).

Even though no attempt is made here to classify definite article usage in our field according to any of these frameworks, since none seems to include the particular usage of interest, these schemes do point to a critical factor concerning definite article reference function; as with other issues in communication, the cognitive framework of the speaker and that of the listener are of concern. Without some degree of shared understanding or familiarity with the referent, communication would be very difficult. Tied to this are the speaker's assumptions about the listener and the listener's assumptions about the speaker, as shared understanding can be impacted by the correctness of those assumptions. The listener's prior understanding of a referent might be assumed by the speaker, correctly or incorrectly, in *immediate situation* and *larger situation* usage, or the speaker not making such an assumption may take care to provide the additional information to achieve shared understanding, as in the *anaphoric, cataphoric,* and *logical use* examples.

Critical questions about the speaker's understanding include:

- Does the speaker believe the referent is unique?
- Does the speaker believe the referent is non-unique?
- Does the speaker believe neither that the referent is unique nor non-unique?

The speaker's actions raise questions:

- Does the speaker state or imply uniqueness?
- Does the speaker state or imply non-uniqueness?
- Does the speaker state or imply neither uniqueness nor non-uniqueness?

Regardless of whether there was a conscious implication on the part of a speaker, there may or may not have been corresponding inference made by the listener, so we should ask:

- Does the listener infer uniqueness?
- Does the listener infer non-uniqueness?
- Does the listener infer neither uniqueness nor non-uniqueness?

Even if an inference is made, it might not alter the listener's belief, so we might finally ask after listening:

- Does the listener come to believe the referent is unique?
- Does the listener come to believe the referent is non-unique?
- Does the listener come to believe neither that the referent is unique nor non-unique?

This listing allows for an intention from the speaker that may be misinterpreted by the listener. That is, a teacher can believe there are many forecasting methodologies, and not want to imply there is just one method, but refer a particular method using the phrase, "the forecasting method assumes a linear trend," meaning, "the example shown in this week's reading assumed a linear trend;" but a student could understand the teacher to mean "This is the only forecasting methodology, and whenever you forecast, you must assume a linear trend." The teacher's reference was likely *immediate situation* and *anaphoric*, whereas the mistaken listener believed the teacher to use a *logical* function of *the.* The teacher had made an inaccurate assumption about the listener in this situation. There are implications here for actions to prevent giving precisely the wrong understanding by altering a choice to use a definite article. A listener may have been primed for a *cataphoric* use, when the speaker instead was using a *larger situation* use, although the listener was not aware of the required background information to make sense of that use.

More serious is where the speaker purposefully uses language to imply the reference is unique when in fact it is not. A common cause for this may be traced to the speaker's own education, where such a misunderstanding may have been propagated. Implications for action here would be to seriously call into question the possible inaccuracy of one's content and schemes. It could be that a descriptive model was inappropriately used prescriptively, or that one just never bothered to question some basic assumptions.

Falsely Implying Uniqueness in Technology Education

Of interest here is where there is a false implication or inference of uniqueness in technology education's language conveyed by definite article usage. While there may be examples where we could suspect the speaker's or writer's motive, it seems likely that most such instances may occur where the speaker or writer is unaware their words convey a false sense of uniqueness. As often happens, I noticed this problem in my own teaching and writing before observing it in our field. I found myself teaching students about "the five families of materials," "the six types of material processing," "the definition of technology," "the rules for brainstorming," "the environmental impacts of our obsession with lawns," and "the way to cite a journal article." But are there exactly five families of materials, and are these five *the* five? In each of these instances, I seemed to be attempting to convey to students that one particular model, list, or procedure was the only (or the only important) model, list, or procedure, and they had better learn it. But even if I did not intend to convey this uniqueness, it is understandable for some listeners to have inferred it; after all, a speaker could have chosen some alternative phrase to "the five families of materials are," such as: "One classification of materials uses the following five families." If I teach students "The definition of technology is…" it conveys something different than had I said, "A definition for technology is…"

Technology education is not alone in receiving such criticism. Fendley (2009) opened his critique (in science) with:

> In a 2006 book that garnered much press for its silly attacks on string theory, author and physicist Lee Smolin provides a list of "The Five Great Problems in Theoretical Physics." There are many offensive things about this list, starting with the use of the definite article in the title, which implies that people not working on these problems (the majority of theoretical physicists) are working on less-than-great problems. (p. 32)

Within technology education, a few key cases concerning questionable implications of uniqueness in definite article usage are found not just in a single author's work, but in some phrases common to the field.

***The* Universal Systems Model**

Based on an Industrial Arts Curriculum Symposium at Jackson's Mill, West Virginia, Snyder and Hales (1981) wrote, "To assist in understanding the construct 'system', a universal model of a system is presented in Figure 4" (p. 10). After a graphic showing only four terms (input, process, output, and feedback) with arrows and boxes, there was additional discussion of "the universal systems model." Article usage did not carry an assumption or implication that this was the only model, since the initial mention used an indefinite article, with the definite article used afterwards in *anaphoric* reference to that which had been presented: "the [*this*] universal systems model."

Since that time, others have used "the" seemingly to indicate that there exists only one such model; a search on Google for "the universal systems model" resulted in 21,800 hits (but fewer than 100 for "a universal systems model.") A typical hit is a sample from the ITEA 8^{th} grade course on technological systems (ITEA, 2006), where students "should look at the parts that make up these systems, the intended purpose, and categorize the parts as inputs, processes, outputs, and feedback, according to the universal systems model" (p. 27). Georgia State Standard ENG-FET-3 states, "Students will explain the universal systems model" (Georgia Department of Education, 2007, p. 1). These are not anaphoric references to that which was previously presented, but instead seem to imply there is only one model. But even where an indefinite article is used, a convergent and perhaps dogmatic approach can sometimes be seen, as with one of the learning standards technology teachers in Massachusetts use for Technology/Engineering in Grades 6-8: "2.6 Identify the five elements of a universal systems model: goal, inputs, processes, outputs, and feedback" (MA Dept of Ed, 2006. p. 87). Ironically, the model Snyder and Hales presented had four elements, not five. McCarthy (2009) left out the article altogether, though seemed to convey deference to "the universal systems model" when he shared something titled "Universal cover sheet" that included input, process, output, and feedback (p. 21). Could it be that as a profession, we have *input* a creative bit of descriptive modeling, *processed* it by reinterpreting this to be the one and only model for systems, which we then *output* to others in a way that asks them to memorize, list, and apply rather than to critique and ideate? Would it not be more intellectually stimulating to encourage our students to ask why this is a systems model since it does not seem to model a solar system, a system of language, a monetary system, or a number system, but instead only models processes? *The* is a symptom of a larger problem that can emerge without *the*, aided in this case by the word, *universal*: an attitude of dogmatic adherence rather than inquiry. One of the participants at Jackson's Mill recently suggested our field question this model:

> During the 1980s and 1990s, the Input-Process-Output Model for technological systems was very popular in curriculum design. With the goals discussed above, this model is probably not as appropriate as it once was. (Ritz, 2008, p. 62).

One could argue that our field has stipulated a definition for *the universal systems model* and the reference is unique, regardless of the fact that this might be neither universal nor a model of all systems, and regardless of the existence of other types of systems models. Language could purposefully be misused in this way, and there are precedents. Some say the Dow Jones Industrial Average is neither industrial nor an average, just as we could suggest that the Technology for All Americans Project (ITEA, 1996) did not mean *technology* but *technology education*, did not mean *all* but *K-12 public school students*, and did not mean *Americans* but *resident citizens and legal resident aliens in the USA*. An argument could be made that *technological literacy* should refer to the abilities to listen, read, speak, and write with understanding concerning technology, and that possibly for reasons of persuasion, the term *literacy* was used to mean something very different in *technological literacy* than it does in *French literacy*. It is clear that language can be used to persuade people to act, or to ask them to rally around a cause, as in *Technology Education: The New Basic*. But when we are teaching and researching, clarity and accuracy ought to be more important than persuasive or flowery rhetoric, especially if our teaching and research are to have credibility.

***The* Problem-Solving Process/Approach & *The* Design Process**

How many approaches are there to solving problems? How many steps are there in different problem solving processes? Parnes (1963) suggested an approach to problem solving that had six steps, while Hutchinson and Karsnitz (1994) described a nine-step approach. A problem of how to get your friend's attention can likely be solved in one step (such as "saying your friend's name") but processes for solving environmental problems resulting from overpopulation are complex, convoluted, and certainly not easy to solve with any single prescribed method. It is true that one can take *an inquiry approach* to a problem, as one can take *a problem solving approach* to a situation. However, just as with *the universal systems model*, some in our field, I among them, have been guilty of dogmatically forwarding statements that seem to imply there exists only one problem solving process, or only one that is worth knowing.

As was mentioned, where a model or process was just introduced, we can make an anaphoric reference back to that model as *the model* or *the process* meaning *the one I just mentioned.* Too often, our literature discusses *the model* or *the process* where there was no initial introduction of *a model* or *a process*, as in the first sentence by Daugherty and Mentzer (2008): "This synthesis paper discusses the research exploring analogical reasoning, the role of analogies in the engineering design process…" (p. 7). This even emerges in the design of research instruments (e.g., "Holistic scoring (points awarded for each stage of the problem solving process)" (Boser, 1993, p. 19); "Steps that comprise the problem solving approach are clearly defined and practiced in a microteaching environment" (Boser, 1993, p. 21); and "Competency: Applying the engineering design process" (Rogers, 2006, p. 73)). Sometimes, a single work switches between an apparent implication of uniqueness and an apparent implication of non-uniqueness. For example, Olowa (2009) studied "the effectiveness of the problem solving approach…" in secondary school agricultural education (p. 37), and employed *the* thusly in both the title and the statement of purpose for that study; however, the article's running head was "Effects of Problem Solving Approaches," which sends a different message regarding uniqueness. To be fair, the title of the work included "the problem solving and subject matter approaches" though the running head, for brevity, displays an alteration to the implication concerning the number of problem solving approaches.

Hanson (1993) suggested that there are advantages to dogmatically presenting students with a single process, though not in those words: "It is quite a comfort for students to discover that the problem solving process has a set of universal steps and that the process involves the development of knowledge parallel to that developed through, for example, the scientific method" (p. 26). It is likely a comfort for teachers and teacher educators to become attached to only one of many approaches, as it protects us from having to question our assumptions and our knowledge. Even though belief systems can provide comfort, we are not there for student or teacher comfort. Our tendency toward procedure-based instruction could shed some light here; an association of "steps" in teaching design and problem solving may be too strong in our field, as Lewis (2005) suggested, and this association could be too dogmatic:

> The problem for the field of technology education in the United States and elsewhere is that the overt description of the stages of the design process, observable when engineers do their work, has become the normative design pedagogy. This stage approach runs the risk of overly simplifying what underneath is a complex process. (p. 44)

When I was presenting a new course on technology assessment to colleagues, one of them kept quizzing me, "But what is the technology assessment methodology?" I shared with him that formal technology assessment has made use of a variety of methodologies depending on the goals at hand and the nature of the information, though I suspect this was an unsatisfying answer. We crave to have a known list of procedures, and we classify that list as curricular content. We may feel that unless we can recite a single sequence of steps, we do not know a process, and therefore we do not have knowledge. Of course, sometimes there is a single sequence of steps, and to suggest otherwise would be inaccurate. But where there exists more than one viable list of steps and we incorrectly imply in speaking or infer in listening that there exists only one list, there is a problem. It is ironic that our educational mission seems to embrace a divergent view of student learning and performance, but some items of curricular content are inappropriately approached convergently, even by experts in the field.

One alternative would be to forward *a process*. ITEA (2007) *Standards for Technological Literacy* lists Benchmark 8H, which states that, "The design process includes…" (p. 97), and then lists twelve separate processes, apparently in order. This is only marginally better as it does not imply that other processes are specifically excluded, though using *the* still conveys a belief that these twelve are required in order for something to be classified as an example of *the design process.* We are then told that "the design process is a systematic, iterative approach to problem solving that promotes innovation and yields design solutions" (pp. 97-98). But what if the very first design solution one attempted happened to be optimal, and there was no need for iteration? Would that mean that this was not an example of *the design process*, since iteration was not a characteristic? As was seen earlier, definite article usage is not the entire issue here, but instead there is an underlying dogmatic proposition refusing to acknowledge alternatives, even though alternatives exist. So while we sometimes use *the* without realizing that readers and listeners could incorrectly infer uniqueness, at other times we use *the* or other linguistic devices to overtly imply incorrect uniqueness.

Other

There are other examples from our field. Aside from uniqueness, definite articles can be used to communicate number. When used with singular nouns, *the* typically conveys singularity. When used with plural nouns, there may be an implication of *all.* For example, Gray and Daugherty (2004) first state, "The purpose of this study was to identify effective recruitment techniques…." (p. 7), seemingly implying *one* purpose and *some* techniques. But they then pose as a research question, "What are the effective recruitment techniques…" (p. 7), which suggests a task to uncover *all* of the techniques that are effective, in a parallel to definite article usage in: "Have you memorized the state capitals?" A classic form for experimental research is to look at *the* effect of *x* on *y*, but maybe it should be to uncover *critical effects*, *important effects,* or *whether any effect could be found.*

Conclusion and Recommendations

While it is not unique to technology education, this field has a *the* problem. We sometimes inappropriately use the definite article to falsely imply uniqueness. At other times, listeners or readers may incorrectly infer uniqueness because we have used *the* even when we did not mean to imply uniqueness. At first, definite article usage may seem a silly, petty, and empty concern: surely there are bigger and more important issues for our attention. Actually, inappropriately communicating uniqueness with *the* is better classified as a symptom than a problem; an underlying problem here is our understanding. Our language choices can communicate an inaccurately narrow connotation. Where this is unintentional, greater awareness of language use specifically attending to this problem may be a solution. Technology education seems to be a profession that has embraced dogma. There is a creed stating "this we believe…" from a premier association (ITEA, n.d.). Why is there such a need to believe? Why do we have difficulty deferring judgment and admitting alternatives? Can we overcome the appeal of comfort brought by satiating our need to believe?

One solution to the problems mentioned concerning definite article usage and the bigger issue of dogma is to question our assumptions, even at the expense of our comfort. A teacher or speaker who is about to state "The five types are…" could first reflect, asking herself or himself if this classification scheme has alternatives, then if these five types are mutually exclusive and exhaustive. Questions such as "Might there exist a sixth type?" and "Could types 1 and 4 be the same?" should be entertained by the speaker prior to such an assertion and encouraged in the listener. We should take advantage of instances where *the* might be used to inappropriately imply uniqueness as beacons, prompting us to ask questions about our assumptions and implications, and asking us to consider the listener's or reader's understanding and what they infer from our use of *the*.

There is a parallel with sexism in language. Decades ago, using *man* to refer to humans and using masculine pronouns to refer to one of unknown sex were acceptable and taught, though this was discouraged in our profession as early as 1985 (Boben). Those who were slow to adopt sex-fair language may have thought sexist language to be a non-problem that was a silly, petty, and empty concern of others. Using the word *guys* to refer to a mixed sex group is not merely a problem of language usage, but instead reaches to our basic systems of values and beliefs. We may not be conscious of our implication that this is a field best fit for *guys,* but others could bring it to our attention that this is the message they heard from our use of that word. Learning that offensive language is determined by the listener rather than the speaker is a lesson that parallels definite article usage and dogmatism, where we might not intentionally imply false uniqueness, but our words might convey just that. Because language use and belief systems are so ingrained in who we are, we should not expect to eliminate sexist language or inappropriate, unique implications of *the* from our field in a short time.

Perhaps when we make a conscious effort to reduce our own use of sexist language, we become less sexist in our thinking and our belief systems, and in so doing we encourage this in others. If we become aware of dogmatism coming across in our language, and we then take steps to avoid that dogmatism, are we becoming more open-minded and encouraging this in others? With careful attention by a few, and assistance by them in spreading this attention to others, we may be able to effect a systemic change in our field and beyond concerning not merely definite article usage, but dogmatism and open-mindedness. It is about how we think, not about our use of a little word. It is a question of convergent or divergent thinking. It is an issue of accuracy, and the courage and humility required to admit that there are alternatives to what we are claiming to be knowledge.

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STEM Education and Leadership: A Mathematics and Science Partnership Approach

Chris Merrill and Jenny Daugherty

Introduction

The issue of attracting more young people to choose careers in science, technology, engineering, and mathematics (STEM) has become critical for the United States. Recent studies by businesses, associations, and education have all agreed that the United States' performance in the STEM disciplines have placed our nation in grave risk of relinquishing its competitive edge in the marketplace (e.g., *Rising above the gathering storm*, 2007). A Congressional Research Service (2006) report stated that, a "large majority of secondary students fail to reach proficiency in math and science, and many are taught by teachers lacking adequate subject matter knowledge" (Congressional Research Service, 2006, p. 1). Students lacking in STEM skills will not have the ability or skills to enter in the professions of science and engineering or areas requiring mathematics, science, and technology literacy.

To counteract these circumstances, multiple STEM-based initiatives and funded projects have been developed. Two particular initiatives that have and will impact technology education are: (a) the National Science Foundation funded National Center for Engineering and Technology Education (NCETE), and (b) the United States Department of Education funded Mathematics and Science Partnerships (MSP). Based on the lessons learned through NCETE, efforts were leveraged into developing a successful MSP grant proposal focused on the establishment of a science, technology, engineering, and mathematics (STEM) Education & Leadership Program.

The purpose of this manuscript is to share with the STEM education profession, particularly the technology education community, an explanation of the Federal Mathematics and Science Partnership programs and what this type of funding opportunity can do for technology education's future direction. It is believed that advanced STEM-focused opportunities and experiences, such as those afforded by the MSP program, will strengthen the content knowledge, pedagogy, research (especially action research), and leadership capabilities of teachers. Although the MSP program at Illinois State University has not been

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completed, the resources made available by the MSP program and the activities associated with the initial planning phase have allowed the research team at Illinois State University to build a significant theory base from which to implement a sound program. By sharing the theoretical grounding of the STEM Education & Leadership Program, it is hoped that the field can begin to move in a similar direction to address the needs of students and teachers.

To provide a better understanding of the NCETE and MSP programs, the components of each of these funded projects are outlined next. A review of the related literature is then outlined with particular attention paid to the unique components of the proposed STEM Education & Leadership Program. Following the literature review, an overview of the approach that will be proposed for implementing the program is provided. Given the parameters set by the MSP grant, the related literature, and the STEM Education & Leadership Program approach, potential impacts are predicted for the particular teachers involved in the program and for the future of technology education and STEM education more broadly.

NCETE and MSP Background

The National Center for Engineering and Technology Education (NCETE) was funded by the National Science Foundation as one of seventeen 10 million dollar Centers for Learning and Teaching in the United States in 2004 (National Center for Engineering and Technology Education, 2007). NCETE, headquartered at Utah State University, is a collaborative network of universities (University of Georgia, University of Illinois at Champaign-Urbana, University of Minnesota, Utah State University, Brigham Young University, Illinois State University, North Carolina A&T State University, University of Wisconsin-Stout, and California State University, Los Angeles) with backgrounds in technology education, engineering, and related fields. The mission of NCETE is to build capacity in technology education and improve the understanding of secondary teachers and students in relation to the engineering design process. A significant component of this mission is focused on the professional development of teachers. During the first three years, NCETE's professional development efforts were concentrated on the enhancement of technology education teachers in the area of engineering design. As these initiatives have progressed, NCETE has shifted its focus to the development and testing of a model for engineering and technology education professional development.

In 2003, the United States Department of Education released 100 million dollars for Mathematics and Science Partnerships (MSP) in response to the No Child Left Behind Act of 2001, Title II, Part B. In 2004, the federal appropriation for the MSP rose to 150 million dollars, and by 2005 through 2007, the annual appropriation rose to 180 million dollars (U.S. Department of Education, 2007). The overarching goal of the U.S. Department of Education's MSP program is to increase students' achievement in mathematics and science by increasing teachers′ content knowledge and pedagogical skills. The MSP grant supports partnerships between mathematics, science, and/or engineering faculty of institutions of higher education and high need school districts, in addition to other partners such as schools of education, business, and nonprofit organizations. The MSP program is a formula grant program to the states. Each state administers a competitive grants program, monitors their grantees´ progress, and documents their effectiveness, working with the U.S. Department of Education. State-funded MSP projects report to the federal government on an annual basis.

The MSP program is specifically focused on increasing the math and science content knowledge and teaching skills of classroom teachers to enable them to meet the qualifications for highly qualified status in science and/or mathematics and other educational areas like technology education. In addition, partnerships are also focused on teachers meeting the qualifications for endorsement in teacher leadership. Essential elements of the MSP programs are the processes, principles, and concepts of mathematical inquiry and problem-solving, scientific inquiry, and technological/engineering design. In addition, formative and summative assessment, analysis, and evaluation strategies are built into the design and implementation of the partnerships. Action research conducted by the MSP teachers is an additional requirement of the partnerships. The primary vehicle for accomplishing the goals of the MSP grant is by establishing and maintaining an effective partnership between the school district(s) and the university.

In establishing the partnership, the school district partner must meet certain criteria including that: (a) its standardized, norm-referenced, and/or criterion-referenced data must reflect that achievement in mathematics and science is falling below 60% of students meeting or exceeding the Illinois Learning Standards, and (b) 15% or more of students have to be from low income families. Teachers participating in the program must also be uncertified in mathematics and science and "not-highly qualified" as outlined in the local school district's annual report for not-highly qualified teachers. In addition, the participating teachers must exhibit leadership potential, have less than ten years of experience, and have fewer than five graduate courses in mathematics or science content or educational methods.

The mathematics and science partnerships are to develop Master Degree programs and professional development designed to: (a) improve teachers' subject matter knowledge, strengthen their instruction, and promote student academic achievement; (b) promote strong teaching skills through access to the expertise of mathematicians, scientists, and engineers, and their technologies and resources; and (c) increase the understanding and application of scientifically based educational research pertinent to mathematics and science teaching and learning. Given these requirements, individual MSP programs must plan a comprehensive approach that incorporates all of the essential elements. In particular, three of these essential elements stand out as particularly important to the MSP initiative: (a) educational partnerships, (b) teacher leadership, and (c) action research. A review of the literature in these areas is provided next.

Review of the Related Literature

Educational Partnerships

As stated above, partnerships between schools and universities are at the core of the MSP projects. Thus, the development and maintenance of the partnership is crucial to the success of an MSP project. However, as indicated by the literature on educational partnerships, the development and continuation of partnerships is difficult. Cordeiro and Kolek (1996) outlined key elements and processes essential to the development of successful partnerships. These include a common purpose, autonomy, and voluntary links to and from the schoolhouse, emergent leaders, and patterns of interaction within the partnership. Cordeiro and Kolek also argued that certain preconditions need to be present for partnerships to succeed, including leadership, trust, stability, readiness, and a common agenda. With good communication, reciprocity, the alignment and/or pooling of resources, and knowledge of the community, partnerships can be supported and sustained.

Restine (1996) argued that two trends have emerged specifically concerning partnerships between schools and institutions of higher education. One trend is the development of professional communities between schools and universities. The other trend is the strong belief that efforts at professional collaboration and service integration are incomplete without professional pre-service and in-service education. Klein (1990) outlined seven common barriers to the development of these types of partnerships, which included the illusion of consensus, failure to develop a common vocabulary, open conflict over status, too large of a group, equating mission with vision, not designating a leader, and failing to involve all stakeholders (parents, students, etc.). In order to overcome these barriers, Lawson and Hooper-Briar (1994) suggested that partnerships should develop guiding theories of social development, organizational renewal and change, language and communication, education and constituency building, leadership, and assessment, evaluation and research. Essentially, partnerships should develop the "core or bedrock values that define the essence of the work and provide consistency, cohesiveness, and a source of renewal" (p. 38).

Teacher Leadership

Teacher leadership is another important element of the MSP programs. Teacher leaders "mobilize the efforts of their closet colleagues to enhance the school's program for the benefit of students" (Danielson, 2007, p. 17). The benefits of embracing teacher leadership for teachers, according to Johnson and Donaldson (2007), include: (a) being able to share expertise with others, (b) reducing the isolation, which is prominent in teaching, and (c) offering opportunities to vary responsibilities and expand influence. The roles of teacher leaders can be broken into two categories: (a) formal or (b) informal. Formal roles for teacher leaders include department chair, master teacher, and instructional coach. Principals often appoint teacher roles such as mentor coordinator and data analyst as well. These roles are formalized through an application and selection process. Informal roles are not as structured and typically have no positional authority. These roles often "emerge spontaneously and organically from the teacher ranks" (Danielson, 2007, p. 16).

Teacher leadership is an alternative model of school leadership, which operates under a relational or distributed leadership model (Beattie, 2002). Krovetz and Arriaza (2006) stated that this distributed leadership model is "based on the recognition that many people in a school possess leadership skills and do leadership work and that by utilizing these resources in a coherent way, schools will be more effective in educating students" (p. 25). Teacher leadership, however, must be supported within the school. As Johnson and Donaldson (2007) pointed out, support structures within the school are necessary in order "to reap the full benefits of teacher leadership" (p. 9). These support structures must be established to encourage teacher leadership or else "there will be only a token use of this valuable resource" (Moller and Katzenmeyer, 1996, p. 12). With structures in place, principals can support and encourage a culture that allows for teacher leadership.

Teacher leadership has become an increasingly important concept in education because it is believed teacher leaders are positioned to influence school policies and practices, student achievement, as well as the teaching profession. In order to affect this type of change, teacher leaders must be able to (a) understand and navigate the school organization, (b) work productively with others, and (c) build a collaborative enterprise (Murphy, 2005). In addition, some argue teacher leadership should grow to encompass addressing coherence issues (Krovetz and Arriaza, 2006). Teacher leaders should be equipped and enabled to look at the school's resources, link these resources to the focus and vision of the school, and make decisions about what is likely to impact student learning and what can be discarded as unnecessary. Lambert (1998) also believed an important aspect of teacher leadership is the ability to define issues, collect data, construct meaning, and frame actions for the school. In doing so, teachers not only develop their own leadership capacity, but the school's as well. An important skill to accomplish this role is action research.

Action Research

Action research performed by the teachers within the program is a necessary component of the MSP programs. Education action research can be defined as "continual disciplined inquiry conducted to inform and improve our practice as educators" (Calhoun, 2002, p. 18). The roots of action research reside in Kurt Lewin's theory of action research that was focused on workplace studies in the 1930s. Lewin's process of action research was described as spiraling because it "included reflection and inquiry on the part of its stakeholders for the purposes of improving work environments and dealing with social problems" (Hendricks, 2006, p. 6). Although it took awhile before this spiraling approach to research impacted the classroom, these ideas eventually were connected to Dewey and Count's progressive education movement. Today, education action research, if not mainstream, is widely utilized, appearing in academic journals and developing into networks in the United Kingdom, Australia, Canada, and the U.S.

Action research has been offered as an alternative method of providing empirical evidence for teacher change than the traditional university led research. For example, action research is practitioner-based or as McNiff, Lomax, and Whitehead (2003) stated, "it is insider research" (p. 12). Thus, action research embodies the values of the practitioner. Action research is also focused on change or improvement. Collaboration is also often a key feature of action research. With action research, the "I" is at the center of the research and thus research questions have "a clear intent to intervene in and improve one's own understanding and practice, and to accept responsibility for oneself" (McNiff, et al., p. 19). Reflection becomes a key component in this approach so the researcher is aware of how to improve his or her practice.

Action research has also been discussed as an avenue for individual professional development, school collaboration, and educational reform. As Calhoun stated, action research "can change the social system in schools and other education organizations so that continual formal learning is both expected and supported" (p. 18). Much has been written about how to conduct action research. Hendricks (2006) outlined a continual process of reflect-act-evaluate to action research. Based on the evaluation, the process continues again. Sagor's (2005) four-step process to action research also included reflection as key. This process includes:

1. Clarifying the vision and targets of the research.
2. Articulating a theory.
3. Implementing action and collecting data.
4. Reflecting on the data and planning informed action.

STEM Education & Leadership Program

In 2007, Illinois State University's Technology Education Program was funded for a Mathematics Science Partnership (MSP) project entitled the STEM Education & Leadership Program. As specified by the requirements of the MSP outlined above and the establishment of a partnership at the beginning of the planning process, the STEM Education & Leadership Program has sought to overcome some of the common barriers to partnerships and advance a sense of cohesiveness and trust. The STEM Education & Leadership Program's design is being guided by the experiences fostered by the NCETE professional development efforts, grounded in the related literature outlined above, and structured around a needs assessment of the partners involved in the program.

The STEM Education & Leadership Program will target measurable increases in STEM-related teacher content knowledge, instructional practices, student achievement, quality of professional development, and organizational support. The team has articulated a model (see Figure 1 below) that is grounded in the literature, which will be used to guide the development and implementation of the program. With the long-term goals of changing the culture of the schools and increasing schools' achievement, specific processes have been outlined for the two key activities: (a) the development of a new Master of Science Degree and (b) the formulation of a professional development program. Both of these components are outlined next.

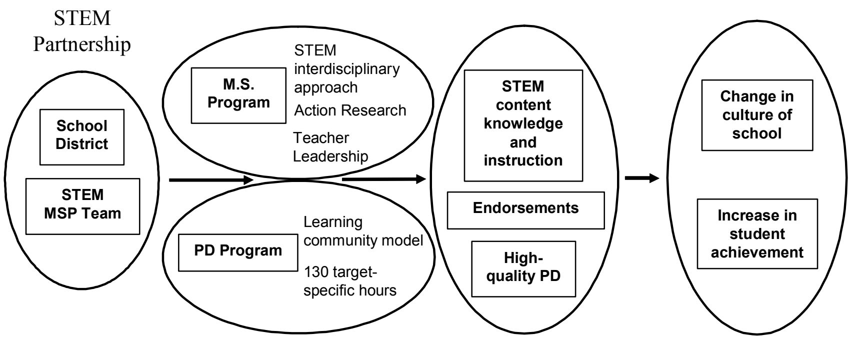

Figure 1. STEM Education and Leadership Master of Science Degree and Professional Development program model

Proposed STEM Education & Leadership Master of Science Degree Program

One of the solutions to addressing the decline in the number of U.S. citizens who are educated in STEM is to assist students in elementary and middle schools to make decisions to pursue engineering and science in high schools and STEM degrees in college. It is therefore imperative to offer more STEM-based courses through the K-12 school system to enable students to be successful in STEM courses at the college and/or university levels. That also means there needs to be more teachers that are qualified to teach STEM courses.

The framework for the STEM Education & Leadership Master of Science Degree program is based on existing programmatic offerings at Illinois State University, findings from STEM-based literature, examinations of other advanced degree programs in the U.S., and the need for participants to earn teaching endorsements/highly qualified status. By integrating field-based experiences and action research projects into the graduate coursework, teachers will be prepared to provide high quality education so that their students' learning is increased and more students will pursue STEM degrees at the post-secondary level. The Master's Degree program, 33 credit hours total, will be comprised of a four-course STEM Education & Leadership core, two-course Research & Cognition core, and student selected cognate areas in mathematics, science, and/or technology education. These course offerings will result in the requisite number of hours for degree and subject-specific endorsements. The proposed program extends Illinois State University's capacity for building connections to school districts throughout the state and will extend the reach of the university's graduate program by integrating a distance education model with a residential option for coursework.

A unique aspect of this Master of Science Degree is its intent to integrate multiple disciplines: science, technology, engineering, and mathematics. Currently, only one other university, Virginia Tech, has developed an integrative STEM program. The emphasis on integrated or multidisciplinary curriculum is emerging as an important avenue for educational reform. As Moss et al. (2003) argued, “subjects in school can no longer be portrayed as isolated content areas in which the memorization of subject-specific material takes precedence” (p. 7). The boundaries between disciplines have been argued to be artificial, primarily serving to structure the public school system. Moss et al. (2003) stated that disciplines should not serve to divide the educational experience but should be portrayed as a perspective or “a way of looking at the world that contributes to a more complete understanding of it” (p. 7). Disciplinary knowledge should be recalled in problem-solving so that an integrated or holistic understanding of the world is developed. As Froyd and Ohland (2005) pointed out, the ability to integrate through processes is “an educational goal, worthy of standing alone, and as a necessary counterbalance to what has been portrayed as a near universal emphasis on understanding via decomposition” (p. 148).

Science has been offered as an avenue of integration, especially with technology, engineering, and mathematics. Moss (2003) argued that considering science as merely one element of human knowledge allows this discipline to be seen as “part of a larger whole with its boundaries blurred among all other disciplines” (p. 61). In addition, design projects “have the potential to help students make connections among subjects, material, and applications” (p. 155). Technological/engineering design, which is an essential element of both the MSP programs and the NCETE’s efforts, has been defined as being “of and about the artificial world and how to contribute to the creation and maintenance of that world” (Cross, 2001, p. 54). Within technology education, technological/-engineering design has centered on problem solving and the application of scientific understanding to a given task (Hill & Anning, 2001). An integrated STEM curriculum centered on technological/engineering design is at the core of the STEM Education & Leadership program.

The STEM Education & Leadership Program is utilizing a learning community approach to its professional development. Central to the learning community model is the belief that when “teachers, students, and parents are connected to the same ideas they become connected to each other as well” (Sergiovanni, 1999, p. 18). Once people become connected they share common goals and values and a community of mind emerges. Individual practices are not ignored, but a community of shared practice is developed. A school as a learning community is focused primarily on the culture of the school where learning is seen as important work for the entire school. The aim is to maximize learning for all involved in the community so that the school’s capacity to build the knowledge, skills, norms, habits, and values necessary to adapt, renew, rethink, and inform classroom practice is firmly established (Shaw, 1999). According to

Butt (1999), two processes are essential to the creation of a learning community: (1) collaborative school-based professional development, and (2) peer and self-evaluation.

Collaborative professional development is thus an essential aspect of the STEM Education & Leadership Program. High quality professional development has been discussed by many researchers. For example, Loucks-Horsely (2003) identified four clusters of variables that affect the quality or nature of professional development. These clusters include: (a) content; (b) process; (c) strategies and structures; and (d) context. Further, high quality professional development must include "a focus on content and how students learn content; in-depth, active learning opportunities; links to high standards, opportunities for teachers to engage in leadership roles; extended duration; and the collective participation of groups of teacher from the same school, grade, or department" (Desimone, Porter, Garet, Yoon, & Birman, 2002, p. 82).

Thus, the STEM Education & Leadership Program is pursuing high quality professional development through a learning community approach. The composition of the learning teams (community) will consist of a technology education/engineering teacher, a mathematics teacher, a physical science teacher, the principal, a guidance counselor, and a parent from the same school; STEM faculty from within and outside Illinois State University; and related professionals from the STEM community. The professional development will be continuous throughout the school year and summer months. In total, the learning teams will partake in a minimum of 130, target-specific hours per year. The targeted outcomes of this sustained effort are to conduct high quality professional development that will ultimately affect the culture of the school and student achievement in a positive manner. It is believed that the composition of the learning teams (teachers, principals, guidance counselors, and parents) is best situated to achieve these targeted outcomes based on the literature. Below is a brief discussion of this literature which supports principal, guidance counselor, and parental involvement.

Principals

Studies exploring the role of high school principals have largely concluded that they are crucial to school success. A consistent finding in studies about principals is that high performing schools have strong, competent leaders (Rodgriguez-Campos, Rincones-Gomez, & Shen, 2005).

Principal leadership can be analyzed through interactions or the overt actions, covert deliberations, and physical presence of one person that influence others. Hart and Bredeson (1996) outlined three elements of interactions that are important to principal leadership, including: (a) motivation, (b) interaction processes, and (c) structuring processes. Through the structuring processes of interactions facilitated or dominated by a principal, an organization's culture is developed or altered. In other words, organizational culture is the outcome of interactions among group members and includes the behaviors, norms, dominant values, philosophies that guide policy, and unwritten rules of the school.

An emerging and important role for principals is as the instructional leader for the school. In addition to managing the school's day-to-day operations, principals are increasingly expected to be effective leaders in areas such as instructional approaches that engage the staff in renewing their own approaches (Rodgriguez-Campos, Rincones-Gomez, & Shen, 2005). As Hart and Bredeson (1996) stated, principals are expected to "master not only the knowledge base current at the time of their professional preservice education but the skills necessary to develop professional habits of learning and of tying their constantly expanding knowledge to their professional actions" (p. 26). Principals should then continuously upgrade their educational skills so as to be effective leaders and positively impact the culture of the school. By engaging in professional development, principals can upgrade their skills, gain new knowledge and skills, and model self-improvement. The STEM Education & Leadership Program will necessitate the active participation of the teachers' principals in the professional development efforts.

Guidance Counselors

In addition to principals, guidance counselors will be recruited to participate in the STEM Education & Leadership professional development so a learning community can be better established. Guidance counselors serve an important function within schools. For example, the American School Counselor Association (2004) defined professional school counselors as individuals "who deliver a comprehensive school counseling program encouraging all students' academic, career and personal/social development and help all students in maximizing student achievement" (p. 2). As indicated by this definition, the roles of guidance counselors have come to encompass the personal, social, educational, and occupational development of an individual student. Sears (1993) pointed out that guidance counselors "are being asked to assume a greater role in the lives of their students and the students' families" from offering parenting classes, to trying to prevent substance abuse, to helping student learn test-taking skills (p. 384).

Anderson and Reiter (1995) argued that the "quintessential role of the counselor is to facilitate the primary function of school: helping children to learn" (p. 269). However, many argue that this role has not been fully developed in most schools. Pershing and Demetropoulos (1981) stated that for this to happen "a reorientation of guidance related practices in schools so that the involvement of teachers will be encouraged and facilitated must occur" (p. 455). Davis and Garrett (1998) outlined four methods by which school counselors can ensure mutual understanding with teachers about their role: (a) meeting with the faculty, (b) consulting with teachers, (c) observing classroom dynamics, and (d) enlisting teachers as co-facilitators. By including guidance counselors in the professional development efforts of the STEM Education & Leadership Program, these connections can be further enhanced so that the primary function of schools can be better achieved.

Parental Involvement

Similar to the significant impact that principals and guidance counselors have on student achievement, parents also have a tremendous influence. Thus the approach of the STEM Education & Leadership Program is to also involve parents in its professional development efforts. Hoover-Dempsey and Sandler (1997) pointed out that within "a range of studies, there has emerged a strong conclusion that parental involvement in child and adolescent education generally benefits children's learning and school success" (p. 3). This positive impact includes "improved school attendance and behavior, more positive perceptions of classroom and school climate, stronger self-regulatory skills, stronger work orientation, and higher educational aspirations" (Hoover-Dempsey, Walker, Jones, & Reed, 2002, p. 843). For example, in a study investigating the impact of parent involvement on student's improved academic achievement, 220 parents of elementary students from a largely minority, low-income, but high-performing schools were surveyed. Results indicated that "a link exists between parent involvement in children's education and the educational outcomes of their children" (Ingram, Wolfe, & Lieberman, 2007, p. 494).

Hoover-Dempsey, et al. (2005) offered a list of strategies to increase a school's capacities for involving parents. This extensive list included: creating an inviting, welcoming school climate; empowering teachers for parental involvement; learning about parents' goals and perspectives on child's learning; and offering a full range of involvement opportunities. Another strategy the researchers offered is for schools to create a dynamic, systematic, and consistent approach to improving family-school relationships. Comer and Haynes (1991) agreed, stating that "parent involvement programs are most effective when they are part of an integrated ecological approach to school enhancement" (p. 277). After implementing a successful parent involvement program in an inner-city school, Hara and Burke (1998) offered some suggestions for individuals planning to develop a parent involvement program including ongoing staff development, reviews of school and district policies and procedures, joining a network of schools, and obtain related guides and parent involvement materials.

Conclusion

As discussed, the STEM Education & Leadership Program is a comprehensive MSP initiative focused on impacting teacher quality and student achievement in the STEM disciplines. At the time of this manuscript submission, the MSP was in its first year of a five-year funded project. The entire first year must be spent on planning the MSP program, with the following years being used for implementation. The development of an educational partnership focused on enhancing teacher leadership and action research capabilities are the major components of all MSP initiatives. In addition, the proposed STEM Education & Leadership Program includes an integrated approach to its Master's Degree and a learning community approach to its professional development. The STEM Education & Leadership Program at Illinois State University is attempting to answer the call to produce more highly qualified teachers in science, technology, engineering, and mathematics so as to increase student achievement in these disciplines by not only increasing teachers' content and pedagogical knowledge, but also impacting the culture of the school.

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Characterization of a Unique Undergraduate Multidisciplinary STEM K-5 Teacher Preparation Program

Steve O'Brien

Introduction

The K-5 school years are crucial, setting the framework for all subjects as well as critical thinking skills. The single most important component in a classroom is the teacher. However, in a formative timeframe for elementary-school aged children, the number of K-5 teachers that are educated with a Science, Technology, Engineering or Math specialization ("STEM") is substantially underrepresented. A lack of STEM subject matter expertise and experiences, coupled with high anxiety and low self-efficacy can lead to low teacher effectiveness.

At The College of New Jersey (TCNJ) it was felt that the Department of Technological Studies was well positioned to provide a unique academic major by combining the T&E with the M&S components of STEM, resulting in a program breadth that matches the breadth of skills needed by a highly skilled K-5 teacher. Additionally, it was thought that the field of technology education (TE) should be substantially more involved at the K-5 level, an age range that historically has little presence in TE in the USA. Such a program was established at TCNJ and is formally referred to as the Math-Science-Technology or MST program.

Two key motivations for the program were to achieve a higher number of STEM-trained K-5 teachers and to bring valuable contextual experiences to future teachers, and subsequently their K-5 students, through substantial and relevant T&E content. If these goals are achievable, then the MST program could have important implications for K-5 teacher preparation, potentially having a long-term and beneficial impact on student outcomes in STEM, and non-STEM, subjects in grades K-5, and eventually 6-20 and beyond.

In 1998 The College of New Jersey (TCNJ) approved the MST multidisciplinary major for elementary education students. The program has substantial requirements in all STEM areas and takes a truly integrated-STEM approach. To the authors' knowledge, this is the only undergraduate STEM major for K-5

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teacher preparation in the USA that has substantial T&E as well as M&S components. Currently, there are about 150 MST majors in the program. All students in elementary, early childhood, special education, and deaf and hard of hearing education can elect the MST major as their required second major.

A concern with multidisciplinary programs is that their breadth adversely affects the depth of the content learned. The purpose of the research reported herein was to quantitatively investigate the depth of content knowledge in the MST program in both the STEM elements as well as key non-STEM subjects. The growth of the program was also investigated. This paper also discusses how co-existing MST and TE programs impact each other. Technology education departments are in a unique position to initiate similar programs since they have enabling capabilities in the both the technology and the engineering components of STEM, components that have critical hands-on, integrative, and contextual attributes.

There are many factors that constrain or eliminate the ability to generalize the results of this study to other programs and institutions. Among them are political and administrative climate, state and institutional requirements for the preparation of teachers, admission requirements, and program philosophy. Nonetheless, it is hoped that the article will inspire ideas in how to increase the learning experiences that young people have in school by properly preparing the teachers who will provide these experiences.

Program History

Following the adoption of the first New Jersey Department of Education (NJDOE) Core Content Standards in 1996, the Department of Technological Studies, under the leadership of Dr. John Karsnitz, was asked to convene chairs from the departments of elementary education, mathematics, biology, chemistry, physics and the coordinator of TCNJ's "NJ Statewide Systemic Initiative to Improve Math, Science and Technology Education in K-12" (Dr. Robert Weber) to consider designing a new multidisciplinary major to fulfill a recognized need for more K-5 teachers with strengthened STEM skills. There was concern over the trade-off between disciplinary "depth" and interdisciplinary "breadth." However, this concern was overcome by creating a major with a broad "core" and a required in-depth "specialization" in one of the three disciplines of mathematics, science (biology, chemistry or physics), or technology. The major was approved by TCNJ's Board of Trustees in 1998 and subsequently by the NJDOE in 2000.

The MST major is one of several program offerings in the Department of Technological Studies in the School of Engineering. Other programs include a Technology/Pre-engineering education major and a Masters in the Art of Teaching (MAT). All majors are fully accredited by the National Council for Accreditation of Teacher Education (NCATE). All advising, recruiting, and requirements for the MST program are coordinated by the Department while all education requirements are coordinated by the School of Education.

There are four works that set important context to TCNJ's Department of Technology Studies curriculum and the design of the MST program: (1) *Benchmarks for Science Literacy* ("Project 2061") (American Association for the Advancement of Science, 1993), (2) *Technological Literacy Counts* (Sechrist, Anagnostopoulos, Lewis, and Coburn, 1998), (3) *Standards for Technological Literacy* (International Technology Education Association [ITEA], 2000), and (4) *Technically Speaking: Why All Americans Need to Know More about Technology* (National Academy of Engineering, 2002). These documents discuss the important role of teacher preparation in meeting educational goals in math, science, and technology. In *Technology Literacy Counts*, (Sechrist et al, 1998, p. 3) representatives from Schools of Education and Engineering gathered to dialogue on how these two diverse groups could work together to effect change. One of the recommendations was to plan a meeting of Deans with the purpose of " … open[ing] up channels of communication and promote teacher training that better prepares educators to teach technology and foster technological literacy." The MST program was designed to do this with the recognized importance of math, science, and technological literacy in K-5.

The T&E components are a unique and potentially very beneficial aspect of the MST program because they include skills such as problem-solving, design and modeling, and making. As discussed in previous articles (Brophy, Klein, Portsmore, & Rogers, 2008; Lachapelle & Cunningham, 2007; Zubrowski, 2002), the T- and E-components can be key in connecting math and science skills to the real world of the student, providing valuable contexts and increasing learning effectiveness. T&E components can effectively answer the common student complaint, "I'll never need to know this. Of what good is this?" Design skills are also important for highly talented teachers since they constantly design lesson plans, design (manage) their time, and design curricula. T&E activities are also effective in helping students learn non-STEM subjects (Koch & Feingold, 2006).

The STL (*Standards for Technological Literacy*, ITEA, 2000) states that technological literacy is critically important for the general population, not just for STEM-oriented persons. A STEM teacher preparation program is consistent with this philosophy, bringing STEM skills to an important group—teachers of impressionable K-5(8) students (Michaels, Shouse, and Schweingruber, 2008). The focus was to establish a pre-service program, providing a systemic solution to the K-5 "STEM-teacher void." Teachers, after all, are the largest single influence on a student's education (Carey, K., 2004; National Commission on Teaching & America's Future, 2000; The Teaching Commission, 2004).

Program Description

All MST majors have the same core requirements but every student must also complete a specialization. Through an analysis of the specializations chosen over a four-year period (2009-2012), totaling 125 students, it was found that the technology and math specializations were chosen most often, each comprising about 35% of the total. Science specializations were chosen by about 16% of the students, while 12% were undecided. Past experience indicates that the majority of the undecided will choose a technology specialization. Prior to the MST program, the only STEM majors chosen by K-5 students were mathematics and biology.

The MST major is a 32 unit (128 credits) baccalaureate degree with requirements generally divided into three areas: Liberal Studies, MST Core Studies, and Professional Studies.

Liberal Studies [10 units]

TCNJ has extensive liberal learning requirements that include history, arts & humanities, global studies, gender, race & ethnicity, community-engagement, a freshmen seminar experience, mid- and senior-writing experiences, as well as requirements in science and quantitative reasoning. Calculus-I and Creative Design are required of all MST majors.

MST Core [12 units]

The MST academic core consists of 8 units including Multimedia Design, Structures and Mechanisms, two additional science options, one additional math, two MST electives (fulfilled by taking M, S or T), and a course titled "Integrated MST for Young Learners." The final four units are reserved for specialization courses.

Professional Courses [10 units]

MST education majors at TCNJ meet the New Jersey State Certification requirements for a K-5 "highly qualified teacher." Courses include several literacy/literature courses, psychology, math and science methods and a series of student teaching experiences.

In New Jersey, MST majors can also obtain middle-school endorsements in math or science, with both often being completed. A middle school endorsement has two requirements: completing 15 credits of appropriate course work in the discipline and passing the appropriate content knowledge Praxis^{TM} test. A K-12 certification in Technology Education is also possible for an MST major by possessing at least 30 specified credits in technology and passing the Praxis^{TM} technology education test.

The MST program was designed to be structurally consistent with the TE program. TCNJ's TE program has its roots in industrial education, dating back to the 1930's. A major revision of the TE major was completed in 1985 with an emphasis on studying the human-designed world. The program was revised again in 2005 with a "pre-engineering" emphasis, integrating more math and science (Sullivan, Karsnitz, O'Brien, 2007). Some of the curricular aspects of the modified TE program are represented in a recent high school level textbook (Karsnitz, O'Brien, and Hutchinson, 2009).

Program Growth and Gender

The MST program has experienced substantial growth. The MST program grew from 2 to over 25 graduates from 2002 to 2009. Current class sizes predict graduating class sizes in excess of 40 in the next few years. A high growth rate is a sign of a healthy program but also produces more STEM-trained teachers, an important and under-represented population for K-5 (National Research Council, 2007). Previous to the MST program, non-STEM majors (Psychology, English, History … etc.) made up approximately 90% of the total, leaving historically 5-13% for the STEM majors of mathematics and biology.

The growth of the MST program, measured as a percentage of the total K-5 graduates, is shown in Figure 1. Also included in Figure 1 are the percentages for the other two STEM majors of math and biology. For the most recent 4 years, math and biology graduates have comprised approximately 6% and 2% of the total, respectively. From 2004 to 2009 the MST program grew from 5% to 20%. Current class sizes predict that the MST major will grow to about 30% in the next few years, resulting in a total STEM percentage of about 38% after adding in the historic numbers for math and biology majors.

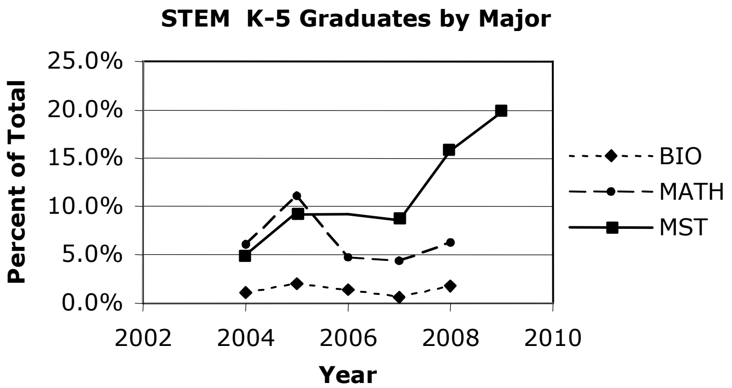

Figure 1. The number of MST, math and biology K-5 program graduates by year as a percentage of the total number of K-5 graduates.

This level of STEM-trained K-5 teachers is 4-to-5 times higher than the previous average of about 8% at TCNJ. A comparison of TCNJ's level of STEM-trained teachers to a National average would be interesting but the author could not find these data. Some states do not require a second major and in states that do the type of majors chosen is not tracked.

An interesting gender effect was discovered in the analysis. For non-MST K-5 majors the fraction that are male has been about 6% (see Figure 2). The number of male math and science graduates over the last five years has averaged 4%. The national average of male K-5 teachers in 2001 was about 9%, down from about 18% in 1981 (Scelfo, 2007; National Education Association, 2003 p. 91). In contrast, the fraction of male MST graduates has been a consistent 20-

25%, a 4-to-6 times increase over the TCNJ averages and almost three-fold higher than the 2001 national average. Investigations into the reasons for the higher male fraction have not been undertaken. However, it may be that males are attracted to the T&E components, a dominant effect in engineering schools across the USA.

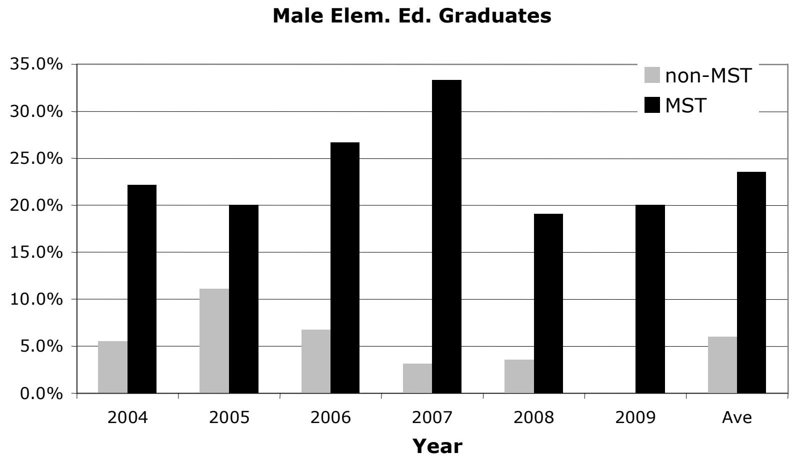

Figure 2. Comparison of male MST and non-MST program graduates.

Competencies in STEM and Non-STEM Components

In this section a description of competencies in science, mathematics, and technology/engineering are presented, as are the two non-STEM subjects of language arts and social studies.

Math and Science

All K-5 teacher candidates in New Jersey are required to take the Elementary Education Content Knowledge test (test #0014), maintained and monitored by Educational Testing Service (ETS). ETS published a national summary for 2008-09 (Educational Testing Service, 2008) and a portion of the summary is reproduced in Table 1 under the column National Averages. Praxis™ scores were manually collected from TCNJ students starting in April-2002. The collection of these individual scores enables a more detailed statistical analysis than is possible by looking at the general statistical parameters provided by ETS.

Each category of TCNJ students performed well compared to the national averages. For example, the median Praxis™ score for TCNJ students was approximately 16% above the national average. (Note: the minimum possible score is 100.) Moreover, the middle 50% distribution of scores is substantially narrower for the TCNJ populations. For example, the 50%-width of the national distribution is 25 while the TCNJ distributions are 15 for the non-MST students and 13 for the MST students.

Table 1
Elementary Education Content Knowledge Praxis^{TM} test score comparison by major to national averages

Parameter	National Averages	TCNJ Non-MST	TCNJ MST
Possible Score Range	100-200	100-200	100-200
No. of Examinees	92910	346	59
Median Score	164	179	181
Range of Average Performers (middle 50%)	151-176	169-184	174-187

The total populations for the TCNJ data were 346 non-MST majors and 59 MST majors. The MST population scored on the average of 180.3 on the Praxis^{TM} with a standard deviation of 9.3 compared to the non-MST population that exhibited an average score of 176.3 with a 15% larger standard deviation of 11.0. A *t*-test was completed using Microsoft Excel and indicated that the difference between the MST and non-MST populations was significant at the 95% confidence level ($p = 0.003$).

Over the same timeframe, the subject-specific subscores in math, science, language arts, and social studies for the Praxis^{TM} test (#0014) were also collected, enabling a detailed statistical analysis. The average test scores are shown in Table 2 for four subgroups: non-MST, MST, Math, and Science. Figure 3 shows a summary of the average Praxis^{TM} subscore tests for MST graduates as a percentage, a percentage *relative to the non-MST* students.

Table 2
Subject matter specific subtest results for Non-MST majors, MST majors, Math majors and Science majors on the Elementary Education Content Knowledge Praxis^{TM} examination

	Math		Science		Lang. Arts		Soc. Studies	
Population	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Non-MST	25.5	3.2	21.9	3.2	25.9	2.4	19.1	3.0
MST	26.9	2.7	23.6	3.0	26.2	2.4	18.9	3.2
Math	28.3	1.0	23.0	3.5	27.2	1.8	19.8	3.9
Sci. (Bio.)	27.5	1.7	23.5	2.4	26.5	1.7	19.8	3.3

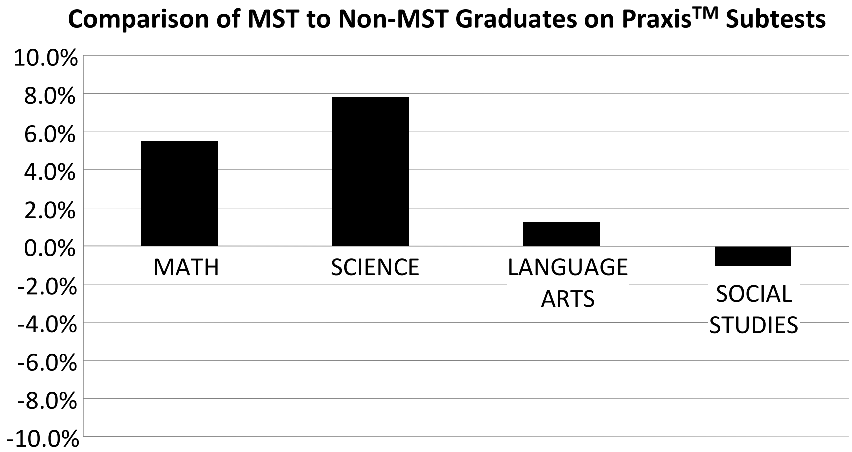

Figure 3. Relative percent comparison of subtest scores of MST graduates to non-MST graduates on the Content Knowledge Praxis™ examination. (i.e., the MST population scored 5.5% higher than the non-MST population on the math subtest).

A *t*-test was conducted for both the math and science subscore distributions between the MST and non-MST populations reported in Figure 3. This analysis indicated that for a 95% confidence level the 5.5% and 7.8% differences for math ($p = 0.004$) and science ($p = 0.001$) were significantly different, whereas the language arts and social studies subscores were not. These data show that, compared to non-MST majors, MST graduates scored significantly higher in math and science competencies, while maintaining high competency on non-STEM subjects.

Other useful comparisons are scores in math and science amongst only the STEM majors (MST, biology and math). All of the STEM majors scored high on the math and science tests, within a few percent of each other. Perhaps as expected, the math majors scored highest on math but did not perform as well on science. The only STEM populations that had statistically significant differences were the MST and math major populations in the subject of math.

The average Grade Point Averages (GPAs) for MST and non-MST populations over the same time frame were 3.41 and 3.47 and the difference did not reach significance. These data indicate that MST and non-MST majors are generally performing identically in their college course work. The combined Scholastic Aptitude Test (SAT) scores for the MST and non-MST populations were 1250 and 1195, respectively. The difference in these scores is due primarily to higher scores on the math portion of the exam, which is not surprising due to the higher interest level in math and science for the MST population. Finally, scores on the math and science middle school Praxis™ exams for Spring-2009 also verified high competence for MST majors, with scores at or above the national median.

Technology & Engineering

The required coursework in the T- and E-components include technological literacy, skills in modeling and making, substantial emphasis on design processes, and science and math required for basic design. Key subject matter includes industrial, graphics and architectural design, creative design, human factors, structures, mechanisms, materials bio-technology and electrical technologies. The original MST-program proposal also included a course to reinforce the importance of integrated STEM teaching. This course is called "Integrated-STEM for Young Learners" and is required for all MST and TE majors (see for example Sanders, 2009). In the course MST majors acquire experience and comfort with T&E content related to young learners, enabling them to more easily, and more frequently, integrate activity, inquiry, and context into learning experiences. As stated in the Standards for Technological Literacy (ITEA, 2000, p. 7), "… the study of technology is a way to apply and integrate knowledge from many other subjects- not just mathematics, science, and computer science classes, but also the liberal and fine arts."

Another potentially valuable aspect of the T&E courses is that significant time is spent on investigating how to effectively teach STEM and non-STEM, concepts through T&E-based activities. T&E professors are acutely aware that they are preparing future teachers, not engineers or scientists. This additional educational element is not part of teacher preparation programs in other subject areas. Though this element is similar to the familiar "methods" classes, that have beneficial effects (Hiebert, Morris, Berk, & Janson, 2007), there are unique differences as well.

The fields of math and science have established methods to measure content knowledge (i.e., Praxis™ tests). However, no such assessment for K-5 T&E content knowledge exists. Simply having substantial T&E content in an undergraduate K-5 program is itself unique, but the question remains of how to assess competency at this level. In this paper it is proposed that since the MST program is using the same courses as the ongoing NCATE accredited Technology Education program, an analysis of the T&E courses taken by MST majors is sufficient to quantify T&E competence. Correspondingly it is believed that competencies in T&E can be characterized by looking at three items: a mapping of the T&E curricula onto the STL, an analysis of grades of MST majors compared head-to-head with TE majors in the same courses, and performance on the TE Praxis™ exam. Mapping the T&E curricula onto the STL quantifies the level of T&E exposure while an evaluation of grades indicates if T&E content is being learned. Lastly, MST student performance on the TE Praxis™ test gives an external measure of T&E content knowledge.

Mapping T&E content onto STL.

TCNJ's TE program produces 10-15 graduates per year and, in order to teach, they must pass the TE Praxis™. Analyses of the institutional reports provided by ETS over the last four years indicate that TCNJ's TE graduates score roughly 30-40 points above the median. Moreover, the width of the distribution of TCNJ TE graduates, as measured by the total range of scores, has been one-half to one-third that of the national average. Assuming that TCNJ's framework of T&E courses is a major contributor to the Praxis™ scores as well as to the overall success of TE graduates in technology teaching positions, and that the Praxis™ scores represent a measure of T&E competence, then the level of exposure that MST majors to the T&E course work would be a good indicator of T&E competence. This level of T&E exposure depends on whether the MST student specializes in math, science, or technology. MST majors with a math or science specialization complete a minimum of five T&E courses (20 cr.). MST majors with a technology specialization complete approximately nine T&E courses (36 cr.). Common additional courses include Engineering Design, Analog Circuits & Devices, Digital Electronics, Environmental and Biotechnical Systems and Architectural & Civil Engineering Design and Facilities Design & Management. TE majors take approximately 16 T&E courses (about 64 cr.).

To summarize, math and science specialization MST graduates take about 32% of the T&E course load of a TE major, while technology specialization students take approximately 56%. This number of courses represents a high level of T&E content, especially considering that typical teacher preparation programs require no T&E content, no "integrated-STEM" educational content, and only minimal math or science. Statistics available on the U.S. Department of Education's Institute of Education Sciences (IES) website for National Center for Education Statistics (NCES) shows that an education major graduate in 1992-93, the most recent year that data was available, completed an average number of 6.3, 10.4 and 0.3 semester credits in math, science and engineering, respectively. An MST major exceeds these figures with a minimum of 15-20 credits in math, 15-20 credits in science and 20 credits in T&E.

The content of the T&E course load is better defined by mapping it onto the STL. The STL consist of twenty standards organized into five categories. Benchmarks are given for each of the twenty standards for four age groups; K-2, 3-5, 6-8 and 9-12. There are 101 benchmarks for grades K-5 and another 85 benchmarks for grades 6-8. Keeping in mind that there are two MST populations with differing amounts of T&E content, Figure 4 shows the results of the mapping process for grades K-2, 3-5 and 6-8.

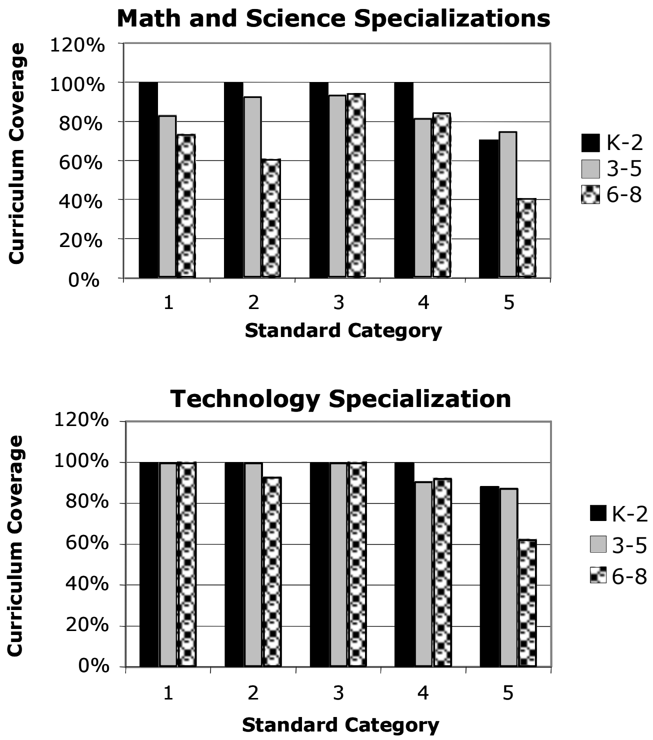

Figure 4. A mapping of TCNJ's T&E curriculum onto Standards for Technological Literacy for the two specialization groups of (a) math or science and (b) technology.

This mapping indicates that, except for Standard category 5, the math and science specializations have 80-100% coverage for grades K-5, while the technology specialization has 90-100% coverage. The fifth category of the Standards includes benchmarks for seven very specific technologies and the narrowness of breadth of the MST program does not allow coverage of all of these technologies. In category 5, the MST program coverage is at the 60-70% level for math and science specializations, and above 80% for technology specializations.

Grades in T&E courses.

In the previous section, it was shown that MST majors are exposed to most of the T&E content suggested by the STL. However, are MST students learning the T&E content? The analysis presented here shows that MST majors, compared head-to-head to TE students in the same T&E courses, achieve grades that are equal to or higher than TE students. In essence, the TE students serve as a standard of comparison and, given the history of good performance of the TE majors, this seems to be a valid comparison.

Figure 5 shows data from a 3-year period for four courses that include two required courses and two popular elective courses. These data represent grades for the 163 MST students enrolled in these courses. For individual assignments, MST students scored between 2% and 7% higher than TE students in these courses. Similar results were obtained for an upper level Architectural & Civil Engineering Design course that included intensive writing and human factors design assignments (see Figure 6). Investigations of several other courses, including the required courses of Creative Design and Integrated-MST for young learners yielded similar results.

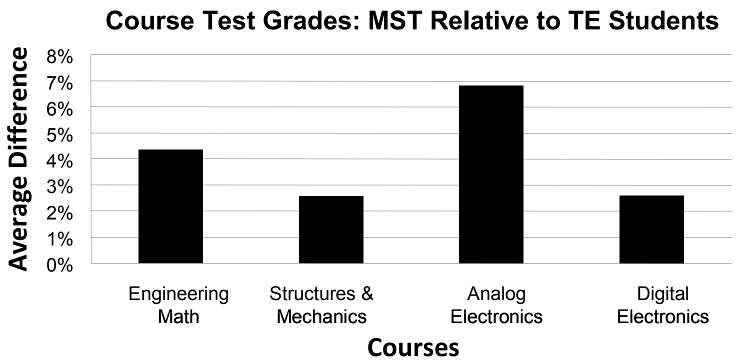

Figure 5 Grades of MST students relative to the TE students in four selected courses.

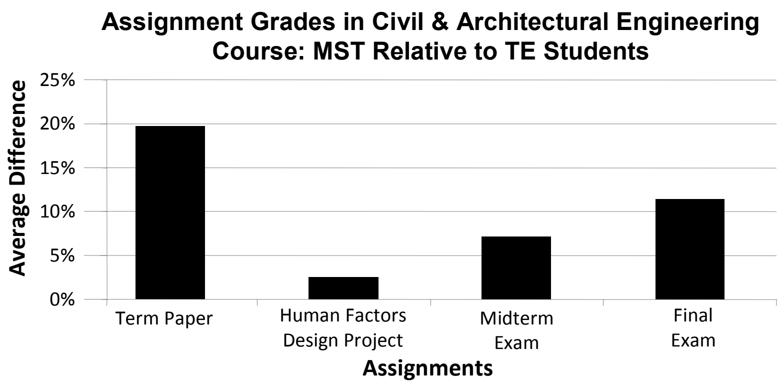

Figure 6. Grades of MST students relative to the TE students on four assignments in a selected course.

An analysis of grades over a three year period for a lab-intensive materials processing class produced the same result: MST grades were on par, or better, than TE students. This result was counterintuitive because MST majors start the program with clearly weaker skills and lower comfort with laboratory tools. However, MST students tend not to hesitate in asking for help in understanding a process and a TE student is often the one providing the help. This is mutually beneficial but it may not explain the unexpected differences.

In summary, MST students are not simply passing T&E courses but are actually performing on par or better than the TE students. This is a strong indication that MST students are learning substantial T&E content.

Technology Education Praxis™ results.

Approximately 15% of the MST students choose the technology specialization go on to obtain a Technology Education endorsement, requiring passing the TE Praxis™. The TE Praxis™ scores for three MST majors were found to be between 630 and 640. These scores were within the national average performance range of about 620-680. These external data also suggest that MST graduates are learning substantial T&E content.

Discussion

Mutual Effects on the MST and TE Programs

In general, the MST and TE programs have had several positive impacts on each other. One important and desirable result is that TE & MST students receive a better understanding of the teaching skills required for a broader age range. MST majors are passionate about teaching K-5, while the TE majors are primarily interested in learning skills for grades 7-12. This difference in intended teaching age range among the majors leads to fruitful interactions in a variety of formal and informal settings, giving both majors more skills and experiences. This prepares each group to be better teachers, and to potentially fill broader roles in the school districts in which they will be employed.

A second effect concerns academics. MST majors in general tend to be more skilled in classic academic tasks like writing, research, and organization. This has a beneficial effect since, through interaction with MST majors, TE majors can improve their skills in these areas. There is also give-and-take because the TE majors have more skill and comfort with hands-on materials processing, so MST majors benefit by interacting with TE majors relative to these tasks.

A third effect deals with pedagogy. TE students, especially early in their program, are more interested in the technological aspects of their education. In contrast, as entering freshmen MST students are interested in how to teach. MST students also have teaching-related experiences earlier in their programs. Thus, in subsequent interactions, MST students can positively influence TE students relative to pedagogical concepts.

A fourth effect is social in nature, but likely has an important academic impact. TE majors are primarily male while MST majors are primarily female.

This has led to substantial social interaction. For example, the students organize both a "Welcoming Picnic" in the Fall, with particular attention to incoming freshman, as well as a Spring "Semi-formal Dinner Dance." Additionally, MST participation in the regional Technology Education Collegiate Association (TECA) conference is increasing sharply, due to both professional and social forces. MST and TE majors interact at a significant level throughout the course of an average school week. In the last few years the level of social interaction has increased significantly, perhaps due to the growth in the number of MST students which consequently has reached a critical mass. This informal "out-of-the-classroom" learning environment likely increases the content and practical knowledge of both student populations.

A fifth effect concerns gender diversity. The MST population is primarily female while the TE population is primarily male. This diversity results in several benefits, including a higher awareness and expectation of exemplary female role models in technology education.

The MST Program as a National Model for K-5 STEM Education Program

As mentioned earlier, the representation of STEM-trained K-5 teachers is low. Therefore, programs that can substantially increase the number of STEM-trained K-5 teachers should have a beneficial impact on K-5 student outcomes, resulting is higher skills and interest in STEM subjects. TCNJ's MST program has increased the fraction of graduating STEM-trained K-5 teachers by about three-fold in the last five years. If an MST program is, by its nature, more attractive to students, then initiating such programs across the USA would increase the number of STEM-trained K-5 students on the national level.

A second reason to expect a positive impact from MST graduates is the inclusion of substantial T&E content and skills in an integrated fashion with the M- and S-components. Research indicates that the hands-on "active" model and make and open-ended problem skills are valuable in achieving high quality learning experiences in both STEM and non-STEM subjects (Brophy, 2008; Hmelo-Silver, Duncan, Chinn, 2007; Lachapelle, 2007). These skills are just what are learned in the MST program. This gives existing Technology Education programs a substantial advantage in initiating valuable K-5 programs because they have well-established, education-based T&E course frameworks, facilities, and faculty.

Summary and Future work

In this paper, it was demonstrated that a multidisciplinary MST program has been successful both in terms of growth and content knowledge. The MST program should be particularly well-suited to today's educational environment in which substantial numbers of students in STEM-related areas are lost, their scores are low on quantitative literacy, and they would likely score low on measures of technological literacy (Steen, 2001). Even with the breadth of the multidisciplinary program, MST graduates scored significantly higher than non-MST majors on national Praxis™ tests for both math and science, while also scoring equivalently high on non-STEM subjects. Graduates also demonstrate high skills in T&E content that has substantial overlap with the STL. With extensive training and experience in all areas of STEM and integrated-STEM concepts, MST graduates are well prepared to thoroughly engage their prospective students in learning STEM and non-STEM subjects.

By means of summary the faculty believe there are five key attributes of the MST major:

1. *Breadth through STEM*
   Through its multidisciplinary nature, STEM develops a broad, high quality skill set that closely matches what is needed by teachers in a K-5 classroom. Important among these skills is knowledge of each of the four STEM fields. The T&E portion of STEM is of critical importance since it provides a realistic context and relevant activities.
2. *Content integration*
   At all educational levels, but perhaps more importantly in the younger years, the interrelationships among the four elements of STEM are of vital importance. MST graduates have substantial experiences with these interrelationships.
3. *Attractive to students*
   The growth of the program indicates that the MST major is attractive to students and can bolster the overall enrollment in the program.
4. *Teacher modeling*
   All students in the T&E courses aspire to be teachers. Thus, unlike a general science or math course, a teaching context is always present as the students are engaged in the courses.
5. *Gender benefits*
   Most MST students are female, thus providing positive role models in STEM to female students in grades K-5.

If programs like that described herein were to be implemented across the nation, it could have a dramatic effect on the presence of technology education in the elementary school. For example, 35 TE programs with 30 MST graduates per year would yield over 1000 new integrated STEM teachers at the K-5 level each year. Given a 1000 to 1 impact ratio over the course of a teacher's career, this would potentially impact at least 1 million students. This would have a significant impact on increasing the technological literacy of students in the lower grades and could result in considerable advantages to the credibility and acceptance of technology education as a vital part in K-12 education, as well as teacher preparation.

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A Case for the Nationwide Inclusion of Engineering in the K-12 Curriculum via Technology Education

Thomas E. Pinelli and W. James. Haynie, III

Introduction

This paper resulted from discussions between a technology teacher educator and a colleague who has served in various education outreach roles with NASA. The basis of the paper was developed by the NASA director and two engineers, one serving with NASA and the other with the National Institute of Aerospace. That colleague is also a professor of mechanical and aerospace engineering at a major research university. The technology teacher educator read the original paper as published in the NASA Technical Report Server (NTRS) ntrs.nasa.gov/search.jsp (as document 20080018711) and realized that, though it addressed an audience of engineers, its implications for technology educators were obvious. As evident in the paper, the engineering community seeks a means to reach into the K-12 curriculum at the same time that leaders in technology education are promoting design and engineering in our curricula nationwide (Daugherty, 2005; Kelley and Kellam, 2009; Wicklein, 2006). Since we are both on the same page, it is important to cross-communicate—this revised version of the engineering paper with added implications for technology education provides support for current trends in our profession and shows how the linkages can best be implemented.

Some disclaimers are needed before proceeding. The reader will note that the perspective in much of the following discussion is that of the *engineer* as he or she describes their own role and differentiates it from the role of a scientist. Further, it is the engineering community of the United States. Hence, there are quotations and excerpts that may be perceived by some readers as extremist, parochial, exclusionary–perhaps even rudely so. Additionally, of the four letters in the oft-used acronym STEM, we in Technology Education frequently decry that the T is under stressed in our education community while the “S” and the “M” are emphasized. However, in this paper the perspective of the engineer makes much mention of “S”, “T”, and “E” while rarely mentioning the “M.”

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Mathematics is rarely mentioned even in discussions about the differences and similarities among science, technology, and engineering. That is because, to the engineer, math is simply a way of life and a tool of the trade. Obviously, for both the engineer and the scientist, mathematics is central to every new discovery and application; math is at the heart of technology; and math will certainly be employed and reinforced in the new engineering-based courses in technology education. Further discussion of the importance of mathematics, however, is beyond the scope of this paper.

If a given cited reference or quotation in this paper seems to indicate that science and engineering are totally unrelated (using terms such as "always" or "exclusively"), that is one source's opinion or perspective, but the readers of the JTE are wise enough to cast that citation against others and find middle-ground norms. Still, this paper often presents genuine, though not always well accepted, perspectives that should be heard. This is done not to promote an "Americentric" or "engineering only" basis for technology education, but just so JTE readers will see the perspectives of the US engineering community without the "polishing" (read: smoothing out by abrasive action) of educators. That said, if nothing in this paper disturbs you a bit or seems overstressed, then you likely did not read carefully enough!

Engineering Education - Background

In a global, knowledge-based economy, technological innovation with its influence on competitiveness, long-term productivity, and improved quality of life is critical. One key factor to consider for the nation's primacy in technological innovation, national security, and its economic vitality is engineering education and practice. The leadership of the United States in technological innovation is challenged by the increase in research and development (R&D) by China and other nations. This accelerates the pace of discovery and application of new technologies, and demands the education of a 21st century technical (engineering) workforce. The US is experiencing a continued erosion of the engineering research infrastructure due to inadequate and lagging investment; declining interest of American students in science, technology, engineering, and mathematics (STEM); and an insufficient ability to attract and retain gifted engineering and science students from abroad at a time when foreign nationals constitute a large component of the US R&D workforce. (NAE, 2005). The nationwide inclusion of engineering in the K-12 curriculum through technology education could raise the interest of American students in STEM and in engineering careers.

Increasing acceptance of engineering as a discipline and profession in the United States has involved ongoing tensions and a search for a clearer identity; the same is true for engineering education. A college degree has not always been required to become an engineer because some believed that the skills needed could be better gained through experience rather than education. As Grayson (1993) pointed out, early, traditional universities viewed engineering as pragmatic and too utilitarian to be included as a discipline in higher education.

Westward expansion, the Morrill Act of 1862, and the industrial age led to new acceptance of engineering curricula in colleges. The twentieth century saw further expansion due to two world wars, Sputnik, and the rise of the United States as a world leader in technological innovation. Over the last 200 or so years, engineering has evolved into a recognized profession and a discipline with its own body of (engineering) knowledge. However, the current problem has more to do with identity and less to do with acceptance. Simply put, engineering is not (exclusively) applied science (though application of scientific principles is a part of what engineers do). Engineers are not scientists nor do they drive trains. Henry Petroski (2007) asks how engineering can be the most unrecognized occupation in the world when the results of what engineers do (make, produce) are so clearly obvious and important? It is very possible that the nationwide inclusion of engineering in the K-12 curriculum via technology education could help resolve the identity problem and also increase the interest of American students in engineering careers.

Science and Engineering

Science is concerned with the natural world and, as such, it is an introverted activity. Scientists study problems such as logical discrepancies, inconsistencies, or anomalous observations that lie beyond the existing intellectual framework. Scientists do their best work when investigating problems of their own selection in a manner of their own choosing (Amabile and Gryskiewicz, 1987). The output of science is knowledge and it is regarded by scientists essentially as a free good. The expectation within the scientific community is that knowledge will be made universally available through presentations at conferences and professional journals.

In opposition, engineering is an extroverted activity concerned with the designed world. It uses the design process of identifying a problem, designing a solution, and testing and improving the design to produce workable solutions and create the innovations that give us modern life with all its advances and conveniences. While engineering yields effective and workable solutions, it does not (often) pursue the why (Salomon, 1984).

Technology

Technology, the output of engineering, includes processes, products, systems, and services. Technological knowledge is not freely communicated and shared—there is usually a profit motive. "Technology, unlike science, often is not made universally available. Technology successfully functions only within a larger social environment that provides an effective combination of incentives and complementary inputs into the innovation process." (Lindberg, Pinelli, and Batterson, 2008, p. 2) Technology is a process dominated by engineers rather than scientists (Landau and Rosenberg, 1986).

The Relationship between Science, Engineering, and Technology

Science and engineering play major roles in technological innovation through the production, transfer, and utilization of knowledge. In a capitalistic system, innovation relies on market forces and application of scientific and technical knowledge, along with human, technical, and financial resources, to create or improve products, processes, and services. Technical progress and economic growth depend upon innovation and economic growth fosters further technological innovation which creates jobs and raises the standard of living.

The assumption that technology grows out of or depends upon science suggests a linear path (or metamorphosis) from basic research (science) through applied science (with engineering as one aspect) to development (utilization or technology). This common notion may explain the use of the conventional phrase "scientists and engineers." In fact, science and technology (as developed by engineering) are somewhat interrelated in that advances in one may both depend upon and open the door for advances in the other. Differing aspects of this relationship can be examined in detail in Shapley and Roy (1985) and Allen (1977). "In short, a normal progression from science to technology does not exist, nor is there direct communication between science and technology. Rather, both are directly and indirectly supported by each other." (Lindberg, Pinelli, and Batterson, 2008, p. 3) No direct communication system among science, engineering, and technology exists other than the flawed one that exists in education.

Some recent researchers question the classic distinctions between science and technology as well as between scientists and engineers. They argue that if observations are made at either the actor level or the societal level, the distinctions between science and technology appear to fade (Latour, 1987). Through summarizing viewpoints of some theorists of technological studies, it appears that the structures of societies determine the technologies that will be developed (Law, 1987; Law and Callon, 1988; Rip, 1992; and Weingart, 1984). Rip (1992) asserted that "the dancing partnership of science and technology [is] a relation between activities oriented to different reference points and groups, rather than a matter of combining different cognitive-technical repertoires" (p. 257). Thus, science and technology, scientists and engineers, do many of the same activities but in different ways or with differing purposes.

The distinction between science and technology is further clouded when one looks closely at the varieties of actors and organizations that constitute technology.

> For example, in aerospace some engineers and scientists are working on methods to explore the edge of the universe and others on how to best design an aircraft . . . Some deal with very abstract ideas and others with difficult technological, economic, or management issues. Much research that attempts to understand the differences between science and engineering has examined what Constant (1980) termed radical science or technology. That is, much research focuses on changes in paradigms or fundamental ways of thinking about a phenomenon or artifact. For example, Constant examined the role of presumptive anomalies in technology to understand fundamental changes. His best example is the adoption of the jet engine. Little research focuses on the day-to-day activities of scientists and engineers where science and technology

are maintained through routinized activities (Lindberg, Pinelli, and Batterson, 2008, p. 3).

Engineers and Scientists

The key difference between engineers and scientists can be defined on the basis of the primary goal of the output of their work–scientists produce knowledge (facts) and engineers produce designs, products, and processes (artifacts). There are other important differences such as the nature of their education and the type of work activities, but they point mainly to differences in their information-seeking behaviors and information needs.

Neither self-classification nor the analysis of tasks has accurately determined differences between engineers and scientists. Citro and Kalton (1989) found such errors when they attempted to describe differences based on analyses of tasks, job descriptions, education, and self-identification. Even using multiple indicators did not reduce the error. It is possible the increasing bureaucratization of these professions makes it more difficult to accurately differentiate them. Kintner (1993) used job classification, education, and job history as a means to identify engineers, but missed 15% of those who were actually doing engineering work.

The term "technoscience" to describe the relationship between engineering and science was employed by Latour (1987). Using a network actor perspective, he described daily activities of scientists and engineers. Results showed that:

> …personal success in technoscience did not depend primarily on how well engineers and scientists performed their jobs, but on how well they were able to recruit others into believing in the value of what they did. For those in technoscience, recruiting others included writing proposals, looking for funding for projects, doing research, and other activities that would not be considered either science or engineering. That is, success . . . does not depend so much on what is made (engineers) or on the development of new knowledge (scientists) but rather on how well the engineers and scientists are able to recruit others into the process of technoscience" (Lindberg, Pinelli, and Batterson, 2008, p. 4).

In short, when one examines engineers and scientists over the course of their careers, it may be difficult to distinguish between them. When making new products and knowledge, traditionally considered the activities of engineers and scientists (respectively), each group appears to behave quite differently; yet many of their activities, including management, are the same. The casual observer faced with these contradictions develops the misunderstanding that engineers are the same as scientists.

Differences between Engineers and Scientists

Despite changes in engineering and science over the past 20 years, Ritti (1971) found a marked contrast between the goals of engineers and scientists. Engineers in industry are concerned with meeting schedules, developing successful products, and helping the company expand. Although both engineers and scientists desire career advancement, for the engineer it is tied to activities within the organization while for the scientist it depends upon the reputation established outside the organization. Finally, publication of results and professional autonomy are highly valued goals of the Ph.D. scientist, but they are valued little by the baccalaureate engineer.

Blade (1963) noted that engineers and scientists differ in training, values, and methods of thought. Their individual creative processes and products differ with scientists most concerned with discovering and explaining nature while engineers use and exploit nature. Scientists search for theories and principles while engineers seek to develop and make things. To the scientist a result is sought for its own end. Engineers are engaged in solving problems for practical results while scientists create new unities of thought; engineers invent things and solve problems. Danielson (1960) found that engineers and scientists are fundamentally different in how they approach their work, the type and amount of supervision required, the recognition desired, and personality traits. In fact, Allen (1977) conjectured that the type of person who is attracted to engineering is fundamentally different from one whose career is in science:

> Perhaps the single most important difference between the two is the level of education. Engineers are generally educated to the baccalaureate level; some have a master's degree. The scientist is usually assumed to have a doctorate. The long, complex process of academic socialization involved in obtaining the Ph.D. is bound to result in persons who differ considerably in their life views. (1977, p. 5)

In a later work, Allen (1984) concluded that the differences in values and attitudes toward work are reflected in an individual's behavior and in their use and production of knowledge.

Much of the research on differences between engineers and scientists is aging and fails to consider the impact of changes in post-World War II engineering curricula and the Sputnik era to meet military and industrial challenges (Grayson, 1993). The Grinter Report (1955), prepared by a committee of the American Society for Engineering Education (ASEE), urged inclusion of more science and liberal arts in engineering education. This transformed engineering education in two decades from "hands-on" training to a more theoretical perspective resembling other academic disciplines such as the sciences. Grayson (1993) calls the period from World War II through 1970 the "scientific" period. Since the 1960s the distinction between the training of engineers and scientists has blurred. Likewise, the types of work that they do in large bureaucratic organizations makes it increasingly difficult to differentiate them by title alone.

> Engineering can be defined as the creation or improvement of technology. As such, it clearly encompasses both intellectual and physical tasks (i.e., both knowing and doing). Engineering . . . is a social activity in that it often involves teamwork, as individuals are required to coordinate and integrate their work (Lindberg, Pinelli, and Batterson, 2008, p. 5).

They continue to explain that "the production of the final product depends on the ability to maintain successful social relationships (e.g., negotiate with vendors, maintain smooth personal relations among members of a work group). Membership in a community is important for the effective functioning of . . . engineers." (p. 5). Engineers work in an embedded set of contextual relationships while scientists often conduct activities with only a vague reference to others doing similar work.

Similarities between Engineers and Scientists

At times engineers behave very similarly to scientists and adopt scientific methods to generate knowledge. Ritti (1971) asserted that engineering work includes scientific experimentation, mathematical analysis, design, drafting, building and testing prototypes, technical writing, marketing, and project management. More recently Kemper (1990) noted that typical engineers define problems, develop new ideas, produce designs, solve problems, manage the work of others, produce reports, perform calculations, and conduct experiments. Florman (1987) described engineering work as encompassing both theory and empiricism while Ziman (1984) concluded "technological development itself has become 'scientific'. It is no longer satisfactory, in the design of a new automobile, say, to rely on rule of thumb, cut and fit, or simple trial and error. Data are collected, phenomena are observed, hypotheses are proposed, and theories are tested in the true spirit of the hypothetico-deductive method (p. 130)."

In 1980, Constant described the similarities between engineering and science in his history of the development of the jet engine. He used a "variation-retention" model to describe how engineers and scientists create technological change. Change in technology results from random variation and selective retention. Technological conjecture may occur as a result of knowledge gained from scientific theory or engineering practice. It yields potential variations to existing technologies. In the case of the turbojet, technological conjecture was based on engineers' knowledge of scientific theories. In contrast, when writing, scientists often describe their methods as following the hypothetico-deductive method. However, in their daily research activities, they often use methods similar to those of engineers such as the variation-retention method.

Engineering in the K-12 Curriculum through Technology Education

In recent times one often hears that within STEM education, the "E" is silent. In K-12 education, engineering is partially represented via science and mathematics, so it would be incorrect to say it is totally absent. The point is that both science and mathematics have supporting national standards and career information, and both exist nationwide in grades K-12, yet engineering does not have a significant presence at this level of education. At the same time, engineering was included in the National Research Council's (1996) *National Science Education Standards*. The problem is that it is represented as applied science rather than as engineering. The same is true for science standards in many states. On a related note, the International Technology Education

Association (ITEA, 2000) has promulgated the *National Standards for Technological Literacy*. Likewise, the National Council of Teachers of Mathematics (NCTM, 2000) published the *Principles and Standards for School Mathematics,* The American Association for the Advancement of Science (AAAS) published *Benchmarks for Science Literacy* (1993) and *Science for All Americans* (1989). Two chapters of this publication – "The Nature of Technology" and "The Designed World" – refer to the "human control of technology" which is tacit acknowledgement of engineering. The ITEA sources also use the same terminology freely. Within K-12 STEM education, national standards exist for the "S", "T", and "M" but not the "E" except as it is represented piecemeal in those for "S", "T", and "M."

Engineering is not entirely absent from grades K-12. Massachusetts, for example, has developed and implemented a K-12 engineering curriculum complete with corresponding standards:
http://www.doe.mass.edu/framework/scitech/2001
Several states appear to be moving in this same direction and there are three nationally available K-12 engineering programs – Ford Motor Company's *Partnership for Advanced Study (PAS)*; *Project Lead the Way*; and Texas Instrument's *Infinity Project*. Ford's PAS (http://www.fordpas.org/about/) program is inquiry- and project-based, academically rigorous, and interdisciplinary. The program provides students with content knowledge and skills necessary for future success in business, economics, engineering, and technology.

Project Lead the Way (PLTW) (http://www.pltw.org/about/about-us.html) was created in New York state to fill a curriculum gap for high schools. PLTW is a not-for-profit organization promoting engineering courses for the middle grades and high school grades in partnerships with public schools, higher education institutions, and the private sector to increase the quantity and quality of engineers and engineering technology graduates.

The Infinity Project (http://www.infinity-project.org) was developed by the Institute for Engineering Education and Texas Instruments, working in partnership with the U.S. Department of Education and the National Science Foundation, to help fill the need for U.S. engineering graduates by encouraging more young students to pursue engineering careers.

The common reasons for not offering K-12 engineering are familiar: no room in the curriculum, lack of funds, and difficulty finding qualified teachers. A common solution is to include engineering concepts in existing courses. It is our contention, however, that "engineering is a stand alone discipline with an established body of knowledge that deserves to either 'stand or fall' on its own merits . . . the value it adds to K-12 education and to the teaching and learning of STEM, and the role it plays in helping to create a technologically literate citizenry and society." (Lindberg, Pinelli, and Batterson, 2008, p. 6, representing the engineering community) Within this context, three reasons for nationwide inclusion of engineering in the K-12 curriculum are offered below.

1. To Support the Engineering Pipeline

The United States faces a critical shortage of engineers in the decades ahead. The NSF estimated that the shortage of engineers in the United States will reach 70,000 by the year 2010. Is there really an engineering shortage? It depends on who is telling the story. One thing is certain: It is difficult to pick up a magazine or paper, or look at a news and commentary website, without seeing knowledgeable people bemoaning and debating the “engineering shortage.” Though they may not pass the scrutiny to stand as refereed evidence, here are some factoids gleaned from the Web as by Lindberg, Pinelli, and Batterson (2008, p. 6).

- Fewer than 15 percent of all current high school graduates have the math and science background necessary to successfully pursue an engineering degree.
- More than 85% of students today aren't considering careers in engineering.
- Only two of every 100 high school graduates go on to earn engineering degrees.
- Only five of every 1,000 female or minority graduates become engineers.
- Europe produces nearly three times as many engineering graduates as the United States. Asia produces almost five times as many.
- More than half of all U.S. engineers are near retirement age.
- Nationwide, engineering enrollment and retention is down.
- Engineering has a perception problem that discourages students from pursuing the profession.
- K-12 schools lack an engineering tradition.
- American students are lazy and engineering is boring; the smart kids choose more exciting majors.

If there is a shortage, steps need to be taken now to introduce more middle and high school students to engineers and engineering careers. We must make them aware of the importance, challenge, and excitement of engineering and make certain that they have reliable information about the courses needed to prepare for college. Adding engineering to the K-12 curriculum could serve as a means of closing the gap. Lindberg, Pinelli, and Batterson (2008) identified learning objectives for K-12 engineering from the literature:

- Understand why and how humans design, engineer, and innovate to meet our needs.
- Develop critical thinking and analytical skills by applying the design process.
- Use, manage, and evaluate designs and technology-based systems.
- Understand the relationship between STEM concepts and STEM courses.
- Learn to communicate engineering and technical content individually and as part of a team.
- Understand the historical implications and significance of engineering and its relationship to societal evolution.

- Become aware of and appreciate engineering as a career path. (p. 7)

2. To Enhance and Enrich the Teaching and Learning of STEM

Engineering should be viewed as curriculum only when it directly supports the engineering career pipeline. Engineering does, however, complement the learning objectives of other subjects, particularly science, technology, and mathematics. Some understanding of engineering is an important attribute of both scientific and technological literacy. The problem solving orientation and teamwork characteristics of engineering, essential 21st century workforce skills, directly support the overall goals of elementary and secondary schools. Many science and mathematics educators believe that engineering, especially the engineering design process, provides the context for valuable application opportunities and motivation for students.

Engineering can reinforce scientific inquiry and the scientific method. It can provide clear illustrations to help students understand scientific and mathematical concepts. In recent years, the NSF has funded curriculum projects in which engineering was used as methodology for demonstrating the interdisciplinary nature of mathematics, science, and technology. Some of these projects were university-developed and yielded engineering-based learning modules and professional development activities for K-12 teachers.

Lindberg, Pinelli, and Batterson (2008) identified the following valuable outcomes of using engineering to enhance and enrich the teaching and learning of STEM in K-12:

- Develops problem solving and critical thinking and skills.
- Develops reasoning, estimating, and analytical skills.
- Illustrates the relationship(s) between “higher level” math and science concepts and the “real world”.
- Demonstrates the value of teamwork, cooperation, and collaboration.
- Builds language arts and communication skills.
- Increases scientific and technological literacy.
- Nurtures creativity, ingenuity, and innovation.
- Fosters organizational, planning, and time management skills. (p. 7)

Despite the apparent benefits, a number of challenges still exist to using engineering to enhance and enrich STEM learning in K-12. One challenge is teacher certification and professional development. Another is the overcrowded curriculum, mentioned earlier and this is aggravated by “high stakes” testing. Without fundamental knowledge, curriculum developers who are not themselves engineers, and engineers who have no pedagogical knowledge, may not be able to make the “content connections” between engineering and other subjects. They may have difficulty establishing appropriate learning outcomes and effective instructional strategies integrating engineering concepts. Likewise, policy makers have little or incorrect information on which to base decisions concerning student achievement in STEM or the potential value of using engineering as "methodology" to teach other subjects.

3. To Create a Technologically Literate Citizenry and Society

Though there are several competing definitions of technological literacy, most have similar elements. The authors define technological literacy as "knowledge about what technology is, how it works, what purposes it can serve, and how it can be used efficiently and effectively to achieve specific goals" (Lindberg, Pinelli, and Batterson, 2008, p. 8). Conventional wisdom assumes we live in a world that is increasingly dependent on technology; technological literacy is essential for job readiness, citizenry, and life skills; it is vital that Americans be technologically literate; and to be technologically literate requires understanding the nature of science and technology. From a societal standpoint, a technologically literate citizenry (especially decision makers and public policymakers) improves the likelihood that decisions about the use of technology will be made rationally and responsibly. Sadly, too many Americans are poorly prepared to think critically about today's important technological issues. Much is known about people's opinions or attitudes about technology but very little about how much they understand it. Some educators hold the opinion that students should develop technological literacy skills in the context of learning and solving problems related to academic content. An engineering-based curriculum is well suited to help meet these needs. Students are generally considered to be technologically literate if they can:

- Demonstrate a sound conceptual understanding of the nature of technology systems and view themselves as proficient users of these systems.
- Understand and model positive, ethical use of technology in both social and personal contexts.
- Use a variety of technology tools in effective ways to increase creative productivity.
- Use communication tools to reach out to the world beyond the classroom and communicate ideas in powerful ways.
- Use technology effectively to access, evaluate, process and synthesize information from a variety of sources.
- Use technology to identify and solve complex problems in real-world contexts. (Lindberg, Pinelli, and Batterson, 2008, p. 8)

The programs and publications of the National Center for Technological Literacy (http://www.mos.org/nctl/), the publication of the *Standards for Technological Literacy*, (ITEA, 2000) (http://www.iteaconnect.org/) and the publication of *Technically Speaking*: *Why All Americans Need to Know More About Technology* (Pearson and Young, 2002) (http://www.nap.edu/catalog) in combination, created new impetus for technology educators to adopt an engineering approach to teaching. The ITEA standards suggest that students should know and appreciate engineering, understand the role that design and engineering play in the creation of technology, and be able to carry out engineering design activities (Meade and Dugger, 2004).

Toward Nationwide Inclusion of Engineering via Technology Education

There is concern that the current curricula, instructional strategies, and emphasis on rote learning (driven by end of course standardized testing) will not produce the higher order thinking and analytical skills needed in the 21st Century workforce. Perhaps new methods of teaching, new and innovative (cognitive-based) instructional strategies (employing student-centered learning), and new approaches to teaching and learning will help. We are passionate in our belief that the inclusion of engineering in the K-12 curriculum, via technology education, provides the opportunity to make these changes. How can it happen? The following are certainly needed:

- Commitment from the engineering community.
- Leadership in the form of a "champion."
- Identification and engagement of the stakeholders.
- Implementation of a series of strategically crafted alliances, collaborations, and partnerships.
- More programs for producing teachers.

Lindberg, Pinelli, and Batterson (2008) asserted that major responsibility for securing the political and economic capital to develop and implement K-12 engineering curricula rests with engineering school deans in collaboration with educators—especially technology educators. At the state level, the deans are best suited and positioned to assume a leading role in this effort and to develop the coalition needed to receive the approval of their respective state legislatures. The development of national engineering education standards is crucial. Perhaps the National Academy of Engineering in cooperation with the American Society of Engineering Education (ASEE), the International Technology Education Association (ITEA), and a coalition of professional engineering societies are best suited to accomplish this task.

A Novel Perspective for Engineering in Technology Education

Despite this clearly portrayed case for the inclusion of engineering in technology education and the rush by many professionals to promote it, one issue has received too little attention. That issue is the elitist nature of many proposed courses that would exclude many students. In the recent dialog concerning a potential shift in the curriculum of technology education towards engineering, most of the engineering-based courses have a mathematics or mathematics and physics pre-requisite. These pre- or co-requisites deny entry into the courses for students in the "average" and "below average" academic groups. Technology education still has a responsibility to meet the needs of those students who are not at the top academically. A possible means to meet the needs of some of these students while advancing engineering in the TE curriculum is to do exactly what engineering teams do in real life (Wicklein, Smith, and Kim, 2009). Engineering teams in large organizations generally include some members who execute the plans and build the prototypes. Rarely are these the same folks who set up the mathematical algorithms and solve the calculus problems. Additional skills and talents beyond mathematical adeptness that are needed in a successful engineering team include:

- Communication of ideas by written, graphic, and oral means.
- Construction and testing of mock-ups and prototypes
- Understanding of how to make things
- A "feel" for how strong materials are in building prototypes
- Creative brainstorming with multiple viewpoints represented.

A truly successful engineering design team rarely is one-dimensional consisting of stereotypical "math geniuses." Rather, it is more likely to be a large tent under which many and diverse beings can gather and work together comfortably to solve a problem. Sometimes in real life it is the technician who finally solves the thorny problem that is blocking the success of a venture or project. Technology education must insure that its engineering-based courses do not succumb to the temptation of becoming elitist safe harbors for only the top students—there are already plenty of those in every school in the nation. Technology education must maintain its democratic and inclusive ability to meet the needs of all students.

A Possible Approach to Consider

There must be some means of reaching all students through an engineering-based TE curriculum. Previously in this paper it was noted that in the early days of classic education, engineering was considered too practical in nature to be worthy of academic status. Now it seems that it is too academic in nature for some students to enjoy or even participate. What follows are two approaches for consideration. The details are not provided as the TE and engineering communities need to collaboratively develop them. Both approaches involve teams or design groups of future engineers and future technicians working together:

1. All levels of students enroll in the same course but performance expectations differ such that the "engineers" in the groups receive some form of honors credits, or
2. Two courses (designed for different levels of students) meet simultaneously in the same lab and work in teams to solve engineering problems.

Both schemas allow students of all academic levels to learn from each other and develop an appreciation of each other as they work closely in the engineering teams. Both approaches mirror what happens in large-scale engineering teams.

In contrast, the approach taken by many current engineering programs operating under the technology education umbrella may be leading potential engineering students into concluding that their careers will involve mainly the hands-on construction of prototypes, models, or products since "technicians" have not been identified within the design teams in their class and consequently the "engineer" members do the building themselves. In the real world, except in very small companies, the two roles are played by very different sorts of people with vastly differing educational preparation, knowledge, and skills. Under this scenario, there is room for both groups to work together.

The courses most certainly will integrate a variety of subjects, including communication, technology, engineering, mathematics, science, and the arts. A key component of such an approach, of course, is the provision of high quality, directly pertinent professional development (see Merrill, Custer, Daugherty, Westrick, and Zeng, 2008). Responsibility for this will fall on teacher educators in technology education working in collaboration with colleagues in engineering.

Conclusions and a Challenge

Whatever approach is used, it is imperative that engineering be included in the K-12 school curriculum, both as a discipline and as a source of enrichment and context for teaching other subjects. There is no better place for this to occur than in technology education. The authors hope that the perspective from the community of engineers shared in this paper will lend support to those leaders in technology education who are working to include engineering, resulting in the development of a fuller context for their arguments and providing some useful ideas as to how engineering can be included without eliminating the positive outcomes of contemporary technology education and the industrial arts of yesteryear from which it evolved. Wright, Washer, Watkins, and Scott (2008) clearly pointed out that some TE teachers view their courses as college preparatory while others do not. There should be a way in our discipline to reach the needs of all students through working together in goal-oriented groups. Kelley (2008) noted the importance of the groups having diversity in problem solving approaches. We contend that the groups should be diverse in all ways that society is diverse, including academic ability levels and interests.

New technology education courses employing multi-dimensional engineering design teams can better portray the engineering profession, aid in recruitment of future engineers, and meet the needs of a diverse array of tomorrow's students. They will also better represent the ITEA standards, even for those students who will not pursue a career in engineering. Creative engineering problems in a school environment can provide a context for problem solving, attaining technological literacy, and developing 21st century skills. We challenge our colleagues to develop new approaches incorporating the ideas presented to develop engineering-based technology education courses that meet the needs of all students while helping supply the engineers for the future.

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Engineering Student Outcomes for Infusion into Technological Literacy Programs: Grades 9 -12

Craig Rhodes and Vincent Childress

Introduction

In 2004, the National Center for Engineering and Technology Education (NCETE) secured funding from the National Science Foundation (NSF) to infuse engineering design into the schools through technology education. In order to reach this goal the researchers, in cooperation with NCETE, conducted a two phase study to identify outcomes for high-school students studying engineering. The first study (referred to as a Phase I) focused on students who intended to enter an engineering program after high school, answering the question:

> *What are the engineering student outcomes that prospective engineering students in grades 9 through 12 should know and be able to do and prior to entering into a post-secondary engineering program?*

This initial study by Childress & Rhodes (2008) started with preexisting items selected from ten sources, including focus groups and national standards projects. At the end of the Delphi Round 3, very few of these items had been dropped since the consensus on all of them was high. Therefore, the researchers decided to have selected engineers categorize the outcome items into groups of conceptual likeness and to assign categorical names to the groupings. These groups then formed the basis of the instruments for the remaining Delphi rounds.

This resultant baseline of achievement outcomes for prospective engineering students was then used to design a modified Delphi instrument for the second study (Phase II) reported herein. This study focused on students who were enrolled in technology education for general education purposes and sought input from technology education teachers, teacher educators, and supervisors regarding the following question:

> *What are those engineering outcomes that should be taught in a high school technology education program in which the focus is general technological literacy and not pre-engineering?*

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Background

Wicklein's "Five good reasons for engineering design as the focus for technology education" (2006; cf. NAE, 2004; Lewis, 2004) effectively identified the importance of this study. In presenting the advantages of infusing engineering into technology education, he stated that the optimization, analysis, and predictions are among the more important things and those students should know about engineering. This study takes the next step by identifying the related engineering design concepts to be included in a technology education curriculum.

Among recent efforts to identify engineering outcomes for high school students, Dearing and Daugherty (2004) used a modified Delphi technique to identify concepts that would prepare secondary students for postsecondary engineering, in the context of a course promoting technological literacy. Their experts were secondary and postsecondary educators.

Method

To develop the Delphi instrument for the present study, the results of Phase I were categorized and a ranked list of 40 outcomes, recommended by engineers for high-school students who want to pursue postsecondary engineering education, was determined.

Twenty-two technology educators served as Phase II Delphi participants: 7 high-school teachers, 6 administrators, and 9 teacher educators (Table 1). Each was paid a participation stipend. Participants were selected based on the researchers' knowledge of their professional expertise, or in some cases, on the recommendation of a person deemed qualified for participation. Potential

Table 1
Participant demographics

Gender		
Female	13.6%	(*n* = 3)
Male	86.4%	(*n* = 19)
Race		
Caucasian	95.5%	(*n* = 21)
African American	0%	(*n* = 0)
Hispanic	4.5%	(*n* = 1)
Age		
Mean	46.8	
Range	26 to 62	
Years Teaching Experience		
Mean	21.95	
Range	4 to 37	
Years Experience in Current TE Role		
Mean	13.4	
Range	4 to 31	

participants were asked to describe their level of knowledge of engineering and its relationship to technology education (Table 2).

No one participating in the study was an employee of an institution that is a full partner in the NCETE. Participant #4 and #22 dropped out at Round 1. All participants who completed Round 3 were paid a fee for their full participation.

Table 2
Participant Expertise

ID No.	Yrs. Experi-ence	Position	Self-Description of Knowledge
1	7	Classroom teacher	Described STLs and relationship to engineering
2	25	Supervisor	Strong
3	7	Classroom teacher	Past president of TE related association
4	7	Classroom teacher	BS in Mechanical Engineering
5	4	Classroom teacher	MS in Bioengineering
6	14	Teacher educator	High
7	36	Supervisor	Taught engineering for 15 years; curriculum writer
8	32	Supervisor	Chair of a standards team; wrote cross reference of standards with PLTW.
9	6	Classroom teacher	Did specific research on it in college; writing standards for state
10	19.5	Classroom teacher	Role is to prepare students to major in engineering
11	36	Teacher educator	Consulted with engineering firms regularly, co-inventor of medical research apparatus, keep in close contact with engineering departments
12	37	Teacher educator	Have studied and written about engineering concepts
13	25	Teacher educator	Unsure. *Called for follow-up. Is not an engineer but understands role of engineering in technology education*
14	29	Teacher educator	Above average
15	18	Classroom teacher	Teach engineering
16	31	Teacher educator	Know enough to be dangerous *Works with College of Engineering and has published and consulted on engineering related projects.*

Table 2 (continued)
Participant Expertise

17	15	Teacher educator	Understand principles of engineering through applied teaching and learning activities and involvement
18	24	Supervisor	High
19	27	Supervisor/ Classroom teacher	Understands the basic engineering process and tools needed to be an engineer like math and teamwork skills, knowledge of specific engineering fields is very minimal
20	30	Teacher educator	On a scale of 1 to 5, I am a 4 – better than average, not expert
21	33	Teacher educator	Very high
22		Supervisor	(none provided)

In Rounds 1 through 3, participants were given the list of outcomes items from Phase I. They were informed that the items had been selected by engineers for inclusion in high school pre-engineering programs. The Phase II participants were asked to rate these items, reword them if needed, add and rate new items, and provide comments. They were also asked to rank the importance of the items using a five point scale (Least Important, Less Important, Important, More Important, Most Important; Clark & Wenig, 1999). The descriptions for each of these categories are reported in Table 3. The interquartile range (IQR) was used as the statistic for variability of rating responses; an IQR of 1 was determined by the researchers to indicate consensus on an item (Wicklein, 1993).

Table 3
Explanation of ratings

Rating Statements
1. Least Important: Not necessary for inclusion in a technological literacy program.
2. Less Important: Less than necessary for inclusion in a technological literacy program.
3. Important: Necessary for inclusion in a technological literacy program.
4. More Important: Essential for inclusion in a technological literacy program.
5. Most Important: Most essential for inclusion in a technological literacy program.

Thirty-five of the 44 items from Phase I achieved consensus after Round 3. Three additional items were identified by participants after Round 1 and these items achieved consensus after Round 2. After Round 3, consensus had been reached on 38 engineering outcome items. Eleven items were rated as “Important” to include in a technological literacy program, 22 items were rated “More Important” and five items were rated “Most Important.” For comparison, after three rounds the participants in Phase I reached consensus on what should be taught 1st, 3rd, and 7th places in order of importance. However, in Phase II after three rounds, the participants reached consensus on the order of only one grouping, Emerging Fields of Engineering, and it was ranked lowest in importance. In Phase II, no engineering outcomes items were dropped due to a low median importance ratings; however, those outcome items that were not

Table 4
Third round consensus ratings of engineering outcomes and rankings of the seven outcome groupings

Item Rating	Rank	Group: Engineering Design Regarding engineering outcomes for Engineering Design the student in grades 9-12:
4	Rank Undeter-mined	Is aware of how engineering principles must be applied *when* designing engineering solutions to problems.
4		Understands that creativity is an important characteristic for engineers to apply in design.
4		Believes in his/her ability to design a solution to a problem.
5		Recognizes that there are many approaches to design and not just one "design process."
3		Understands engineering as it is actually practiced as a future career option.
		Group: Application of Engineering Design **Regarding engineering outcomes for Application of Engineering. Design the student in grades 9-12:**
4	Rank Undeter-mined	Designs, produces, and tests prototypes of products.
4		Understands that there is no perfect design. Designs that are best in one respect may be inferior in other ways (cost or appearance). Usually some features must be sacrificed as trade-offs to gain other features.
3.5		Conducts reverse engineering and can analyze how a product or process was designed and created.
4*		Understands how to work well on multidisciplinary teams.
4		Applies research and development and experimentation in the production of new or improved products, processes, and materials.
		Group: Engineering Analysis **Regarding engineering outcomes for Engineering Analysis the student in grades 9-12:**
4	Rank Undeter-mined	Uses models to study processes that cannot be studied directly.
4		Applies mathematics and science to the engineering process.
4		Understands that knowledge of science and mathematics is critical to engineering.
3		Uses a physical or mathematical model to estimate the probability of events.
3		Uses optimization techniques to determine optimum solutions to problems.

Table 4 (continued)
Third round consensus ratings of engineering outcomes and rankings of the seven outcome groupings

		Group: Engineering and Human Values **Regarding engineering outcomes for Engin. and Human Values the student in grades 9-12:**
4	Rank undeter-mined	Practices engineering ethics.
5		Is aware of how societal interests, economics, ergonomics, and environmental considerations influence a solution.
5		Understands how other factors, such as cost, safety, appearance, environmental impact, and what will happen if the solution fails must be considered *when* designing engineering solutions to problems.
4		Takes human values and limitations into account when designing and solving problems.
5		Understands that the solution to one problem may create other problems.
		Group: Engineering Communication **Regarding engineering outcomes for Engin. Communication the student in grades 9-12:**
4	Rank Undeter-mined	Understands basic personal computer operations and uses basic computer applications such as word processors, spreadsheets, and presentation software.
4		Provides basic technical presentations, graphics, and reports, and communicates verbally information related to engineering processes.
4		Uses technical drawings to construct or implement an object, structure, or process.
4		Visualizes in three dimensions.
3		Understands computer-aided engineering.
3		Applies the rules of dimensioning and tolerancing.
4		Uses computer-aided design to construct technical drawings.
		Group: Engineering Science **Regarding engineering outcomes for Engineering Science the student in grades 9- 12:**
5	Rank Undeter-mined	Develops basic ability to use, manage, and assess technology.
3		Applies knowledge of basic ergonomics to the engineering process.
4		Develops basic skill in the use of tools for material processes.
4		Applies basic power and energy concepts.
3.5		Applies knowledge of the processes for manufacturing products to the engineering process.
4		Applies knowledge of material processes to the engineering process.
4		Applies knowledge of basic mechanics to the engineering process.
3		Applies knowledge of basic dynamics and motion of rigid bodies and particles to the engineering process.
4*		Understands open and closed loop systems.
3*		Describes the sources, basic chemical structure, recycling potential, and environment al impacts of widely used industrial materials.

Table 4 (continued)
Third round consensus ratings of engineering outcomes and rankings of the seven outcome groupings

		Group: Emerging Fields of Engineering **Regarding engineering outcomes for Emerging Fields of Engin. the student in grades 9-12:**
3	Rank 7^{th}	Understands the importance of nanotechnologies in developing the next generation of innovations (less power, smaller).

* Indicates a consensus item added by the participants themselves.

included in the final list were those for which consensus was not reached. The final engineering outcome item ratings and group rankings for Phase II are presented in Table 4. A complete statistical analysis of all data, (including non-consensus items) is available at http://www.ncete.org/flash/Outcomes.pdf.

As indicated in Table 5, the consensus rate for technology educators in Phase II was very similar to the consensus rate for the engineers in Phase I.

Table 5
Comparison of percentage of consensus outcome items per round per phase

Round	Tech Educators (Phase II)	Engineers (Phase I)
1	41%	42%
2	62%	63%
3	80%	78%

With the exception of the Emerging Fields of Engineering group, it was difficult for both groups of participants (engineers and technology educators) to reach consensus on outcome grouping. Among the plausible reasons are that both phases dedicated only three rounds to consensus building for the groupings, and the initial groupings were juried instead of being crafted by a complete Delphi process.

Discussion

As of Round 3, there are several consensus items that provide reinforcement of the importance of the engineering design processes that the NCETE has selected as its professional development focuses: constraints, optimization, prediction, and analysis (COPA). Other technology educators may be interested in these outcomes also. Those items are presented in Table 6.

Table 6
Consensus items related to constraints, optimization, prediction, and analysis

Item	Outcome	Round 3			Round 2			Round 1		
		IQR	Mdn	SD	IQR	Mdn	SD	IQR	Mdn	SD
14*	Uses models to study processes that cannot be studied directly.	0*	4	.49	.75*	4	.92	1*	4	1.05
15*	Uses optimization techniques to determine optimum solutions to problems.	1*	3	.51	1*	3	.74	1*	3	.98
16*	Applies mathematics and science to the engineering process.	.75*	4	1.02	1.75	4	1.09	1.25	4	1.01
17*	Uses a physical or mathematical model to estimate the probability of events.	1*	3	.85	1.75	3	1.05	1.25	3	1.09
19*	Understands that knowledge of science and mathematics is critical to engineering.	1*	4	.95	1*	4	.95	1*	4	1.00

The use of models for indirect study such as analysis or prediction (Item 14) had an IQR of zero. Typical comments in support of the More Important rating include the following:

- I believe the ability to use models—mathematical, physical, and virtual, is one of the most important skills we can teach in technology education.
- Modeling is part of the 3 – 12 STL Standards and should be central to what we teach since modeling is such a powerful and universal tool.
- Making decisions based on models before construction is valuable.

Optimization (Item 15) was rated as Important to include in a technological literacy program. Comments related to optimization include the following:

- Calculus is not needed for problems solved related to a technology education course.
- For technological literacy, applying math and science to a design process would be vital for optimization and adhering to constraints, as well as analyzing data during testing.
- This is what engineers do. Don't bother to teach "engineering" if you take the math and science out. There is plenty that can be done with high-school appropriate mathematics.

Mathematical analysis-related Items 16 and 19 and predication-related Item 17 were rated More Important and Important respectively to include in a technological literacy program. Supporting comments related to the use of mathematics and science for the analysis items included the following:

- STL currently calls for recognition of such connections between science and mathematics to all technological processes.
- The way this is stated, it seems more like a value or feeling than a technical concept or skill and therefore not that difficult to comprehend. It does not state that one know how to apply science and mathematics to the study of engineering which in my opinion would warrant greater importance.
- Learn by doing

Comments supporting the prediction outcome included the following:

- While the background needed to develop mathematical models on their own may be lacking, students need to be able to work with these models in a meaningful way—not just plugging in data, but interpreting formulas and results, optimizing, etc. "Probability" is really the wrong term, though.
- Virtual modeling is critical to understanding the engineering process because it allows for iterative processing without cost of trials. Perfect for tech ed because you get to simulate what engineers do with limited resources.
- We in TE need to step up and model our solutions and outcomes more

Table 7
Consensus items related to constraints

Item	Outcome	Round 3			Round 2			Round 1		
		IQR	Mdn	SD	IQR	Mdn	SD	IQR	Mdn	SD
21 *	Is aware of how societal interests, economics, …environmental…influence a solution.	1*	5	.604	1*	5	.606	1*	5	.790
22 *	Understands how other factors, such as cost…must be considered when designing…	1*	5	.995	1*	5	1.08	1*	5	1.07

Constraints (Items 21 and 22) were rated as Most Important to include in a technological literacy program. See Table 7. Comments in support of the importance of constraints were.

- Considers when designing should be used
- This is why technological literacy (an outcome we should hope to attain in all students, not just those seeking engineering careers in the future) is so important
- Definite connection to real life: "each action or decision could affect others."

Technology educators, interestingly, rated approaches to the design process differently than did engineers . The technology educators also rated technical drawing slightly higher than did the engineers. After Round 3 for this grouping, the engineers ended with an IQR of 1 while the technology educators has an IQR of zero, as reported in Table 8.

Table 8
Consensus items related to the design process

Item	Outcome	Round 3			Round 2			Round 1		
		IQR	Mdn	SD	IQR	Mdn	SD	IQR	Mdn	SD
6*	Recognizes that there are many approaches to design and not just one "design process."	1*	5	.605	1*	5	.605	1*	5	1.06
28*	Uses technical drawings to construct or implement an object, structure, or process.	0*	4	.459	0*	4	.887	.5*	4	.669

Supporting comments related to recognizing that there is a variety of design processes included:

- General technological literacy ability.
- It is important, but learning the design process as something that is discursive would be fundamental, and perhaps learners who can be identified as more creative would be encouraged to take multiple approaches to design…
- Multiple solutions approach to learning is a characteristic of a technologically literate person

Comments related to support of the technical drawing outcome included:

- Without technical drawings to plan the construction, students are just creating art, no? How do you replicate a design if needed?
- Free hand sketching is needed and can be taught. No time for CAD class prior to TE class. Good class if you go to college for Eng[ineering] Vocational[y].
- I will move to the majority here because your designs and ideas are only as good as they can be expressed to another who might have to use your graphic representation of them in your absence.

These findings were similar to those of Dearing and Daugherty in their modified Delphi study.

Technology educators added an item that did not appear on their Round 1 instrument because it was not a consensus item for the engineers. However, it did appear on the Round 1 instrument for the engineers. This item relates to the NAE's prediction that working on teams will be very important to engineering in the future (Item 47 below in Table 9).

Table 9
Consensus item related to design teams

Item	Outcome	Round 3			Round 2		
		IQR	Mdn	SD	IQR	Mdn	SD
Added 47* add to Grp 2	Understands how to work well on multidisciplinary teams.	1*	4	.67	1*	4	1.07

Comments related to support of the multidisciplinary teams outcome included:

- This is a critical skill addressed by ABET that is applicable to all students in technology education.
- Understands how to work well on multidisciplinary design teams.
- Important addition

Technology education participants did not reach consensus on the importance of managing the engineering design process. Related comments are included following Table 10 below.

Table 10
Statistics for non-consensus item related to managing the engineering design process

Item	Outcome	Round 3			Round 2			Round 1		
		IQR	Mdn	SD	IQR	Mdn	SD	IQR	Mdn	SD
8	Organizes and manages the engineering. design process that includes optimal use…materials . processes…	2	4	1.02	2	3.5	1.03	2	4	1.12

- Optimizing is covered below. I do not feel that "engineering management and organization" as a process should play a significant role in technological literacy.

- Important for engineering literacy but not essential for technological literacy. I would prefer the word "engineering" be deleted from this learning outcome statement.
- Important for engineering literacy, but less important for technological literacy.

Dearing and Daugherty (2004) described a modified Delphi study that they conducted with technology teachers, technology teacher educators, and engineering educators. The purpose of the study was to identify those curricular concepts that are necessary to teach high school students in order to prepare them for postsecondary engineering education, while preserving the mission of teaching technological literacy. Dearing and Daugherty developed a predetermined list based on information from Project Lead the Way, CORD's Principles of Technology, The Standards for Technological Literacy, ASEE, and others. Participants were to decide if a concept should be included in such a curriculum.

Dearing and Daugherty measured consensus in terms of an item's standard deviation. Fifty-two concepts on their list met the criterion for consensus and were retained. While the purposes of the Dearing and Daugherty study differed from this study, they were both focused on technological literacy. Twenty-nine of the engineering consensus items in the Dearing and Daugherty study overlap conceptually with the consensus items in this study.

Finally, it should be noted that the Corporate Member Council of the American Society for Engineering Education has been working on a set of "…National Content Standards for K-12 Engineering/Engineering Technology…" (Morrison, 2007, p. 1). Most of the 70 outcomes derived from these standards overlap with the findings of this study. However, it should be noted that the purposes of the Corporate Member Council's study differ from the purpose of this study. The final findings of the Corporate Member Council's study were not available at the time this article was written.

Recommendations

The following recommendations are offered to technology education teacher educators, technology education teachers, and technology education administrators.

1. Conduct professional development in which teachers are provided the opportunity and guidance to infuse those engineering outcomes agreed upon by the participants into the teachers' own technological literacy curricula.
2. Enhance technology education by infusing selected engineering outcomes into the technology education curriculum for non-pre engineering curricula.

Implications for Technology Education Curriculum and Instruction

There are at least two primary points of view regarding the application of the items identified in this study to general technological literacy programs—those that are not pre-engineering. One is that a curriculum could be designed that is heavily influenced by engineering contexts. Those outcome items identified herein that overlap with the Standards for Technological Literacy would address the same standard, but the delivery would be set in the context of engineering. A second point of view is that the outcomes identified herein would be used sparingly in a program intended to develop technological literacy; engineering would be one of many contexts and topics of study included. Although agreement was reached on only a few groupings, they may still be of use to teachers insofar as the engineers agreed that Group 1, Engineering Design, was the group of outcome items of primary importance in a curriculum that is crowded and has limited time to dedicate to engineering outcomes. Likewise, Group 7, Emerging Fields of Engineering, represents the least important grouping that one would want to teach if time were limited. Finally, a crowded curriculum will actually provide less opportunity for students to learn about engineering in meaningful ways—meaningful ways that will tend to attract underrepresented populations to STEM areas. Just because consensus was reached on as many as 38 different outcome items in this study does not mean that all of them should be taught in one course. They should be applied as needed and when pertinent over the span of the ninth through twelfth grades.

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Miscellany

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