Technology Education Teacher Quality in the STEM Era

Michael Hacker and David Burghardt, Hofstra University, USA
Email: Mhacker@nycap.rr.com..

Abstract

This paper addresses Conference Strand 1 (availability and quality of Technology Education teachers). It discusses how improved teacher quality must be driven by a reconceptualization of Technology Education as a discipline that explicitly contributes to core academic literacy as a full partner in the STEM (Science, Technology, Engineering and Mathematics) education movement. A discussion of work accomplished through the MSTP Project, a U.S. National Science Foundation-funded mathematics, science, and technology partnership, will suggest a potentially transformative approach toward Technology Education reform.

Keywords: Technology Education; STEM; Mathematics Infusion; Technological Literacy.

Introduction

Despite over 20 years of curricular transition from a crafts/industrially-based to a more technologically based program, the field of Technology Education still finds itself to be a subordinate subject, not commonly accepted as a fundamental component of children's education. According to the National Academy of Engineering, there are many challenges facing the field of Technology Education; and those working on the problems of technology and engineering education at K-12 are a small group which is not reaching into the education policy community with great effect [Pearson, 2008].

Impediments to Technology Education Reform

Some of the obstacles to Technology Education implementation relate to public perception (party because technology is not well understood, partly because Technology Education is tainted by its traditions, and partly because Technology Education reform has not gone far enough). Other obstacles relate to the difficulty in making structural change within a system as tradition-bound as the educational system; still others, to the political issues that are interwoven throughout each step of an educational reform process [Hacker, 2000].

A central issue is that many teachers, trained as industrial arts or crafts teachers, are still teaching as they were taught; and despite the overarching need for a technologically literate student body and workforce, many technology education programs are still rooted in crafts teaching [Burghardt and Hacker, 2008]. This creates a mismatch between the needs and learning styles of students in the Internet generation and the capabilities and backgrounds of technology teachers (and the instructional methodologies they continue to practice within their comfort zones). The present cohort of Technology Education teachers is not adequately prepared to meet the challenges that partnering in STEM requires; and new teachers will not be properly prepared unless undergraduate technology teacher education changes dramatically.

Present Technology Education Pre-Service Teacher Preparation

Conveying technological skills and concepts is still the focus of much of the preparation provided by pre-service Technology Education programs in the United States. The study of how things work and the design process are also components of undergraduate study. These are important components of a Technology Teacher's preparation to be sure. However, a lack of preparation is strikingly visible in core academic disciplines. Where Technology Education's role could be enormously powerful – that is, to provide context and serve as a knowledge integrator across STEM disciplines – the lack of rigorous academic preparation limits our teachers' contributions. For example, the typical technology teacher education program (at least in the United States) is astoundingly weak in providing science and mathematics preparation; and this at a time when the professional literature is replete with calls for a transition to a more engineering-based approach [Hill, 2006; Lewis 2007]

In a study completed in 2008 that reviewed the mathematics requirements for Technology Education undergraduates in 19 teacher education programs in the U.S., it was found that the typical mathematics requirement can be satisfied through one course in mathematics, often at the level of shop math [Burghardt and Hacker, 2008a]. Only a few programs have raised the mathematics requirements over the past several years. This study illuminates the difficulty Technology Education and technology educators will have in moving toward engineering on the crafts-industrial arts-technology education-engineering continuum and thus, in assuming a meaningful role as an integrator across the STEM disciplines.

Figure 1. Technology Teacher Education Mathematics Requirements in Selected Universities in the United States

Technology Teacher Education

Name of University	Math Requirement 2008
Appalachian State	One Course
Ball State	One Course
Bowling Green	Two Courses
Buffalo State	Two Courses
Brigham Young	One Course
California University of Pa.	Two Courses
College of New Jersey	Two Courses
Illinois State	One Course
Millersville	One Course
Montana State	One Course
North Carolina State	Two Courses
Ohio State	One Course
Old Dominion	Two Courses
Purdue	Two Courses
Oswego	One Course
Southwestern Oklahoma State	One Course
Stout State	Two Courses
University of Southern Maine	One Course
Virginia State	One Course

Possibilities Offered by Affiliation with the STEM Education Movement

In the United States, the STEM education movement is growing rapidly. The American Competitiveness Initiative [OSTP, 2006a] spawned a bill called the *America Competes Act* that authorizes $43 Billion for STEM research and education programs. Of that, $22 billion would go to the National Science Foundation, with an emphasis on funding programs for the study of STEM in grades K-16. STEM Caucuses have been established in the U.S. Congress to focus on science, math, technology, and engineering education. These groups will increase the visibility and importance of STEM education and work to educate members of Congress and their staffs about STEM issues. Recent important educational reports promote the *TE* component of STEM education [NGA, 2007; NAS, 2005]. Professional organizations, including those outside the Technology Education community (e.g., AAAS, IEEE, NAE, NASA, NSF, and the Triangle Coalition) are promoting the value of Technology Education. A window of opportunity exists for Technology Education to become part of the STEM movement and through this affiliation, part of the educational mainstream.

Assuredly, changes are necessary, and these changes must begin with reform of teacher education which should reorient programs to become more *engineering-like* and increase the mathematics, science, and engineering content of the undergraduate curriculum.

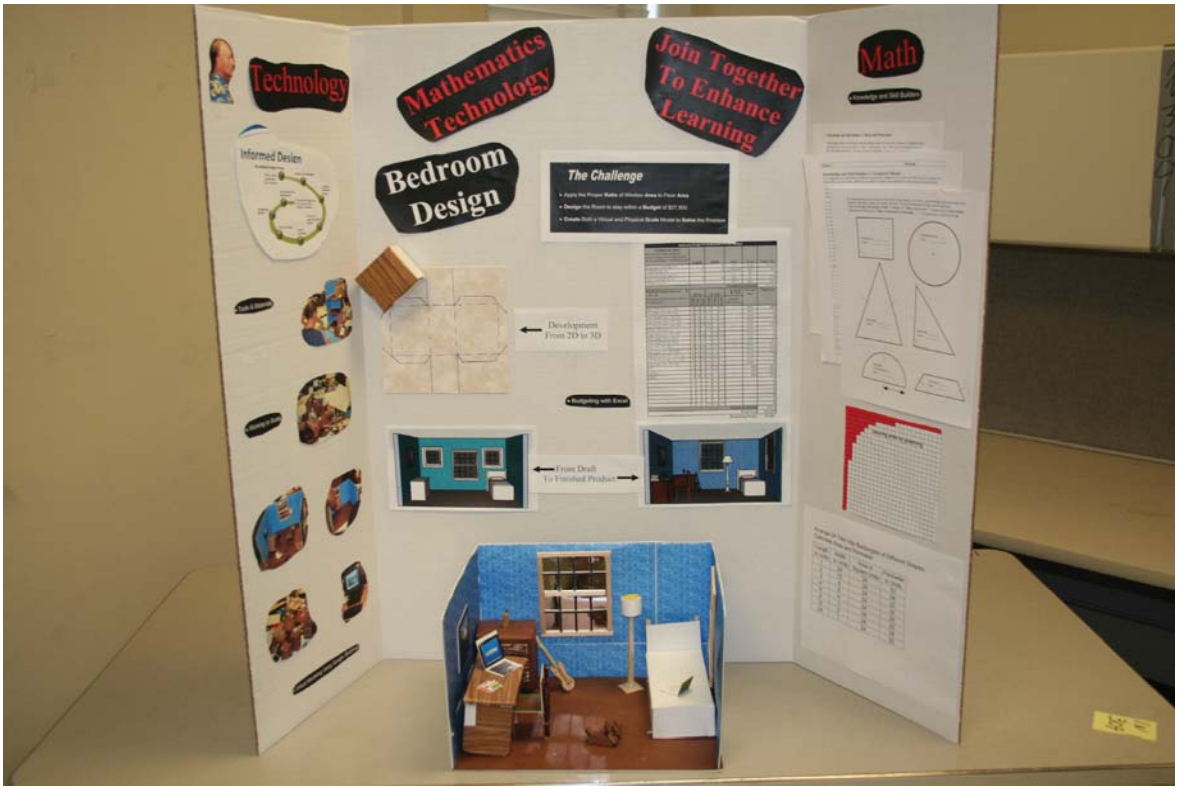
A Potentially Transformative Approach to Technology Education Teacher Education

The Hofstra University Center for Technological Literacy has received over U.S. $25M in National Science Foundation funding over the past 15 years to lead large-scale projects directed toward improving the mathematics, science, and technological literacy of K-16 students and teachers. A noteworthy project that has brought STEM teachers together for the purpose of improving middle school mathematics understanding and results is *Mathematics Across the Middle School MST Curriculum* (*The MSTP Project*), a five-year project targeted toward improving mathematics teaching and learning in 10 school districts in Long Island, New York, where on average 74% of students failed to meet New York State standards in eighth-grade mathematics.

This Project is developing, implementing, and researching a potentially transformative model to reform technology education practice. The model has been used to define and conduct professional development programs for practicing teachers; however, it has significant implications for undergraduate technology teacher education reform as well. The model expands the responsibility of technology educators to reinforce core disciplinary concepts within technological contexts; suggests a collaborative approach with other STEM educators; improves the pedagogy that underpins design activity; and provides the interactivity that today's students demand. The model includes four components that can redefine both current technology education instruction and undergraduate pre-service education:

1. Infusion of core disciplinary concepts (i.e., grade-related mathematics) into Technology Education instruction.
2. Use of STEM teacher teams to collaboratively plan, assess (based on collaborative review of student work), and revise instructional approaches using a pedagogically contemporary lesson planning and revision process.
3. Use of an "informed design" approach to instruction (Hofstra, 2008) that melds guided inquiry with open-ended design and leads students to develop conceptual understanding before they engage in design activity in lieu of the trial-and-error designing that too often characterizes school practice.
4. Establishment of a "hybrid" instructional model that integrates screen-based 3-D simulation and real-world physical modeling into middle school technology education programs. (Once designs are optimized on-screen, students construct physical models and compare their functionality and effectiveness to the simulated virtual models.) An example of this approach is shown in Figure 2.

Figure 2. An 8th Grade Bedroom Design Activity involving hybrid modeling, informed design, and mathematics infusion.



Clearly, to implement such a model requires not only a shift in perspective, but an entirely new conceptualization of the undergraduate teacher education program. Some universities (e.g., The College of New Jersey, Purdue University) have begun to add more academic rigor to their programs and these can provide a point of departure for those wishing to engage in further reform.

Results

The core academic intervention brought about by the MSTP Project over the past several years was revisiting mathematics in science and technology education contexts. MSTP external evaluators report that of eight Project schools originally on the No Child Left Behind (NCLB) Schools in Need of Improvement list, seven are now in good standing and the percentage of students passing the NYS eighth-grade mathematics assessment has increased by an average of 20%.

After participating in targeted MSTP professional development, technology teachers were surveyed regarding the practicality of the math-infusion model and its impact. It is noteworthy that 100 % of the teachers reported the math-infusion model was clear to them and that they could help students understand concepts related to geometric shapes, complex fractions, linear equations, and using graphs to represent data. This is significant considering their meager mathematics preparation. [Flugman and Hecht, 2008]. A formal research study with experimental and control groups is now being undertaken to determine the efficacy of math infusion in Technology Education as measured by pre- and post-assessments.

The MSTP Criteria-Based Mathematics Infusion Model

MSTP has developed an innovative mathematics infusion model to increase the time students spend on math in technology education classes using exemplary pedagogy and curriculum that teachers have adapted to their own settings. Through reiteration of the mathematics most needed by students, Technology Education can become a contributor in improving mathematics understanding; and adding modest amounts of mathematics will enhance technology education curricula as well, by advancing instruction from the present descriptive stage to a form that is more analytical.

Decision Rules for Mathematics Infusion. The mathematics infusion model establishes a set of decision rules in relation to selecting mathematics curriculum topics, instructional methodologies, and professional development emphases. These decision rules serve as criteria to guide curriculum, instruction, professional development, and the development of prototypical materials. The criteria for choosing mathematics for infusion are described as follows:

Mathematics content selection criteria. Selected mathematics content must be important, present difficulty for students (on the basis of low scores on standardized math assessments), and facilitate technology education learning objectives. Important content is based on the weight of curricular emphasis; includes prerequisite mathematics (from prior grades) essential for mastery of eighth-grade subject matter; and reflects knowledge necessary for success in more advanced mathematics courses.

Instruction criteria. These include sequencing instruction, incorporating inquiry/reform-based pedagogy, and using formative assessment to improve instruction. Sequencing involves targeting mathematics that mathematics instructors will address prior to the math-infused technology lesson. Technology lessons will be inquiry-and design-based and will scaffold technology teachers to employ reform-based mathematics pedagogy. Assessment will be embedded within instruction. Formative assessment of student work will help guide instruction in both technology and mathematics. The informed design approach will generate comprehensive samples of student work that make student thinking visible.

Professional development criteria. The need for professional development for the present cohort of Technology Education teachers is clear. Professional development criteria will ensure that PD enhances the participating technology teachers' **mathematical content knowledge**, **skills**, and **pedagogical content knowledge**. Professional development should relate to targeted mathematics content and reform-based mathematics pedagogy related to the math to be infused; diversified assessment; inquiry- and design-based pedagogy; and the development and the use of model mathematics infusion lessons.

Improving Teacher Quality

To ensure high Technology Education teacher quality in the STEM era, several challenges lay before professionals in the field. These include:

-Restructuring undergraduate Technology Education

-Providing professional development for present teachers

-Providing examples of "hybrid" curricula and exemplary materials that infuse core disciplinary concepts (e.g., mathematics) into Technology Education

-Developing a research agenda that supports the role of Technology Education in improving core disciplinary knowledge

Restructuring undergraduate Technology Education. Newly designed engineering-like undergraduate programs should continue to focus on developing teachers who are technically skilled and who can facilitate inquiry- and design-based learning. New emphasis should be placed on understanding how to contribute to people's habits of mind, and most importantly should be placed on inculcating mathematics and science abilities so that Technology Education teachers assist students to synthesize knowledge across STEM domains.

Providing professional development for present teachers. Professional development should address similar content and pedagogy as has been suggested above as appropriate for redesigned undergraduate teacher preparation programs. As has been pointed out, mathematics preparation is paltry for the great majority of people now teaching Technology Education in our schools. Without a strong mathematics background, a move toward an engineering-based program will be impossible.

Professional development should foster a thoughtful pedagogical approach to design that will serve as the core instructional strategy in Technology Education. An *informed design* model (Hofstra, 2008) is suggested where students approach design from a more knowledgeable perspective. Through informed design, students are provided with a foundation of salient concepts and skills through a progression of short, focused, knowledge and skill builders (KSBs) before engaging in design activity.

Finally, professional development must help Technology Education teachers make better use of Web 2.0 technologies. Computer-based simulations can lead to screen-based design activities where students can develop what-if scenarios, optimize design solutions on screen, and then physically model the design solution in the lab. Students will thus use contemporary tools to model solutions, yet they will describe how systems that are simulated virtually still need to be physically modeled, as simulations do not sufficiently capture the irregularities of a complex, real-world environment.

Provide examples of "hybrid" curricula and exemplary materials that infuse core disciplinary concepts (e.g., mathematics) into Technology Education. Curriculum leaders in our field can provide useful models for teachers to use that embed contemporary pedagogical techniques, and contextualize core disciplinary concepts. These materials should characterize Technology Education instruction in the STEM era.

Develop a research agenda that supports the value of Technology Education in improving core disciplinary knowledge. There is a conventional wisdom that Technology Education, by contextualizing knowledge and making it "real" to students improves core disciplinary understanding. The TechEd profession should prove this assertion through rigorous research. A formal research agenda would help this discipline improve its standing and its contribution to students.

SUMMARY

Being associated with STEM can bring financial, political, and public perception benefits to Technology Education. However, if Technology Education is to become a true partner in the STEM enterprise, reform will have to occur within the field, notably at the teacher preparation level.

Pre-service teachers must be prepared with additional mathematics, science, engineering, and Web 2.0 instruction. Leaders in the field are challenged to develop materials that infuse core disciplinary content and are presented through hybrid instructional models.

REFERENCES

Burghardt, David and Hacker, Michael (2008). *Simulation and Modeling in Technology Education. Proposal to the National Science Foundation. Hofstra University.*

Burghardt, David and Hacker, Michael. *The "T" in STEM Education.* Presentation to the NYS Technology Education Association Advisory Board. June 14, 2008. Syracuse, NY.

Flugman, Bert and Hecht, Deborah. MSTP Evaluation Report to the National Science Foundation. Center for Advanced Study in Education. June 2008.

Hacker, Michael. *The Politics of Technology Education Reform.* Presentation to the National Academy of Engineering. September 1, 2000.

Hill, Roger B. *New Perspectives: Technology Teacher Education and Engineering Design.* Journal of Industrial Teacher Education, Volume 43, Number 3. Fall, 2006.

Hofstra University Center for Technological Literacy (2008). Informed Design. http://www.hofstra.edu/academics/soeahs/TEC/tec_informed_design_resources.cfm

Lewis, T. (2007). Engineering Education in Schools. *International Journal of Engineering Education, 23*(5), 843-852.

Pearson, Greg. (2008). Implications of Recent Contributions to Research on K–12 Engineering and Technology Education on STEM Education. National Academy of Engineering. Washington, DC.

National Academy of Sciences. (2005). *Rising Above the Gathering Storm:* Energizing and Employing America for a Brighter Economic Future. National Academies Press. Washington, D.C.

National Governors Association (2007). *Innovation America: Building a Science, Technology, Engineering and Math Agenda*. NGA Center for Best Practices. Washington, DC.

Office of Science and Technology Policy, Domestic Policy Council (2006). American Competitiveness Initiative. The White House. Washington, DC.