The Mississippi Valley Conference in the 21st Century: Fifteen Years of Influence on Thought and Practice

Editors

Michael K. Daugherty & Vinson Carter

62nd Yearbook, 2019
Council on Technology and Engineering Teacher Education

Council on Technology and Engineering Teacher Education
1914 Association Drive, Suite 201
Reston, VA 20191-1539

YEARBOOK PLANNING COMMITTEE

Marie Hoepfl (Chairperson)
Appalachian State University

Michael Grubbs (2019)
Baltimore County School District

Ted Branoff (2019)
Illinois State University

Steve O'Brien (2020)
The College of New Jersey

Raymond Dixon (2020)
University of Idaho

Cameron Denson (2021)
North Carolina State University

David Rouch (2021)
Ohio Northern University

Ashley Gess (2022)
Augusta University

Jim Flowers (2022)
Ball State University

James Boe (2023)
Valley City State University

OFFICERS OF THE COUNCIL

President
Charles McLaughlin, Rhode Island College

Past-President
Marie Hoepfl, Appalachian State University

Vice-President
Scott Warner, Millersville University

Treasurer
Vinson Carter, University of Arkansas

Secretary
Thomas Loveland, University of Maryland Eastern Shore

PROPOSING A YEARBOOK

Each year at the ITEEA conference the CTETE Yearbook Committee reviews the progress of yearbooks in preparation and evaluates proposals for additional yearbooks. Any member is welcome to submit a yearbook proposal, which should be written in sufficient detail for the committee to be able to understand the proposed yearbook's substance and format. A digital copy of the proposal should be sent to the committee chairperson by February 1 of the year in which the proposal is to be considered. The following criteria are used by the committee in approving yearbook topics.

CTETE Yearbook Guidelines

A. Purpose

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

B. Yearbook Topic Selection Criteria

Yearbook topics should be ones that:

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

Yearbook themes related to technology and engineering teacher education may also be structured to:

1. Discuss and critique points of view that have gained a degree of acceptance by the profession;
2. Raise controversial questions in an effort to generate an international dialogue on the topic; and

C. The Yearbook Proposal

1. The yearbook proposal should provide adequate detail for the Yearbook Committee to evaluate its merits.
2. The yearbook proposal should:
   a) Define and describe the theme of the yearbook;
   b) Provide a rationale for selection of the theme;
   c) Identify the need for the yearbook and its potential audience(s);
   d) Explain how the yearbook will advance the technology teacher education profession in particular and technology education in general;
   e) Provide an outline of the yearbook that includes:
      i. A table of contents;
      ii. A brief description of the content or purpose of each chapter;
      iii. At least a three-level outline for each chapter;
      iv. Identification of chapter author(s) and backup authors;
      v. An estimated number of pages for each yearbook chapter; and
      vi. An estimated number of pages for the yearbook (the target maximum is ~250 pages).
   f) Provide a timeline for completing the yearbook.

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

PREVIOUSLY PUBLISHED YEARBOOKS

1. *Inventory Analysis of Industrial Arts Teacher Education Facilities, Personnel and Programs*, 1952.
2. *Who's Who in Industrial Arts Teacher Education*, 1953.
3. *Some Components of Current Leadership: Techniques of Selection and Guidance of Graduate Students; An Analysis of Textbook Emphases;* 1954, three studies.
4. *Superior Practices in Industrial Arts Teacher Education*, 1955.
5. *Problems and Issues in Industrial Arts Teacher Education*, 1956.
6. *A Sourcebook of Reading in Education for Use in Industrial Arts and Industrial Arts Teacher Education*, 1957.
7. *The Accreditation of Industrial Arts Teacher Education*, 1958.
8. *Planning Industrial Arts Facilities*, 1959. Ralph K. Nair, Ed.
9. *Research in Industrial Arts Education*, 1960. Raymond Van Tassel, Ed.
10. *Graduate Study in Industrial Arts*, 1961. R.P. Norman & R.C. Bohn, Eds.
11. *Essentials of Preservice Preparation*, 1962. Donald G. Lux, Ed.
12. *Action and Thought in Industrial Arts Education*, 1963. E. Svendsen, Ed.
13. *Classroom Research in Industrial Arts*, 1964. Charles B. Porter, Ed.
14. *Approaches and Procedures in Industrial Arts*, 1965. G.S. Wall, Ed.
15. *Status of Research in Industrial Arts*, 1966. John D. Rowlett, Ed.
16. *Evaluation Guidelines for Contemporary Industrial Arts Programs*, 1967. Lloyd P. Nelson & William T. Sargent, Eds.
17. *A Historical Perspective of Industry*, 1968, Joseph F. Luetkemeyer Jr., Ed.
18. *Industrial Technology Education*, 1969. C. Thomas Dean & N.A. Hauer, Eds.; *Who's Who in Industrial Arts Teacher Education*, 1969. John M. Pollock & Charles A. Bunten, Eds.
19. *Industrial Arts for Disadvantaged Youth*, 1970. Ralph O. Gallington, Ed.
20. *Components of Teacher Education*, 1971. W.E. Ray & J. Streichler, Eds.
21. *Industrial Arts for the Early Adolescent*, 1972. Daniel J. Householder, Ed.
22. *Industrial Arts in Senior High Schools*, 1973. Rutherford E. Lockette, Ed.
23. *Industrial Arts for the Elementary School*, 1974. Robert G. Thrower & Robert D. Weber, Eds.
24. *A Guide to the Planning of Industrial Arts Facilities*, 1975. D.E. Moon, Ed.
25. *Future Alternatives for Industrial Arts*, 1976. Lee H. Smalley, Ed.
26. *Competency-Based Industrial Arts Teacher Education*, 1977. Jack C. Brueckman & Stanley E. Brooks, Eds.
27. *Industrial Arts in the Open Access Curriculum*, 1978. L.D. Anderson, Ed.
28. *Industrial Arts Education: Retrospect, Prospect*, 1979. G.E. Martin, Ed.
29. *Technology and Society: Interfaces with Industrial Arts*, 1980. Herbert A. Anderson & M. James Benson, Eds.

30. *An Interpretive History of Industrial Arts,* 1981. Richard Barella & Thomas Wright, Eds.
31. *The Contributions of Industrial Arts to Selected Areas of Education*, 1982. Donald Maley & Kendall N. Starkweather, Eds.
32. *The Dynamics of Creative Leadership for Industrial Arts Education*, 1983. Robert E. Wenig & John I. Mathews, Eds.
33. *Affective Learning in Industrial Arts*, 1984. Gerald L. Jennings, Ed.
34. *Perceptual and Psychomotor Learning in Industrial Arts Education*, 1985. John M. Shemick, Ed.
35. *Implementing Technology Education*, 1986. Ronald E. Jones & John R. Wright, Eds.
36. *Conducting Technical Research*, 1987. Everett N. Israel & R. Thomas Wright, Eds.
37. *Instructional Strategies for Technology Education*, 1988. William H. Kemp & Anthony E. Schwaller, Eds.
38. *Technology Student Organizations*, 1989. M. Roger Betts & Arvid W. Van Dyke, Eds.
39. *Communication in Technology Education*, 1990. Jane A. Liedtke, Ed.
40. *Technological Literacy*, 1991. M.J. Dyrenfurth & M.R. Kozak, Eds.
41. *Transportation in Technology Education*, 1992. John R. Wright & Stanley Komacek, Eds.
42. *Manufacturing in Technology Education*, 1993. Richard D. Seymour & Ray L. Shackelford, Eds.
43. *Construction in Technology Education*, 1994. Jack W. Wescott & Richard M. Henak, Eds.
44. *Foundations of Technology Education*, 1995. G. Eugene Martin, Ed.
45. *Technology and the Quality of Life*, 1996. Rodney L. Custer & A. Emerson Wiens, Eds.
46. *Elementary School Technology Education*, 1997. James J. Kirkwood & Patrick N. Foster, Eds.
47. *Diversity in Technology Education*, 1998. Betty L. Rider, Ed.
48. *Advancing Professionalism in Technology Education*, 1999. Anthony F. Gilberti & David L. Rouch, Eds.
49. *Technology Education for the 21st Century: A Collection of Essays*, 2000. G. Eugene Martin, Ed.
50. *Appropriate Technology for Sustainable Living*, 2001. R.C. Wicklein, Ed.
51. *Standards for Technological Literacy: The Role of Teacher Education*, 2002. John M. Ritz, William E. Dugger, & Everett N. Israel, Eds.
52. *Selecting Instructional Strategies for Technology Education*, 2003. Kurt R. Helgeson & Anthony E. Schwaller, Eds.
53. *Ethics for Citizenship in a Technological World*, 2004. Roger B. Hill, Ed.

54. *Distance and Distributed Learning Environments: Perspectives and Strategies*, 2005. William L. Havice & Pamela A. Havice, Eds.
55. *International Technology Teacher Education*, 2006. P. John Williams, Ed.
56. *Assessment of Technology Education*, 2007. Marie C. Hoepfl & Michael R. Lindstrom, Eds.
57. *Engineering and Technology Education*, 2008. Rodney L . Custer & Thomas L. Erekson, Eds.
58. *Essential Topics for Technology Educators,* 2009. CTTE Yearbook Planning Committee, Eds.
59. *Research in Technology Education*, 2010. P.A. Reed & J. LaPorte, Eds.
60. *Creativity and Design in Technology and Engineering Education,* 2011. Scott Warner & Perry Gemmill, Eds.
61. *Exemplary Teaching Practices in Technology & Engineering Education*, 2016. Marie Hoepfl, Ed.

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

PREFACE

This yearbook highlights unpublished manuscripts presented at the Mississippi Valley Technology Teacher Education Conference over the 15-year period from 2001 to 2016 to provide a bridge between Mississippi Valley (MVTTEC) and CTETE as we seek to renew and redefine the technology and engineering teacher education landscape in the twenty-first century.

Although important efforts have been made to expand the conference to a more national scope, membership within the MVTTEC has been limited both geographically and in terms of total numbers within the organization. Yet for over 100 years the MVTTEC has served as a forum for provocative thought within the technology teacher education community, a place where ideas have been tested and alliances formed. As we have seen the number of technology teacher education programs across the nation shrink, there have been multiple calls for stronger ties between organizations that share common goals, including between the CTETE and the MVTTEC (see, for example, McAlister, 2013; Kelley, 2012). Furthermore, for various reasons some of the best papers delivered at the MVTTEC have not been published and are therefore unavailable for reading by a broader audience. This yearbook hopes to rectify that circumstance by publishing a "best of" collection of manuscripts from the MVTTEC, selected from among all of the MVTTEC papers during this 15-year period for their ability to help shape thought and practice within the field of technology and engineering teacher education and beyond. It should be noted that each of the chapters represents a snapshot in time of the year it was presented at the conference. Subsequently, every effort has been made to keep historical relevance intact. For example, names of associations that may have changed remain the same from that time period, where possible original tables and figures were maintained, and the historical voice and essence has been unaltered. We would especially like to thank the members of the CTETE Yearbook Planning Committee for serving as peer reviewers for the considered chapters. Without their assistance, this yearbook would not have been possible.

62nd Yearbook Editors
Michael K. Daugherty & Vinson Carter
University of Arkansas

DEDICATION

This yearbook is dedicated to the memory of Dr. Franzie Loepp who passed away in 2014. I first met Dr. Loepp in 1991 when I accepted my first post-doctorate university faculty position, at Illinois State University. Although I did not know it at the time, Dr. Loepp would become an important part of my personal and professional life and serve as an exceptional mentor for my career in technology teacher education. Dr. Loepp had joined the ISU faculty about twenty years prior to my arrival and was a legend at the university and in the community by the time that I arrived. While he was a brilliant academic mind, he never grew so important as to put his own self-interest in front of other faculty or students at the university. He loved students of all ages and was always willing to put others in front—whether they deserved this advancement or not. As his research agenda matured, his research could always be identified by its dedication to helping young students grow and develop a passion for learning. I am sure that I am in a large crowd when I say that Dr. Loepp stepped aside many times to provide me with abundant leadership opportunities, that I undoubtedly had not yet quite earned. Dr. Loepp served as my department chair, my colleague, my mentor, my friend, and an outstanding example of a reflective, humble, brilliant, caring, Christian man that I will forever hold up as the model of the perfect academic mentor. I was blessed to have been in the company of such a rare and extraordinary man.

Michael K. Daugherty
University of Arkansas

DEDICATION

This yearbook is also dedicated to the memory of Dr. William Edward Dugger, who passed away in 2018. Dr. Dugger began his teaching career in industrial arts in 1959. I was born in 1959, so it is safe to say that Dr. Dugger has influenced me throughout my entire career. It is also safe to say that Dr. Dugger has influenced everyone in technology and engineering education, whether they know it or not. He taught at the secondary and post-secondary levels for over 40 years, served as president of ITEEA, served on numerous boards and as director of numerous projects and journals, but his lasting professional legacy will be his work to lead the development and publication of the *Standards for Technological Literacy*. Dr. Dugger led this effort with scholarly patience, dedication, a soul of inclusion, and a resolute will to ensure that the standards reflected the true spirit of the profession. Most of what drives the profession today is a direct result of his efforts to not only publish the standards, but to gain consensus and to share them with audiences around the globe. Too often in academia we meet well-accomplished leaders in person and find them to be overconfident or standoffish, but this was not the case with Dr. Dugger. Dr. Dugger was a selfless leader who strived to put others and the profession ahead of himself. He mentored countless students, graduate students, and professional educators—young and old.

I had the opportunity to work directly with Dr. Dugger on the standards project and to serve as a standards specialist under his tutelage. It was one of the most influential learning experiences of my professional career. He went out of his way to put others first and to bring everyone into the tent. Dr. Dugger served as a mentor, a friend, and an outstanding example of a reflective, humble, brilliant, caring man that I will forever hold him up as the model of the perfect leader for our profession. I am blessed to have been in the company of such a rare and extraordinary man. He is missed.

Michael K. Daugherty
University of Arkansas

ABOUT THE AUTHORS

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

Mr. Barry Burke was the Associate Executive Director of the International Technology & Engineering Educators Association's (ITEEA) STEM Center for Teaching and Learning before his retirement in 2017. His work included the development of standards-based professional development, curriculum, assessment and research related to Integrative STEM Education. He coordinated a consortium of states that collaborated on the development and implementation of curriculum, instruction, and professional development through the Engineering byDesign™ (EbD™) K-12 standards-based model program. He was the founder of the EbD™ program in 2005, the 6E Learning byDeSIGN instructional planning model, and leader for the I-STEM FocalPoints initiative. Mr. Burke was involved with education for over 45 years as a teacher, resource teacher, teacher specialist, curriculum coordinator, and as the director for Career and Technology Education in Montgomery County Public Schools, Maryland. He spent 19 years in school administration where he was responsible for over 500 teachers and 45 instructional programs and consulted with school districts and superintendents throughout the US. Mr. Burke took an active leadership role in state and national organizations where he served as the Region Director and President of the ITEEA and Maryland's Affiliate (TEEAM). Mr. Burke is a 1974 graduate of the University of Maryland (BS) and a 1991 graduate of The Johns Hopkins University (MS)

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

Dr. Jenny L. Daugherty is the Jones S. Davis Distinguished Associate Professor of Human Resource, Leadership, & Organization Development at Louisiana State University in the School of Leadership & Human Resource Development. Daugherty also serves as the Director of the Leadership Development Institute (LDI), which serves as the umbrella organization promoting interdisciplinary research and collaboration related to leadership development. Daugherty earned her doctoral degree in Human Resource Education from the University of Illinois, Urbana-Champaign where she was awarded a doctoral fellowship with the National Center for Engineering and Technology Education. She is a co-Principal Investigator for the $2.9 million National Science Foundation funded Project Infuse. Dr. Daugherty served as the Membership Chair for the Mississippi Valley Technology Teacher Association from 2010 – 2016.

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

Dr. C. Ray Diez is Professor and Chairperson of the Engineering Technology Department at Western Illinois University in Macomb, Illinois. He earned the Bachelor of Arts in Education (Industrial Arts) and the Master of Science in Industrial Education from Wayne State College in Wayne, NE and the Doctor of Industrial Technology (D.I.T.) from the University of Northern Iowa. He taught and was chair of Industrial Technology at the University of North Dakota and at Western Illinois University. His academic research foci include knowledge management, curriculum development, safety and health, history of technology, and engineering technology education. He has published several SSCI, SCI, and EI papers in international journals. He holds memberships in the Association of Technology, Management, and Applied Engineering (ATMAE), American Society of Engineering Education (ASEE, ETD division), Society of Manufacturing Engineers (SME), Epsilon Pi Tau (EPT), and the Mississippi Valley Technology Teacher Education conference. He served in several leadership positions in ATMAE, is an ATMAE Senior Fellow, and was Regional Director and Board Chair of EPT during his career.

Dr. Anthony F. Gilberti is a Professor in the Department of Technology at Fairmont State University and teaches courses in Engineering Economy, Operations Management, Total Quality Management and Statistical Process Control, and Strategic Planning. Dr. Gilberti is a recipient of the Technology Teacher Educator of the Year, former President of the International Technology and Engineering Educators Association, recipient of the Epsilon Pi Tau Laureate Award, recognized as a Distinguished Technology and Engineering Educator, as was selected as one of the 50 Outstanding Alumni in the last 50 years from Eastern Illinois University.

Dr. Marie Hoepfl is Professor and Graduate Program Director in the Department of Sustainable Technology and the Built Environment at Appalachian State University. She holds degrees in Industrial Education (BS), Education Administration (MA), and Technology Education (EdD). She taught at the middle and high school levels for six years, and has taught at the university level since 1994. Hoepfl has served in various officer roles for the CTETE, most recently as Past President (2016-2019). She was Editor of Volumes 38-39 of the *Journal of Industrial Teacher Education (JITE)*; co-edited the 2007 CTTE Yearbook on *Assessment of Technology Education;* and edited the 61st CTETE Yearbook, titled *Exemplary Teaching Practices in Technology and Engineering Education.* Hoepfl has published a number of articles and chapters on technology education assessment and research, and is co-author of the textbook *Starting the Dialogue: Perspectives on Technology and Society*.

Dr. Daniel Householder began his career as an industrial arts teacher at Roanoke Rapids (NC) Junior-Senior High School in 1953, then taught at East Richland (IL) High School and Southern Regional (NJ) High School. He held faculty appointments at Purdue University, Texas A&M University, and Iowa State University and visiting positions at Trenton State College, University of Puerto Rico, Southern Illinois University, University of New Brunswick, St. Cloud State University, National Science Foundation, Hofstra University, and Utah State University (from which he retired in 2014). He holds B.S. and M.S. degrees from Eastern Illinois University and the Ed. D. from the University of Illinois. He served as President of the Council on Technology Teacher Education (now CTETE), President of the International Technology Education Association (now ITEEA), and Life Chair of the Mississippi Valley Technology Teacher Education Conference.

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

Dr. Brian McAlister, DTE, currently teaches in the Technology Education program within the Department of Teaching, Learning and Leadership at University of Wisconsin-Stout. He earned a B.S in Industrial Education and an M.S in Industrial Technology from Western Illinois University and his Ph.D. from the University of Illinois at Urbana-Champaign. He holds active memberships in the International Technology and Engineering Educators Association, the Children's Council of ITEEA, Epsilon Pi Tau, the Wisconsin Technology Education Association, the Association for Contemplative Mind in Higher Education, and the Council on Technology and Engineering Teacher Education for which he is a former treasurer.

Dr. Chris Merrill is Professor in the Department of Technology at Illinois State University (ISU). He has been honored several times for his teaching, research, and service, including the 2016 Department of Technology Service Award, 2014 CTETE Technology and Engineering Educator of the Year Award, 2013 ITEEA Distinguished Technology and Engineering Educator Award, 2012 ISU College of Applied Science and Technology Teaching Award, and 2007 ISU College of Applied Science and Technology Outstanding Research Award. Among a number of other professional contributions, Merrill has served as Editor of the *Journal of Technology Education* since 2010.

Dr. Edward M. Reeve is a professor and teacher educator in the area of Technology and Engineering Education (TEE) in the

School of Applied Sciences, Technology and Education at Utah State University (USU). He received his bachelor's, master's, and doctoral degrees in Industrial Technology from The Ohio State University. In addition to experiences as a secondary education teacher and university administrator (including interim vice provost), he is a former American Council on Education (ACE) Fellow, Fulbright Scholar, and Fulbright Specialist. He completed a three-year term (2010-2013) as President of the Council on Technology and Engineering Teacher Education (CTETE) and more recently served as President of the International Technology and Engineering Educators Education Association (ITEEA).

Dr. David Stricker joined the St. Catherine University (MN) faculty in 2016 as Associate Professor and Director of Undergraduate and Graduate Teacher Licensure. Prior to this position, he was a faculty member and Program Director of the Technology and Science Education program at the University of Wisconsin-Stout. He is a graduate of the University of Minnesota as a National Center for Engineering and Technology Education Doctoral Fellow. Contributions include authoring a chapter of the 60th CTETE yearbook, articles in the *Journal of sTEm Teacher Education*, *Technology and Children*, and *The Science Teacher*. He also has presented at regional and national settings such as ITEEA, NSTA, Engineering and Design Education Research Summit, Colloquium on P-12 STEM Education Research, and FABLEARN: Conference on Creativity and Making in Education Conference at Stanford University.

Dr. Scott Warner is a Professor in the Department of Applied Engineering, Safety & Technology at Millersville University. His professional credentials include degrees from Millersville University (B.S.Ed., 1985), Ball State University (M.A.Ed., 1988), and West Virginia University (Ed.D., 2000). His professional resume includes teaching experiences at the middle school, high school, and university levels. He is an active member of several organizations that deal with education and design including the International Technology and Engineering Educators Association (ITEEA) and the Industrial Designers Association of America (IDSA). He has been the author or co-author of over 30 articles or book chapters in various professional publications and has given over 40 presentations to educators and design professionals at state, regional, and international conferences.

Dr. John G. Wells is a Professor in the School of Education at Virginia Tech (VT). He is co-developer of the Integrative STEM Education (I-STEM ED) Graduate Program at VT, the only such program in the country, and served as program leader from 2010 to 2015. Prior to joining the VT faculty Dr. Wells was an Associate Professor at West Virginia University (WVU) from 1992 to 2005, where he served as Director of the *Trek 21: Educating Teachers* As *Agents Of Technological Change* PT3 (US DOE) project, the *Technology Education Biotechnology Curriculum Project* (NASA), and the *Teaching and Learning Technologies Center* of the College of Human Resources and Education at WVU. Dr. Wells is an internationally recognized scholar on Integrative STEM Education and on Technological/Engineering Design-Based Learning (T/E DBL) in the field of Technology Education.

Dr. Kenneth Welty recently retired from his role as Professor in the School of Education at the University of Wisconsin-Stout, where he taught curriculum development, teaching methods, and student assessment courses for science and technology education at the undergraduate level and research methods and program evaluation at the graduate level. His work has included directing several curriculum development projects for the State of Illinois, investigating students' conceptions of technology and engineering, working with public schools to enhance their technology education programs, serving as a curriculum consultant for the American Association for the Advancement of Science, and evaluating the treatment of engineering principles and ways of thinking in STEM curricula for the National Academy of Engineering.

TABLE OF CONTENTS

Yearbook Planning Committee iii
Officers of the Council iv
Proposing a Yearbook v
Previously Published Yearbooks vii
Preface x
Dedications xii
About the Authors xv

Chapter 1: **The Mississippi Valley Technology Teacher Education Conference in the 21st Century 1**
Michael K. Daugherty and Vinson Carter
University of Arkansas

Chapter 2: **Technology Education: A Rich History and Challenges 22**
C. Ray Diez
Western Illinois University

Chapter 3: **Are Technology Education Teachers Prepared to Teach Engineering Design and Analytical Methods? 61**
Brian K. McAlister
University of Wisconsin-Stout

Chapter 4: **The Diversity Imperative: Attending to Gender Differences in Technology and Pre-engineering Education 86**
Kenneth Welty
University of Wisconsin-Stout

Chapter 5: **Perceptions of Technology Education among Science, Mathematics, and Engineering Educators …………………… 102**
Daniel L. Householder
Utah State University (Retired)

Chapter 6: **The Soul of Technology Education: Being Human in an Overly Rational World …… 113**
Scott Warner
Millersville University of Pennsylvania

Chapter 7: **Technology, Innovation, Design, and Engineering (TIDE) Education ………….. 137**
Anthony F. Gilberti
Fairmont State University

Chapter 8: **Highly Qualified Technology Education Teachers: Their Attributes, Competencies, Assessment, and Preparation for Tomorrow's School …….. 149**
John L. Iley and Susan E. Bastion
Pittsburg State University

Chapter 9: **Perspectives on the Future of Technology Education ………………………………….. 181**
Barry N. Burke
International Technology Education Association

Chapter 10: **STEM Education: The Potential of Technology Education ……………………. 195**
John G. Wells
Virginia Tech University

Chapter 11: **Expert and Novice Technological Literacy 230**
David Stricker
University of Wisconsin-Stout

Chapter 12: **Tracing Technology Education's Lineage, With an Eye Toward the Future ………… 245**
Marie Hoepfl
Appalachian State University

Chapter 13: **Technology Education Perspectives of STEM Education ………………………….. 277**
Chris Merrill
Illinois State University

Chapter 14: **Teaching Technology: Are We on the Right Path? ……………………………… 300**
Jenny L. Daugherty
Louisiana State University

Chapter 15: **A Reflection on the Engineering Design Process Models used in Technology and Engineering Education Classrooms and those used in Engineering ……………….. 328**
Edward M. Reeve
Utah State University

Chapter 16: **The Mississippi Valley Technology Teacher Education Conference and the Future of the Profession ………………… 345**
Michael K. Daugherty and Vinson Carter
University of Arkansas

The Mississippi Valley Technology Teacher Education Conference in the 21st Century

Chapter 1

Michael K. Daugherty & Vinson Carter
University of Arkansas

Introduction

To memorialize the 100th meeting of the Mississippi Valley Technology Teacher Education Conference (MVTTEC), a commemorative yearbook was published in 2013 (Erekson). This yearbook included specifically developed articles to review the past century of the conference and set the stage for the future. Such an analysis had been conducted twice prior, first in 1929 by William T. Bawden and again in 1988 by Dale Lemons (Wells & Love, 2013). This yearbook marks the fourth effort to publish content originally designed for presentation within the confines of the MVTTEC. Founded in 1909, the MVTTEC was never envisioned as an association whose purpose was to set policy, publish position papers, or promote an agenda, rather the MVTTEC was created for the purpose of sharing research, promoting discussing, field-testing ideas, and sparking ideas. Given that unique niche, it may surprise some to note that the MVTTEC may have done more to settle problems, plant ideas, field-test concepts, spark interests, and set agendas than adjoining associations who had those as express objectives. It is difficult to measure the multitude of refereed journal articles, research projects, textbooks, and grant proposals that may have had their launch while members were conducting research for an assigned presentation at the upcoming MVTTEC. The major issues that confront the profession have served as the impetus for presentations at the annual meetings of the Conference. Since its inception in 1909, the driving purpose of the MVTTEC has been to be an exporter of thinking, a motivator of discussion and a place to expose strong positions with respect to what needs to be done to bring about desired changes in the philosophy, goals, content, standards, and learning approaches used in our profession (Deiz, n.d.).

Given that singular purpose, many have suggested that perhaps countless notable and worthy position papers and field-tested ideas may have remained on the cutting room floor after each annual meeting concluded. The purpose of this yearbook was to resurrect some of the best, unpublished research proposals, position papers, and field-test ideas that had been presented at the MVTTEC since the year 2000. To launch this project, an editorial review panel comprised of the CTETE Yearbook Committee reviewed all research papers presented at the MVTTEC since the year 2000. All papers that had yet to be published were considered. In total, 40 manuscripts originally submitted for presentation at the MVTTEC, were reviewed by the editorial review panel. The panel was charged with the task of reviewing the intellectual merit, the potential impact, and the professional relevancy of these 40 manuscripts. After an extensive review process, 14 manuscripts were selected for inclusion in this yearbook and the authors were contacted. The authors were asked to address editorial remarks and suggestions made by the editorial review panel. Care was taken to not advance the original manuscript to the present day, but rather to leave the manuscript as a snapshot in time so that the reader could envision the arguments and discussions that were being addressed during a particular time period. For example, during the 93rd MVTTEC in Nashville, TN in 2006, there was a great deal of debate about the descriptors that should be used to define the profession following the addition of engineering design, and the dissemination of the *Standards for Technological Literacy*. Although the debate has since been largely settled, Anthony Gilberti presented an impassioned debate about the processes that should be used to describe the profession (2006). This debate is informative for future discussions and the meaning would have been lost had the manuscript been advanced twelve years to the present day. The chapters that will follow this introduction exemplify the strength of the MVTTEC research papers of years past. These chapters illustrate what the authors believed, was critical at the time, was valued, and the professional opinions on topics that many were compelled to address.

The History of MVTTEC

At the 89th MVTTEC, C. Ray Diez presented research concerning the long debated notion that technology education should be recognized as a subset of public school general education (2002). If this notion is true, technology education teachers contribute to the history, structure, and order of society, and apply the concepts, theories, and laws of science, and mathematics. Diez set forth to prove this premise and to determine whether other school disciplines accept the philosophy, premises, and contributions of technology education to the mainstream of general education. To make his argument, Diez discussed the early American organization and the nature of the 18th century rural academy, the manual labor movement epitomized by the New Harmony School, and early theological seminaries, like the Maine Wesleyan Seminary. He expanded on this narrative by exploring early industrial schools established for poor and delinquent children, like the Farm and Trades School in Boston and the Girard School in Philadelphia, as well apprenticeship programs and factory training systems. Diez also provided ample history of the early American mechanics institutes and the lyceum movement and then expanded into the early manual arts movement by expanding upon institutions like the Gardiner Lyceum and the Rensselaer School. Rensselaer would later become the first school of engineering in the United States, particularly relevant given the increased treatment of engineering in technology education during the last 18 years. This chapter provides a rich historical perspective for anyone seeking to understand our disciplinary roots and the epistemological underpinnings of the technology and engineering education profession.

Are the Teachers Ready to Teach Engineering Design?

At the 91st MVTTEC, Brian McAlister presented research that attempted to determine whether technology education teachers were prepared to teach engineering design (2004). The publication of the *Standards for Technological Literacy* resulted in a call for technology educators to integrate additional engineering content into the curriculum. This led McAlister to question whether technology education teachers were prepared to teach engineering design and analytical methods in high schools. Specifically, he sought to determine whether existing technology education teachers had the requisite math and science knowledge to teach engineering design. To answer his questions, McAlister conducted two separate research studies. The first study sought to identify the prerequisite mathematics and science educational competencies held by newly minted teachers by reviewing the courses of study in post-secondary technology teacher education programs across the nation. The second study asked current technology education teachers to self-identify their perceived preparation to implement engineering design concepts. The results of the two studies indicated that while most of the newly minted and existing technology education teachers had nominal coursework in upper level mathematics (i.e., trigonometry, calculus, etc.) and science (i.e., physics, etc.), almost 50 percent believed that they would need no further training or coursework to successfully implement engineering design into their technology education curriculum. Given that engineering design has, largely, been integrated into the technology and engineering education curriculum at the time of this yearbook writing, it would be interesting to see whether these perceptions have changed and whether the post-secondary mathematics and science course requirements in technology teacher education have been altered.

A Disproportionate Number of Male Teachers

At the 91st MVTTEC, Kenneth Welty presented research concerning the continuing lack of female student representation in technology education (2004). Welty presented research confirming a commonly held belief that most students participating in K-12 technology education courses are male at a time when the profession espouses the belief that all students (male and female) should be provided with an education that prepares them all for a life interacting with an unprecedented level of technology. Welty argued that women, as a population, bring a unique perspective to the study of technology and that perspective was woefully under-represented in the curriculum that existed in 2004 (Welty). Welty noted that while there was no single reform that would quickly add additional female students to the technology enrollment, he did offer some definitive steps that could be taken to make the study of technology more gender inclusive. Notably among those suggested steps, he pointed out that the curriculum proffered in most secondary technology education classes was unduly attentive to male points of view in its efforts to prepare a predominantly male population for adult life in a technologically sophisticated society. He suggested that this subliminal gender bias misses opportunities to honor women's contributions and ways of knowing and doing (Welty, 2004). To eradicate this problem and serve the technological literacy needs of all students, Welty suggested that the discipline should integrate the perspectives, contributions, and learning styles of women into the study of technology. He concluded that such an integration would enrich and help balance technology education classes, and would reap many benefits, not the least of which will be to inspire future technology education teachers.

While it is unclear whether substantial gains have been achieved in female students enrollment in K-12 technology education since this research was presented, antidotal observations suggest that the introduction of engineering design as a substantial driver of the curriculum has resulted in considerable increases in female enrollment.

Perceptions of STEM

At the 92nd MVTTEC, Daniel Householder presented research concerning the perception of technology education among science, mathematics, and engineering educators (2005). The newfound emphasis of STEM education within the field of technology education had necessitated a need for increased collaboration between technology educators and educators in the adjoining fields of science, mathematics, and engineering education. Householder addressed this necessity and the frequently recounted lack of collegial support from those educators as a major barrior to continued advancement. His investigation sought to explore perspectives of stakeholders from the science, mathematics, and engineering education communities with the goal of developing a clearer understanding of their opinions regarding the roles and purposes of technology education (Householder, 2005). He notes in his research that many of today's professionals in science, mathematics, and engineering are unaware of the potential contributions of technology education in the development of technological literacy. In some cases, his sample also seemed unaware of the *Standards for Technological Literacy.* However, he was also keen to point out that some high-profile educators in those fields have been fierce advocates for STEM, technology education, and the implementation of an integrated curriculum. For example, Gerhard Salinger, formerly a research physicist at the Rochester Institute of Technology, has been a major champion of technology education at the National Science Foundation. Householder also discussed the substantial contributions of Rodger Bybee of Biological Sciences Curriculum Studies (BSCS) and the national Science Forum, who has been instrumental in the establishment of policies to promote technology education, the development of new and expanded programs, and the professional practices required to realize the common goal of technological literacy for all. Householder concludes by instructing members of the profession to expand its vision and develop communications for much broader audiences. Those audiences included the general public, national, state, and local policy makers, K-12 curriculum developers, teacher educators, school administrators, and, numerous other population groups who view themselves as stakeholders in the K-12 arena (Householder).

The Sole of Technology Education

At the 93rd MVTTEC, Scott Warner presented impassioned research concerning the soul of technology education (2006). He noted that four of the *Standards for Technological Literacy* (ITEA, 2000), are devoted specifically to technology and society. These four standards (4, 5, 6, and 7) explore the non-technical aspects of technology and the relationships between technology and the social/cultural environment in which it exists (Warner, 2006). Furthermore, Warner explained that even in those four standards the role of human qualities and values such as emotions, intuition, and aesthetics in the implementation and use of technology is largely overlooked. He remarked that if technology does indeed reflect the spirit and values of its designers (as noted in the introduction to the *Standards for Technological Literacy)*, then the ability of a technologically literate person to be objective about technology may be difficult at best. A review of the history of the profession of technology education illustrates that such qualities and values have also provided both an overt and subtle role in the study of technology. Warner expressed a concern that if technology education is to become a vital part of the general education curriculum, it will need to examine the story it wishes to tell. He argued that an alignment with engineering could result in our profession focusing unduly on the machine or the technology itself, rather than focusing on the human or societal side of technology—which would result in greater diversity of students in our courses.

Technology, Innovation, Design, and Engineering Education

At the 93rd MVTTEC, Anthony Gilberti presented research concerning the name and tagline that should be associated with our profession (2006). Specifically, he argued for technology, innovation, design, and engineering education (TIDE) to be the future descriptor for the profession. In 2006, the recent publication of the *Standards for Technological Literacy* had ushering in a great debate about the need to redefine the name and perhaps the descriptors used to define the profession and its purpose in the modern school. Gilberti spoke with conviction and steadfastness regarding the underlying values and purposes of the field and the need to have a name that properly represents the profession to internal and external audiences. This paper reflected Gilberti's (2006) beliefs and his position on the use of the TIDE acronym as a descriptor for the technology education curriculum area, even though he was not particularly fond of the title. Gilberti also noted that he believed that the ITEA been ineffective in adopting a clear tagline and name for the profession since the *Standards for Technological Literacy* had been disseminated. He suggested that in the previous ten years, the ITEA had proffered several new taglines for the profession, including, *Technology: The New Basic, Anything is Possible,* and *Technology is Human Innovation in Action;* abandoning all of them in a relatively short time. He further implied that the profession continued to be unprepared to embrace the TIDE tagline. However, he encouraged the ITEA leadership to consistently use the TIDE tagline on all publications and correspondence with its constituents for at least five to ten years, suggesting that research advises that the public requires at least five years before constituents make a connection with a tagline or branding to the organization. He concluded by noting that the consistent and repeated use of TIDE as a tagline can be effective, if it is used on all publications and correspondence, and if it is used for an extended time. It was not.

What Constitutes a Highly Qualified Technology Education Teacher?

At the 94th MVTTEC John Iley and Susan Bastion presented research attempting to discern the qualities that exemplify a highly qualified technology education teacher (2007). To answer this question, the authors identified numerous studies that acknowledged attributes, characteristics, and/or qualities one should possess to be a highly qualified teacher. Iley and Bastion addressed the question by adapting ideas from a April 2007 report prepared for the National Association for Sport and Physical Education entitled: *What Constitutes a Highly Qualified Physical Education Teacher?* (NASPE, 2007). The authors then proposed a list of qualities for highly qualified technology education teachers by adapting ideas originally generated in this report and generated exhaustive lists of teacher attributes and characteristics. Iley and Bastion recommended that highly qualified technology education teachers should possess characteristics such as enthusiasm; genuine care and desire for teaching young people; a commitment to the profession; a positive attitude; the ability to change and adapt positively; a sense of humor; and a good work ethic among numerous other qualities. Finally, the authors noted that a new technology education teacher entering the profession should aspire to fulfill the role of one or more of the five types of effective educators identified in the research, and work to avoid assuming the three less effective or undesirable types of identified teachers.

A Professional Transformation

Barry Burke presented perspectives on the future of technology education at the 94th MVTTEC (2007). He proposed that the profession was likely to undergo significant changes during the subsequent ten-year period, and he was right! Burke noted that history has taught us that the educational climate in the country dictates and necessitates adaptation in content and philosophical understandings. At the time, federal and state efforts to improve schools through numerous legislative initiatives like the *No Child Left Behind* initiative, had, and continued to have a major impacts on all school disciplines. These impacting policies affected the methods by which teachers would be certified, the number of qualified teachers available, the standards and curriculum content delivered in classes, and the methods by which instruction would be delivered and assessed. He suggested that as education continued to utilize standards and assessment as the impetus for school reform initiatives, the technology education profession had to either get involved or face extinction. Likewise, he suggested that the survival of technology education was not about saving teacher jobs but about preparing students for the global workplace. Supporting this assertion, Burke recommended that we should focus on realizing the often untapped, unrealized potential of students, that when properly motivated will lead to the next generation of technologists, innovators, designers and engineers (2007).

STEM and Technology Education

STEM education was becoming the hottest theme in education during the first decade of the 21st Century—one could hardly pick up a newspaper or listen to a politician without seeing or hearing about the need for increased levels of STEM education. John Wells addressed this rising trend during the 95th MVTTEC with a presentation that explored the relationship between STEM education and technology education (2008). He suggested that disciplinary perspectives on science, technology, engineering, and mathematics (STEM) education afford an opportunity for insights into how these respective fields of education view their roles in the schooling of American children within the current context of STEM education reform (Wells, 2008). He further warned that, like other disciplines, we must be wary of our innate tendency to view STEM and its effect on and role in our profession with extreme disciplinary bias. To combat this tendency toward disciplinary bias, Wells sought to corroborate data gathered for his presentation through an analysis of valid sources from adjoining disciplines, personal experiences, governmental and other non-specific disciplinary sources. He noted that, when taken as a whole, these reports and calls for STEM action to advance U.S. economic vitality and national security was largely not supported by the current educational system. Supporting this assertion, he underscored the notion that most STEM courses were not integrated in secondary schools and most continued to be delivered to students in singular course fashion. To achieve the wholesale ideal of integrated STEM education, sustained systemic changes in secondary schooling in the form of substantive restructuring of schooling would be required. This would require schools to remove numerous barriers to the wholesale integration of STEM education. Restructuring would need to address class scheduling that allowed for common planning times, team teaching, co-design of instruction, multi-modal testing (classroom and standardized), professional development, and the development of new strategies for teacher preparation (Wells, 2008). He concluded by suggesting that wholesale changes in school infrastructure and programs are long-term goals, but short-term or incremental change could serve as a key starting point. Strategies for change that focus on improving teaching practices provide the greatest potential for improving learning outcomes in our PK-12 students and technology education is in an ideal position to provide this short-term reform. Technology education at the secondary school level has the teachers, the preparation programs, and an established PreK-12 presence to launch substantial integrated STEM education programs that others could model as long-term changes are adapted.

The Nature of Expertise

In 2009, David Stricker presented research on the characteristics of expert and novice technologically literate citizens at the 96th MVTTEC. Stricker noted that while little cognitive science research has been published in technology education, the field of technical education has enjoyed the benefits of a wealth of research designed to identify the practices of expert and novice practitioners in the discipline. Because technical education is so closely linked to the work force, understanding the nature of workers in the field is paramount in developing educational programs and services. Stricker argued that while the missions of the two fields (technology education and technical education) differ slightly, the discoveries made in studying how technicians and other experts in their respective fields use their knowledge and make decisions should be used to inform technology education. He suggested that if the aim of technology education is to offer an opportunity for students to become technologically literate, understanding the findings garnered from cognitive science research regarding the nature of expertise and its effect on problem solving and decision-making can serve to inform technology education practice. The purpose of his research was to apply the findings from cognitive science research regarding expert and novice problem solving in order to reveal the potential technology educators have to impact student learning. Stricker used a locally pending decision regarding the expansion and subsequent additional storage of waste at a nuclear power plant located in Prairie Island, Minnesota to illustrate the differences in opinions between expert and novice thinking and technological literacy. By scrutinizing the comments of the well informed and novice citizens, he was able to discern the role that technology educators might assume in providing essential knowledge and skills, career awareness, and metacognitive abilities of secondary students in technology education. He summarized his research by noting that the urgency is no longer how to offer an opportunity for students to become technologically literate. Rather, technological literacy should be viewed as a tool used by an expert; a scalpel to cut through a menagerie of distractions and half-truths in order to make an informed, authentic, and novel decision that students not only can trace back to sound reasoning, but demonstrate their place in an enlightened citizenry.

The DNA of Technology Education

Hoepfl also presented important research at the 96th MVTTEC. Marie Hoepfl presented her research that traced the lineage of technology education and made predictions about the future of the profession (2009). In her research, Hoepfl argued that the profession should develop a distilled collection of enduring concepts and identify a set of "universal skills" in order to avoid what has proven to be the persistent tyranny of the standards movement—too much to teach. She warned of the common failures that plagued many past curriculum efforts. Specifically, she remarked that many earlier curriculum efforts were too specific and relied unduly on technologies that would quickly become obsolete as well as technologies that were not general enough to stand the test of time. She warned that curriculum developers must resist the tendency to be overly-ambitious. Further, Hoepfl documented that numerous curriculum developers and scholars had urged technology educators to operate at the center of the field and to be wary of the natural tendency to focus on the periphery. She noted that perhaps the best way to achieve such centeredness was to form strategic partnerships with teachers in related fields and focus on an interdisciplinary curriculum. She urged technology educators to accept the reality of what it will take to achieve technological literacy. We need much more than isolated partnerships with engineering educators. We need to embrace the role that will have to be played by historians, scientists, elementary school teachers, and so on if all Americans (not to mention the rest of humanity) are to know more about technology (Hoepfl, 2009). By forming collaborations with the numerous teachers in adjoining fields, we will be able to combine the unique strengths of the training of each in the development of curriculum models. Hoepfl also encouraged her audience to remember the critical role that hands-on learning plays in the field of technology education. She noted that experience with hands-on manipulations and capabilities are seen as critical components of the technologically literate. Conversely, she warned the audience that the reverse is also true: a high degree of technical proficiency alone does not ensure technological literacy, nor can it we presume that engineers or other technical specialists understand the social, cultural, and environmental implications of their work. She notes that many recent attempts to more closely link engineering and technology as nearly synonymous enterprises may be shortchanging one or both of these areas of activity by overlooking critical components. She closes her discussion with a call for educators to reach across the aisle and work with educators from various educational disciplines toward the goal of strengthening our position as the deliverer of technological literacy, while remaining true to our core ideals.

Technology Education and STEM Education

At the 97th MVTTEC in 2010, Chris Merrill presented a perspective on the relationship between technology education and STEM education. Merrill provided research-based findings, approaches, and perspectives of STEM education as they related to technology education. At the time of this presentation, technology education was increasingly transitioning to include the teaching of STEM as a primary purpose for the discipline. His argument was based on a recently released report by the National Governors Association (2007) that called for a new workforce of problem solvers, innovators, and inventors who are self-reliant and able to think logically. This report called upon all educators to develop programs and curricula that developed these skills and strengthened STEM education at the K–12 level. To examine the role that technology education plays in relation to the delivery of STEM, Merrill summarized several recent research reports and numerous recent curriculum projects related to STEM and technology education. He noted that most of these curriculum projects featured substantial amounts of time dedicated to hands-on activities and most were conducted in a small group formats where participants were engaged in design-related activities. He emphasized strong areas of alignment with technology education, including the emphasis on active engagement, problem-solving, experimentation, as well as clear ideas of what constitutes effective learning and teaching. He concluded that, while many educators who teach STEM courses through the various commercially available curriculum packages did not have formal training in technology education, the curricula and professional development training programs for the teachers are largely reflective of the core principles of technology education. He encouraged technology educators to work to make certain that professional development for new teachers of such curricula be flexible enough to meet the needs of teachers while being true to the profession of technology education. He argued that teachers, who have varying levels of science, technology, engineering, and mathematics abilities prior to professional development training, must be exposed to the core principles as well as the STEM curriculum as well as the skills needed to transfer the newly gained knowledge into classroom practice.

The Right Path?

At the 98th MVTTEC, Jenny Daugherty presented research that sought to determine whether the profession was on the right path concerning the teaching of technology (2011). The publication of the National Research Council's *Framework for Next Generation Science Education Standards* (2011) was creating waves across the various STEM disciplines with its inclusion of engineering. Daugherty noted that within technology education, many worried about what the inclusion of engineering in the science standards might mean for the technology education field. There were serious questions concerning whether technology education would emerge as a core component of STEM education or, conversely fracture and be marginalized. Daugherty posed the following questions: If technological literacy is important for all students and is the primary learning outcome of technology education, how can this be achieved? How does a close partnership with engineering, science, or other disciplines better prepare students to be technologically literate? Does technology education have to exist as a discipline for students to become technologically literate or can other disciplines sufficiently address the content so that technology education programs are superfluous and unnecessary? Daugherty reassured participants by noting that technology education can contribute to the new science standards and curriculum efforts by focusing on the core principle of technological literacy. She further offered that preservice programs might evolve into collaborative efforts with science or math programs to prepare STEM or Science & Technology teachers. She warned that this path would likely reach larger numbers of students, at least with a limited exposure to technology education, but might also be the death knell of technology education programs solely focused on technological literacy. She questioned whether the discipline of technology education would continue to exist as a subject or might be destined to be absorbed by science should be a secondary concern if students were indeed becoming technologically literate. She further encouraged the audience to consider whether adding engineering to the science curriculum would actually achieve technological literacy and whether technology education adds additional knowledge to the mix—which contributes to a fully technologically literate student. In summary, Daugherty remarked that technology education must articulate the value added dimension to the STEM equation that is more encompassing than engagement in engineering design activities. She suggested that it seems appropriate that technology education should emphasize engineering, STEM integration, and other interdisciplinary approaches, but we should not lose sight of our disciplinary identity, the development of technological knowledge and literacy, and its impact on student learning.

Engineering Design in Technology and Engineering Education

At the 103rd MVTTEC, Ed Reeve presented research on the methods used to deliver engineering design in technology and engineering education classrooms and the extent to which engineering design had been implemented (2016). The purpose of Reeve's research was to investigate whether the engineering design processes used in technology and engineering education classrooms were an accurate reflection of the models used in industry and related technical fields. Reeve defined engineering design and the engineering design process as problem-solving approaches that have the same meaning and utilize a systematic and creative application of scientific and mathematical principles to solve problems. Reeve began his discussion with a brief review of how the engineering design process is typically practiced in fields of engineering and then reviewed its importance and use in K-12 in technology and engineering education classrooms. He recognized that problem-solving (i.e., engineering design) is a very important skill needed in engineering and these skills should be reflected in the K-12 technology and engineering education classroom. He also acknowledged that while there are varying engineering design models used in engineering, and technology and engineering education, almost all of them utilize similar procedures and processes to assist the end-user in solving problems. In summary, Reeve noted that those involved in the teaching of K-12 technology and engineering education should continue teaching the engineering design process as currently promoted in the field and other related STEM programs. However, those involved in teaching engineering design in technology and engineering education should consider placing more emphasis on the context of the problem, the needs of the customers, analysis of the problem, and real-world constraints related to the problem.

Summary

The first 15 years of the 21st Century saw tremendous change and adaptation in the field of technology and engineering education. As the new century began, there was trepidation about the name of the profession, the standards that should drive our curriculum, our collective history, the nature of the teacher, the role of STEM in the field, our position with adjoining disciplines in the school, our core principles, and whether we were on a prosperous trajectory. Surprisingly, it is clear that many of these questions have been addressed and shockingly, it is clear that many of these questions have been largely settled. As we entered the 21st Century, it was not at all clear whether our field wanted to or should engage with engineering and engineering design. Likewise, it was not at all clear what relationship our field would have with the newly minted STEM acronym. It seems that both of these questions, and many others, have been addressed clearly and definitively. This yearbook provides a snapshot of the first 15 years of the 21st Century. By reviewing these fourteen research papers presented at the Mississippi Valley Technology Teacher Education Conference between 2002 and 2016, one can examine, in real time, the pivotal issues, controversial discussions, and the laborious debates that have largely re-shaped our profession in this new century. It is not hyperbole to say that the technology education classroom that existed during the last decade of the 20th Century is as different from the technology and engineering education classroom in the second decade of the 21st Century as are our forms of communication. During the 1990's almost everyone used a landline telephone, the best way to reach someone quickly was using a pager, few people used e-mail, almost no one had ever heard of social media, and the fastest way to send a letter was via facsimile. Clearly, our world and our profession has changed dramatically. In this year, most programs are recognized by the name technology and engineering education, engineering design is an integral part of our curriculum, integration with adjoining disciplines is recognized as a strength, and STEM education is central to our programmatic offerings. While we continue to hold fast to the core ideals of our profession (hands-on learning, project-based instruction, real-world experiences, etc.) we have adapted substantially, and it has only made our profession stronger and more vital. You are encouraged to examine these fourteen chapters, the impassioned discussions, the pivotal moments, and the groundbreaking ideas that led us to this point in history. Clearly, we are all made stronger by understanding our collective history, understanding how we arrived at this point in history, and how that collective struggle has positioned our profession for an astonishing future.

References

Burke, B. N. (2007, November). Perspectives on the future of technology education. *94th Mississippi Valley Technology Teacher Education Conference*. Chicago, IL.

Daugherty, J. (2011, November). Teaching technology: Are we on the right path? *98th Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Deiz, C. R. (N.D.) *Mississippi Valley Technology Teacher Education Conference Induction Ceremony.*

Diez, C. R. (2002, November) Technology Education: A rich history and challenges. *89th Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Erekson, T. L. (2013). *Proceedings of the 100th Meeting of the Mississippi Valley Technology Teacher Education Conference*. Mississippi Valley Technology Teacher Education Conference. Chicago, IL.

Gilberti, A. F. (2006, November). Technology, innovation, design, and engineering (TIDE) education. *93rd Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.

Hoepfl, M. (2009, November). Tracing technology education's lineage, with and eye toward the future. *96th Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.

Householder, D. L. (2005, November). Perceptions of technology education among science, mathematics, and engineering educators. *92nd Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Iley, J. L. & Bastion, S. E. (2007, November). Highly qualified technology education teachers: Their attributes, competencies, assessment, and preparation for tomorrow's schools. *94th Mississippi Valley Technology Teacher Education Conference*. Chicago, IL.

McAlister, B. K. (2004, November). Are technology education teachers prepared to teach engineering design? *91st Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

Merrill (2010, November). Technology education perspectives of STEM education. *97th Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

National Governors Association. (2007). *Building a science, technology, engineering, and math agenda*. Retrieved from http://www.nga.org/Files/pdf/0702INNOVATIONStem.pdf

National Research Council (2011). *Framework for next generation science education standards*. Washington: National Academy Press.

Reeve, E. (2016, November). A reflection on the engineering design process models used in technology and engineering education classrooms and those used in the engineering profession. *103rd Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

Stricker (2009, November). Expert and novice technological literacy. *96th Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.

Wells, J. G. & Love, T., (2013). Mississippi Valley Technology Teacher Education Conference: Content analysis for 100 years of discussion. *Proceedings of the 100th annual Mississippi Valley Technology Teacher Education Conference*, pp. 1-24, Chicago, IL

Wells, J. G. (2008, November). STEM education: The potential of technology education. *95th Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Welty, K. (2004, November). The diversity imperative: Attending to gender differences in technology and pre-engineering education. *91st Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

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

Warner, S. A. (2006, November). The soul of technology education: Being human in an overly rational world. *93rd Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.

Technology Education: A Rich History and Challenges

Presented at the 89th Mississippi Valley Technology Teacher Education Conference, 2002, St. Louis, MO

Chapter 2

C. Ray Diez
Western Illinois University

Introduction

The discipline of technology education has historically professed itself as a subset of general education. As a result, technology education teachers contribute to the history, structure, and order of society, and apply the concepts, theories, and laws of science, and mathematics. Students are taught to solve problems and develop innovative solutions by employing engineering design principles. We, in the profession, recognize and accept this philosophy, but have the other disciplines? Technology educators claim to augment and utilize, recognize and accept the philosophy, premises, and contributions of technology to the mainstream of general education. Do other disciplines recognize technology education as an equal partner? The purpose of this paper is to trace the historical contribution of the profession to the principles of general education, the partnership among the disciplines, and attempt to determine the status of technology education in relation to science, engineering, and mathematics education.

Background

Mental Training and Manual Labor Movements

A forerunner in the 18th century was the rural academy. The rural academy was described in an April 1887 Columbian Magazine article where children were to work for their education and in return they received an education, and "…academic subjects mentioned as desirable were geography, history, English literature, bookkeeping, geometry, surveying, and mechanics" (Bennett, 1926, p. 94). This is perhaps the first evidence of children being taught a general curriculum that also included subjects of a technological nature.

Another example was the manual labor movement epitomized by the New Harmony School. It was founded by Robert Owen and the curriculum was implemented through the educational direction of William Maclure and the schoolmaster, Joseph Neef. They observed both the Fellenberg and Pestalozzi movements, but opted for the Pestalozzi style because they believed it to be more democratic (Bennett, 1926). The course of study included arithmetic, geometry, the study of machines or exact models, natural history, anatomy, and geography all by hands-on methods.

In addition, students were taught "writing, drawing, music, gymnastics, languages, …and handwork described as follows, plus the first reference to manual training."

> Lithographing and engraving as well as printing are to be carried on in the school building as well as other mechanic arts, that the children may receive manual training. The boys learn at least one mechanical art – for instance, setting type and printing, and for this pursue there are printing presses in each school by the aid of which are published all there elementary books (Lockwood, 1905, p. 238, as cited in Bennett, 1926, p. 177).

The downside to this educational experiment was that it was a social failure after two years and subsequent attempts by

Maclure to revive it under their different names were unsuccessful (Bennett, 1926).

The manual labor movement had a short duration of about twenty years. Efforts were not fruitful because the education focus became a means of physical training as opposed to one of instruction (Bennett, 1926). Theological seminaries provided impetus to the manual labor movement because it was required for all students to be involved with work either of an agricultural or mechanical nature rather than formal classes. One departure was at Maine Wesleyan Seminary where there were two courses of study, one for college preparatory and the other to provide an English education plus knowledge in agriculture or a mechanic art (Bennett, 1926). Other examples include the Oneida Institute of Science and Industry, the Manual Labor Academy and various theological seminaries. The main impetuses in the manual labor movement were to provide means for paying a student's way and provide a way of promoting exercise and health through the unification of study and labor. The manual labor movement failed because it was unprofitable and cumbersome to administer (Bennett, 1926).

Industrial and Industrial Reform Schools

A third precursor to technology education was the industrial schools established for poor and delinquent children, the roots of which can be traced to Germany and England. In America, the Farm and Trades School in Boston and the Girard School in Philadelphia were the earliest examples. The Girard School in 1864 expanded the practical shop experiences to more handwork education. The primary focus was in the printing and related communications industry and became a part of instruction for all boys (Bennett, 1926). The Hampton Institute was established for people of color, but the industrial aspect originally was focused on agriculture with industry education added as needed. Hampton Institute became the leading trade school and the model for those that followed (Bennett, 1926).

The Industrial Reform schools were started to furnish inmates with a way to earn a living and keep them from corruption (Snedden, 1907, as cited in Bennett, 1926). Early reform schools were identified as workhouses. Later, reform school revisions focused on the means by which the character of delinquent children could be improved. Leading reformatories include from 3½ to 4½ hours of schoolwork in addition to the learning of a trade (Bennett, 1926).

Apprenticeship

Apprenticeship has its roots in the Middle Ages. During the Industrial Revolution, people searched for an equivalent substitute for the apprenticeship method. In America, there were no gilds nor craft organizations, but rather it was geared to the needs of the colony. Children placed in apprenticeship were to be given instruction in religion, reading, and writing to enable them to be literate members of society in addition to learning a trade. This led to the establishing of free schools where reading, writing, and ciphering were taught to boys and reading and sometimes writing taught to girls (Bennett, 1926).

The Factory System

The advent of the gathering of machines into one place for the purpose of manufacturing items created a need for education different from apprenticeship. The demand for cheap labor and the mechanization of industry caused people to be trained to operate machines and resulted in factory villages developing along streams to power the factories. Since children worked in the factories, they were required to attend school on Sundays for five hours. This led to half-time schools and eventually to full-time education practices. Children who were a part of the factory system were exploited until laws were passed that afforded them the opportunity for an education (Bennett, 1926).

Mechanics Institutes

The mechanics movement was an education movement to improve the social and economic condition for the agrarian and industrial populace while creating a knowledgeable workforce and citizenry. Premier among the mechanics institutes was the Franklin Institute. Four courses of study were prominent: English, classical studies, modern languages, and mathematical and practical sciences. Drawing was the most recognized of the practical arts being offered in twelve quarters. Other notable mechanics institutes were founded in Maryland, Boston, and Cincinnati and were based on the sciences and the mechanic arts (Bennett, 1926).

The Lyceum

The lyceum movement was an offshoot of the mechanics movement, but for small towns. The purpose of the lyceum was the "emphasis of acquiring useful knowledge" (Bennett, 1926, p. 328). The best source was to apply the natural sciences to agriculture and the mechanic arts. The lyceum movement contributed to the "building up the American ideal of popular education…" (Bennett, 1926, p. 328).

Higher Technical Education and Manual Arts

The Gardiner Lyceum "provided a curriculum preparatory to the higher positions in agriculture, the mechanic arts, and engineering" (Bennett, 1926, p. 348). Benjamin Hale, the principal at Gardiner Lyceum, believed that students should not only know the theories and principles of mechanics, but the mechanics and use of machines as well (Bennett, 1926).

The Rensselaer School was established so people could apply "science to the common purposes of life" and benefit "In the application of experimental chemistry, philosophy, and natural history, to agriculture, domestic economy, the arts, and manufactures" (Ricketts, 1914, as cited in Bennett, 1925, p. 350). Rensselaer became the first school of engineering in the

United States and established mathematical arts to give "instruction in Engineering and Technology" (Ricketts, 1914, as cited in Bennett, 1926, 353).

A great boost was provided to higher technical education when Abraham Lincoln signed the Land Grant Act of 1862 into law. States were now able to establish agriculture and mechanic arts as colleges.

The workshop in a school of engineering was epitomized at the Worcester Technical Institute. A course was designed that not only taught the principles of mechanical engineering, but how to produce and sell commercially the products of their manufacture plus "a theoretical course in applied science and engineering" (Washburn, July 1906, p. 342, as cited in Bennett, 1926, p. 360). The key was that the product was to be done the best way without pay for the education of students (Bennett, 1926).

Illinois Industrial University taught woodworking to architecture students and iron making to mechanical engineering students. The purpose was not to teach a trade, but to illustrate mechanical engineering principles (Bennett, 1937).

The Kansas State Agricultural College educated their students in "science, mathematics, and literary subjects" (Bennett, 1937, p. 314) plus provided them with four years of a trade. Trades included were shops in carpentry, wagon making, blacksmithing, painting, turning, scroll-sawing, carving, engraving, printing, and telegraphy. Also included was a department of drawing. Women also could pursue a course of study in departments of sewing, household economy, and household chemistry, plus courses in drawing, scroll-sawing, carving, and engraving (Bennett, 1937).

At Washington University, Calvin Woodward, a mathematics professor, started requiring his students to learn how to use tools for fabricating items to better understand the forms of applied mechanics, to develop nominal tool skills, and to understand and judge quality in the work of their profession (Bennett, 1937; Barlow, 1967).

John Runkle was influenced by the Russian method and concluded that to teach the mechanic arts, shops should be built just as laboratories were used to teach physics and chemistry. His vision developed the School of Mechanic Arts at the Massachusetts Institute of Technology. Students learned arithmetic, algebra, geometry, English, physics, and drawing, in addition to shop work. Runkle believed that mechanic arts should be included in public schools for both educational and economical reasons.

Woodward, in 1877, envisioned shop work being treated the same as other school subjects. He believed that the mechanic arts should be taught under the same principles that guided teaching methods in the sciences, mathematics and the languages. He did not view it as teaching a trade, but as an important and essential aspect of education as a whole (Bennett, 1937).

Manual Training High Schools

Woodward established the first manual training high school in St. Louis in 1879. His vision and goal was to establish a general training school for the integration of the use of tools into the curriculum as an equal with mathematics, drawing, science, and English. He believed that manual training, as part of the curriculum, more adequately prepared young men for a productive life in society (Bennett, 1937).

The success of the manual training schools stirred opposition to the idea of manual training and the industrial arts. Education leaders tried to thwart the movement in various ways, even suggesting that it should be a school independent from the high school, a vocational school (Bennett, 1937). Even though Woodward continued the crusade for manual training as part of general education, the education conservatives thwarted his efforts until about 1889. The manual training schools proliferated throughout the country. Growth of the field led to enrichment of the curriculum and change toward inclusion with the high school and a more specialized technical high school. Another iteration was the two-track program, one college preparatory and the other an industrial course (Bennett, 1937). This move opened the way for vocational education to be brought into the schools under the guise of manual training. This was the first departure from manual training as general education.

Manual Training in the Elementary School

Manual training was also developed as a subject in the elementary schools. Original subjects focused on industrial subjects and sewing. Drawing and woodworking followed these. The courses appealed to both boys and girls. Many of the courses were influenced by the Russian system (Bennett, 1937).

Elementary school manual training in New York grew out of Froebel's kindergarten. Emily Huntington started the kitchen garden movement that became the Industrial Education Association under the leadership of Grace Dodge. The curriculum originally appeared to be occupational in nature, but was truly defined as general education. Woodwork and mechanical drawing were the courses that introduced manual training in New York City elementary schools. This movement was instrumental in bringing more women into the field (Bennett, 1937).

A second elementary program started with the free kindergarten and developed into the workingman's school that evolved into the Ethical Culture Schools and progressive education. Felix Adler was the leading proponent and his work paralleled that of Dodge. His purpose was to develop an educational program extending over the school life of a child and that industrial work should be an integral component (Bennett, 1937).

Randall Spaulding in Montclair, New Jersey, tried to develop an ideal school system that included industrial or hand training. After five years, the program was considered to be successful in meeting its goals (Bennett, 1937). There were several other elementary school manual training experiments. Jamestown, New York received wide attention because of the various kinds of manual work in the curriculum. It broadened the concept of manual education under Samuel G. Love and Mary R. Willard (Bennett, 1937). L. L. Camp and J. R. French developed manual training in New Haven, Connecticut under the progressive leadership of Samuel T. Dutton in the 1880s. The curriculum was focused on the building of projects for sale to fund the program (Bennett, 1937). The Society for Organized Charity under the leadership of Charlotte Pendleton was influential in public school reform (Bennett, 1937). Manual training in the elementary schools grew rapidly as attested by establishment of schools in "…Omaha, Nebraska; Springfield, Massachusetts; Beardstown, Illinois; and, Washington, District of Columbia" (Bennett, 1937, p. 428).

The Swedish Sloyd movement influenced elementary manual education in Boston. The focus was on "…manual training given for its educational value" (Bennett, 1937, p. 430). It was generally accepted that Boston had developed the most pedagogically sound manual training program (Bennett, 1937).

John Dewey introduced the idea of industrial occupations into the elementary curriculum. He also believed that manual training instruction should be a method for teaching related subject matter (Bennett, 1937). Charles Richards agreed that manual training should be a method augmenting subject matter. He further proposed that manual training be replaced by the term industrial arts. The reasoning was that instruction was resembling industrial elements (Bennett, 1937). Frederick G. Bonser believed that industrial arts should be both subject and a method. He believed in using problem solving as part of teaching procedures (Bennett, 1937).

Progress in Manual Training

Charles A. McMurray traced the development of manual training in a presentation to the Mississippi Valley Conference. He identified five stages of manual arts and parallels those presented in this paper: The practical values, the accuracy of component parts, the useful model as the application of principles or processes, the influence of the arts and crafts movement, and the inclusion in school curriculum as an important part of the program. He noted that manual arts relieved the mental stress of traditional subjects and the field had grown to a subject area of importance. He impressed that the field was highly organized and considers the whole before developing the details. He believed that manual arts experiences should be included as part of a child's education (Bawden, as cited in Barlow, 1907).

Industrial Arts Curriculum Precursors

Early advocates of departure from manual arts wanted industrial arts to provide more realistic experiences. Richards was influenced by Dewey's educational concept that industrial occupations be a focal point of elementary curriculum. Richards also proposed in 1904 that the profession's name be changed to industrial arts (Martin and Luetkemeyer, 1979). Russell, in 1909, advocated that "…stages of production, distribution, and consumption of such raw materials as foods, metals, textiles woods" (Cochran, 1970, p. 6) be included in an industrial arts course.

Bonser and Mossman's view of industrial arts revolved around man's changes of materials to increase value for human consumption (Bonser & Mossman, 1924). A second movement in the industrial arts was a transformation of shops with a single activity shop to those supporting multiple activities. The profession thus embraced the general shop as an organizational tool (Cochran, 1970). The emphasis of the profession remained static during the 1920s although improvements in teaching standards were attempted.

The industrial arts movement continued to develop during the 1930s and 1940s. One investigative study, two curriculum movements, and three publications were influential during

> this period. The Terminological Investigation Study was a reflection of the Dewey-Bonser philosophy and influenced curriculum development of the 1930s (Martin & Luetkemeyer, 1979). They also found that the Terminological Investigation was an attempt to end confusion about terminology. The definition found in the publication is as follows: Industrial Arts is one of the Practical Arts, a form of general education, which provides learners with experiences, understandings, and appreciation of materials, tools, processes, products, and of the vocational conditions and requirements incident generally to the manufacturing and mechanical industries. (p. 33)

Cochran (1970) identified Warner's multiple activity oriented Laboratory of Industries as having a focus on the terms "industry" and "laboratory." Martin and Luetkemeyer (1979) identified the Ohio Prospectus as teaching relationships between industries.

Martin and Luetkemeyer (1979) identified two publications, "Improving Instruction in Industrial Arts" and "An Industrial Arts Curriculum to Reflect Technology at all School Levels," that influenced the direction of industrial arts after World War II. A third influencing publication was Wilber's "Industrial Arts in General Education." The definition of industrial arts promulgated by Wilber has served as the basis for most contemporary definitions. He defined industrial arts "…as those phases of general education which deal with industry, its organization, materials, occupations, processes and products and with the problems resulting from the industrial and technological nature of society" (Wilber, 1948, p. 2).

The trend toward accepting industrial arts as the name for the profession originated at the 38th Mississippi Valley Conference. The philosophy of the conference had held education for industry as its main thrust since its inception. Members had by 1948 recognized that manual arts and manual training were methods of the past. The members attending the 38th Conference therefore changed its terminology to industrial arts from manual arts (Barlow, 1967). The term industrial arts identified the profession until the change to technology education in 1985.

The Curriculum to Reflect Technology was the initial step to including technology as a part of industrial arts curricula. Warner (1965) with the help of his students in 1947 developed a curriculum that proposed to use technology as its basic premise. The content was derived by examining the socioeconomic enterprise system rather than by traditional means. The 1965 update provided a series of detailed content outlines for each of the identified technology subject areas. Streichler (1980) recognized Warner as one innovator of curriculum change for the 1947 AIAA convention report that identified divisions of industrial arts content. These areas included power, transportation, manufacture, construction, communication, and management. It was determined to be a stimulus for the field to reflect technology in its curriculum.

Warner (1965) in A Curriculum to Reflect Technology identified content as in the following:

> Content in the new industrial arts curriculum is derived via socioeconomic analysis of the technology and not by job or trade analysis as of old from the commoner village trades such as those of the carpenter, the blacksmith, the cabinet maker …now, the subject matter classifications are conceived of as including:
>
> a) <u>Power</u>: tidal, solar, atomic, electrical, muscular, hydraulic, combustion …;
> b) <u>Transportation:</u> land, sea, air, space;
> c) <u>Manufacturing:</u> includes the basic industrial methods of changing raw materials into finished products such as foods, textiles, ceramics, metals, woods, plastics, and leathers, similar but broader in concept and application than has been developed in the so-called “general” shop of the past forty years;

d) Construction: simple fabrication, housing, public works, industrial national defense ;
e) Communication: graphic arts including drawing, letterpress, planography, intaglio, and the miscellaneous processes in addition, to electricity, electronics, and other communications media; and
f) Management: including Line and Staff as in business and industry, or labor as well as management (pp. 41-42).

Industrial Arts in the 1950s

A distinctive movement characterized curriculum development of the 1950s. That movement was designed to use technology as the content base. This was a continuation of the trend initiated in the late 1940s. Four plans were typical of this format. Two plans, the Minnesota Plan and the Research and Experimentation (later known as the Maryland Plan), (Cochran, 1970; Martin & Luetkemeyer, 1979) had emphasis placed on "research, experimentation, and technically oriented programs…" (Cochran, p. 11). A third plan, The New Industrial Arts Curriculum, was organized about the three functions of consumption, production, and recreation. The content was relevant to "…power, transportation, construction, communication, manufacturing, and personnel work" (Cochran, 1970, p. 10). Streichler (1980) recognized Olson's "Technology and Industrial Arts" as containing eight major categories of industry: manufacturing, construction, power, transportation, electronics, research, services, and management. A final influence of this period was the report, Industrial Arts in Education. The report provided the industrial arts with definitions for the educational role, instructional areas, and program character at different levels.

Industrial Arts Curriculum in the 1960s

More change and curricular movement trends were initiated in the 1960s than any decade previous. Sputnik and the ensuing emphasis on space exploration provided the greatest influence on the new innovations. Even though the new programs were being embraced in numerous schools, many schools continued to follow the traditional content of automotive, crafts, drafting, electricity, graphic arts, metalworking, and woodworking.

Swanson (1965) noted that others had observed that the diversity of industrial arts programs had a long history and that it (diversity) is sometimes viewed as good. Swanson stated "almost any definition of industrial arts includes mention of the study of occupations, tools, machines, processes, materials, and products of industry" (p. 49). Bennett's description (as cited in Swanson, 1965) of manual arts content in five areas included "…graphic arts, the mechanic arts, the plastic arts, the textile arts, and the bookmaking arts" (p. 49).

Curriculum designers have built on this foundation and, as Swanson (1965) noted, are relative to two thrusts: materials, and the trade, craft, or occupational groupings. Characteristics of these programs are studies in metals and woodworking. Topics included the crafts of welding, machine shop, sheet metal, and foundry for the former and carpentry, cabinetmaking, and pattern making in the latter. Swanson (1965) related:

There are obvious advantages to visualizing industrial arts as the study of tools, processes, materials and operations. Content is relatively easy to identify and organize; the kind of facility needed can be readily justified; and the preparation of teachers (at least in their technical competence) is clear. Further, it is possible to assign a wide variety of purposes to the study of the same content. Some studies may use it for learning a job, others may base further learning on it, and still others may develop problem-solving abilities for use in further activities. (p. 51)

Swanson (1965) indicated that "…industrial arts is the study of the applications of science to the solutions of man's problems: the study of technology" (p. 51), and represented the viewpoint of some in the field. He also noted that mathematics and science principles have consistently been a part of industrial arts. An approach used to extend and upgrade curricula in industrial arts is to adopt parts of another discipline for industrial study. Examples included electricity and electronics, hydraulics, mechanics, and pneumatics as power mechanics (Swanson). Swanson felt that a greater understanding of scientific principles would show that "…industrial arts is related to science in much the way engineering is…" (p. 54). Swanson related that the study of industrial arts was related to the utilization of "…the basic resources of men, materials, machines, and money to produce goods or provide services" (p. 54).

Woodward and Decker (1967) determined the differences among manual training, manual arts and industrial arts centered on the approach to curricular content. The focus of manual training had been on hand skills, woodworking, occupations, engineering school entrance, and student retention. Development of useful articles utilizing skill, selected projects, and good design were key aspects of manual arts. The emphases of industrial arts were on design, problem solving and content with a focus on drafting, woodworking, metalworking, and electricity.

Woodward and Decker (1967) traced curricular change in industrial arts to innovative industrial arts teachers. These teachers recognized changes in industry and modified content to reflect some changes. Inclusive of content refinement was design, material selection, planning, and product development. Later, they identified content elements for a standardized curriculum as:

1. Automotive mechanics.
2. Crafts (in recent years the term <u>crafts</u> has been replaced in many areas by the term <u>industrial crafts</u>
3. Drafting (including engineering, drawing, and architectural drawing)
4. Electricity-electronics
5. Graphic arts
6. Metals

7. Power mechanics
8. Woods (p. 145).

Woodward and Decker (1967) also reported indications that showed plastics, hydraulics, fluid mechanics, and industrial controls were to become part of the industrial arts curricula. Additionally, they identified three curriculum projects as advancements in industrial arts education: the Industrial Arts Curriculum Project, the American Industry Project, and the Maryland Plan.

Barlow (1967) indicated that the research and writings of Keith, Olson, Roney, and Schmitt reflected the need for inclusion of technology in the industrial arts curriculum. Olson and Keith had identified the need for managerial skills in industry for those with application skills. Barlow (1967) concluded that:

> The curriculum in post-secondary institutions will have a base of applied science, mathematics, drawing, general technology, and an appropriate program of general education. Review of the curriculums offered indicates little standardization of content. The tendency of such curriculums is, however, directed toward clusters of closely related occupations rather than the needs of a single occupation.
>
> A newcomer to the field of technician education would be confronted with a mass of ideas, points of view, trends, relationships, and predictions that seemingly have no relationship and that lead to a confused educational situation. This is merely an indication of the complexity of the total problem and suggests that the educational specialist must pay more than usual attention to the nature of this rapidly changing field (p. 424).

Swanson (1965) developed four major headings to aid in classifying curriculum innovation in industrial education. These headings were:

1. The study of common life needs created by or related to industrial and technological advance.

2. The study of crafts or trades, processes, tools, machines, materials, and products.
3. The study of application of mathematics and the sciences.
4. The study of industry (p. 47).

Cochran (1970) used this classification system to help determine commonalties of various curriculum movements in industrial education. Four basic approaches were gleaned from his analysis of contemporary programs. The four approaches were:

1. Integrative programs
2. Interpretation of industry programs
3. Occupational family programs
4. Technology-oriented programs (p. 22).

Cochran's (1970) first contemporary approach category was integrative programs. These programs were those that had "interrelationships between two or more subjects" (p. 22).

The second contemporary approach category identified by Cochran (1970) was: Interpretation of Industry Programs. Five programs were determined to be members of this grouping. Early influencing factors for the position expounded by these programs came from the work of Warner's "Laboratory of Industries" and Wilber's "Industrial Arts in General Education."

The third major category of contemporary programs identified by Cochran (1970) was occupational family programs. These programs were centered on the development of salable skills and competencies in an occupational cluster and were developed based on local or regional needs. Cochran (1970) identified the final contemporary approach as Technology-Oriented Programs. The basis of this category has roots in Warner's "Laboratory of Industry," and succeeding technology oriented proposals, "The Ohio Prospectus" and "A Curriculum to Reflect Technology." The motivation for this approach is founded on the premise that technology is more than technical developments, it also draws on "…scientific management, product demands, and the role of the individual in society" (Cochran, p. 73).

Lux (1967) used Swanson's four groups of industrial arts curriculum proposals to classify nine curricular innovations in secondary school industrial arts. Of the nine identified, only the Maryland Plan was developed to meet the needs of common life as "created or related to industrial and technological advance" (Swanson as cited in Lux, 1967, p. 155). The second group included the Galaxie Program, the Orchestrated Systems Approach, the Partnership Project, and the Study of Technology (Kent State). The third group included the Maryland Plan and the Alberta Plan. All nine programs were included in the fourth group: each of those previously identified plus the Study of Technology (Oswego, NY), the Industrial Arts Curriculum Project, and the American Industry Project.

Two possible leading conclusions were suggested by Lux (1967). The first was that previous curriculum guidelines and methods for comparison cannot cope with merging developments. Second was that a new method of curriculum comparison was needed.

Householder (1974) also classified alternative curriculum project efforts using a similar system that drew from this classification system. Householder (1974) determined several curricula that focused on the technology-centered approach. A second alternative category was the Career-Occupation Emphasis. He further identified alternative curricular strategies that revolved around career or occupational education. One area of alternative programs was individual development emphasis. Householder (1974) finally identified a category for evolutionary approaches to industrial arts. He determined that the emphasis of these programs was based primarily on "…the improvement of the existing industrial arts curriculum" (p. 33).

The two curriculum classifications that had the greatest impact on the development trends of industrial technology curricula were the interpretation of industry and technology-oriented programs. The following examples were included in these classifications.

The interpretation of industry programs included the American Industry Project (Cochran, 1970; Lux, 1967; Streichler, 1980), the Functions of Industry (Cochran, 1970; Streichler, 1980), Orchestrated Systems Approach (Cochran, 1970), the Industriology Project (Cochran, 1970), and the Georgia Plan (Cochran, 1970). The most widely accepted program from this classification was the American Industry Project. Many of its characteristics are typical of programs in this classification. The American Industry Project directed by Face and Flug derived two broad based subject matter objectives (Streichler, 1980) from educational theory based on the Seven Cardinal Principles of Education. "They are (1) to develop an understanding of those concepts that apply directly to industry, and (2) to develop the ability to solve problems related to industry" (Cochran, 1970, p. 40). The instructional content was developed via taxonomy that included thirteen common industrial concepts. "These included communication, transportation, finance, property, research, procurement, relationships, marketing, management, production, materials, processes, and energy" (Cochran, p. 40). Lux (1967) identified a fourteenth concept, physical facilities.

The technology-oriented programs were represented by the Alberta Plan (Cochran, 1970; Householder, 1974; Lux, 1967; Streichler, 1980), Enterprise: Man and Technology (Householder, 1979), Study of Technology: Kent and Oswego (Lux, 1967), The Industrial Arts Curriculum Project (Cochran, 1970; Lux, 1967; Streichler, 1980), Technology as Discipline (Householder, 1979; Streichler, 1980), The Maryland Plan (Cochran, 1970; Streichler, 1980), The Main State Plan (Cochran, 1970; Olson, 1964), and the Parma (Ohio) Approach (Cochran, 1970). The most recognized curriculum plan in this classification was the Industrial Arts Curriculum Project (IACP). A broad overview of technology was provided by the IACP as compared to conventional industrial arts coursework. The rationale and structure for the project were formulated by "…representatives from education, business, industry and labor" (Cochran, 1970, p. 78). Streichler (1980) viewed the IACP as a refinement of earlier work completed in an industrial arts curriculum. It delimited the content of industrial arts into two distinct categories: manufacturing and construction. The content was then organized for ease of instruction.

Two phases, The World of Construction and The World of Manufacturing, were identified as the means to deliver instruction meeting established objectives. The objectives were designed to emphasize industrial knowledge from general knowledge. Industrial technology was defined in the IACP "…as that knowledge which is used to satisfy man's wants for industrial material goods, and it is composed of two principal industrial divisions: construction and manufacturing" (Cochran, 1970, p. 79).

The remaining two curriculum classifications, the integrative and occupational family programs, have not contributed in a significant manner to the development of industrial technology curricula. No programs from these classifications will be included in this literature review.

Industrial Arts in the 1970s and 1980s

Streichler (1980) retraced industrial arts curricula to its roots of woodworking, metalworking, and drafting. He also noted that little change occurred during the 1960s and 1970s as indicated by the Schmitt and Pelley report of 1966 and the Schmitt follow-up of 1976. He did note, however, that while fewer students were enrolled in traditional courses, the new courses were merely an extension of materials and processes, not a broader interpretation of technology.

Streichler (1980) found that Schwalm developed a concept-based curriculum that was interdisciplinary in nature. The difference being that he selected only graphic arts and developed the curriculum in-depth around visual communications. Likewise, Householder (1974) found that Risher had developed a similar program but for applied technical power.

Streichler (1980) analyzed the 1978 Industrial Teacher Education Directory and found that 80% of the teaching areas continued to follow trade, material, or process oriented activities. Additionally, Streichler identified in his analysis titles of academic units that used technology as a modifier to either give credence or communicate diverse practices. These titles included:

- Industrial Education and Technology
- Industrial Arts and Technology
- Industry and Technology
- Engineering Technology
- Industrial Technology
- Technology Education
- Applied Science and Technology
- Engineering and Technology
- Applied Science and Technology
- Engineering and Technology
- Technology (Dept. of, Div. of, School of, College of)
- Science and Technology
- Scientific and Technological Studies
- Vocational Education and Technology

Streichler (1980) further supported his argument of little change in titles by comparison to his 1970 study. This study of topics included in NDEA Institutes reflected diversity in the field. When compared 10 years later to the Industrial Teacher Education Directory, little change had occurred.

Lauda (1988b) related that although technology education has not been fully applied in the entire country, its curricular design has responded to the needs of our culture. It is a sound concept, is attainable, and addresses primary technical activities. The curriculum is designed around the systems concept of the inputs, processes, and outputs for technologies of construction, communication, manufacturing, energy/power, and transportation.

Sterry (1987) proposed the context of the Jackson's Mill human adaptive systems be used to analyze technology content of systems, productive processes, resources, and outputs until something more appropriate is devised. The taxonomy of content concepts for the Jackson's Mill project was used to describe inputs, productive and managerial processes, and outputs. Content was developed to suit the school's needs.

Savage and Morris (1985) recognized that industrial arts began in United States school programs as manual training. Drafting, metalworking, and woodworking courses were organized to develop technical literacy by addressing needed technical attitudes, knowledge, and skills. Typically, emphasis was placed on education for the technical skills and American industry. They determined that current needs dictated that focus should be on developing technological literacy. This would provide an understanding of our highly technological worlds and the relationship to humankind as it affects our future industrial-technological culture.

The Technology Systems Matrix model was proposed by Savage and Morris (1985) as an attempt to encompass the breadth of industrial technology. The Technology Systems Matrix had three dimensions of technology in its content structure as proposed by McCrory. These elements were "elements of technology, contexts of technology, and levels of complexity" (McCrory as cited in in Savage & Morris, p. 7). Conceptually, the Technology Systems Matrix integrated "four industrial technology systems with eight content areas at four levels of instruction…" (Savage & Morris, p. 7). The content areas in a hierarchical model for each industrial technology system in the matrix are: "(a) society and culture, (b) environment, (c) research and development, (d) tools, (e) resources, (f) techniques, (g) maintenance, and (h) management" (Savage & Morris, p.

7). Likewise, a learning task hierarchy for each industrial technology system is provided: "(a) introduction, (b) application, (c) sophistication, and (d) progression" (Savage & Morris, p. 8).

Savage and Morris (1985) designed the second-generation matrix for independent application of each industrial technology system to each content area for each level of instruction. The purpose was to add clarity and direction to the technology system when constructing courses.

Additional course construction clarity and direction are achieved in the third-generation matrix. Independent application of industrial technology component areas to content for each level of instruction possible. Applications for the technical methods from a second-generation matrix component area were also included at this level. The integration of technical methods, content areas, and level of instruction composed the complete third generation matrix. Within the matrix, isolation of a technical method for a specific content area at a distinct instruction level was provided for instructional purposes (Savage & Morris, 1985).

Bjorkland (1988) identified two curriculum innovations of the 1960s and 1970s; "Industry and Technology Education" authored by Sterry and Wright and "The Illinois Plan for Industrial Education" in 1983 that provided a firm foundation for technology-based innovations. Each reflected a focus on industrial clusters rather than materials. The former was patterned after the Jackson's Mill Industrial Arts Curriculum Theory and developed content structures for "…the systems of communication, construction, manufacturing, and transportation (p. 116). The latter curriculum was developed to emphasize the industrial technologies of communication, energy utilization, production, and transportation. He also noted that Minnesota's curricular plan had been revised to utilize four clusters similar to the Illinois Plan.

Sutton and Carter (1986) identified a redirection for the future role of industrial arts. They proposed that students be provided with realistic activities in utilization and manipulation of "materials, tools, processes and systems being developed and utilized in industry and society" (p. 12). Further, they recognized that evolution for manual training through manual arts to industrial arts was a response to societal change. Sutton and Carter determined that a change in industrial technology programs would best "reflect the 'science and technology' thrust of present and future technological development" (p. 12).

A comprehensive industrial technology education program focused on action-based activities to impart knowledge about "technical means, their evolution, utilization, and significance with industry, its organization, personnel systems, techniques, resources, products, and their social/cultural impact" (Sutton & Carter, 1986, p.12). Sutton and Carter found that student time was spent "learning about technological devices and systems with emphasis on developing basic skills in robotics, lasers, electronics, energy systems, computer drafting and design, telecommunications, and other technologies" (p. 12).

Sutton and Carter (1986) when setting goals for industrial technology education used the following content organizers:

1. Communication Systems.
2. Construction Systems.
3. Manufacturing Systems.
4. Power/Energy/Transportation.

Sutton and Carter (1986) proposed that the major instructional objectives of industrial technology education programs at the second level should be:

1. To assist students to develop an insight into and understanding of industry and technology, its place in our society and the free enterprise system.
2. To assist students to discover and develop individual talents, aptitudes, interests, and potentials as related to industry, science, and technology.

3. To assist students in developing an understanding of industrial processes and the practical application of scientific principles.
4. To assist in developing technical problem-solving and creative abilities involving the use of materials, processes and products of industry and technology.
5. To assist students to develop an understanding of industrial and technological career opportunities and their requirements and develop those traits that will help students obtain and maintain employment (pp. 12-13).

Holloway (1987) defined high technology as "the application of state-of-the-art automated, instrumented, or computerized complex systems, devices, or machines that are relatively new to the marketplace" (p. 12). For proper application of high technology curricula, it must be understood that high technology is systematic, has many technologies characterized by computer and microprocessor utilization, and is subject to rapid changes in technical content.

Achievement of overall program objectives and provision of job entry skills should be the goal for high technology curriculum content and organization (Holloway, 1987). He also identified common core competencies needed for successful graduates of high technology programs. Basic core competencies needed:

- Broad based knowledge in multiple technologies.
- Understanding the systems concept and interrelationship among systems and components.
- Working knowledge of electronics, computer science, mathematics, physics, and chemistry.
- Ability to assemble, install, operate, maintain, troubleshoot or repair electronic, mechanical, electromechanical, fluidic, thermal, and optical devices, components and systems.
- Expertise in communicating with a variety of personnel within the occupational hierarchy.

- Flexibility in adapting to new assignments, new situations and changing job requirements (p. 13).

McCrory's (1985) viewpoint of technology education was that it had a broader base than did industrial technology. Industrial technology, he asserted, only impacted on the technologies of industry and did not take into account the effects of technical systems on individuals and society.

Industrial technology education is limited in scope (McCrory, 1985). He contended that its focus was to educate young people about the "organization, materials and procedures of specific manufacturing industries" (p. 2) for careers in contemporary industry. The role of those with post-secondary education is management.

McCrory (1985) recognized that content organizers of both technology and industrial technology education were the same but content emphasis differed. Technology education has a macro view of the evolution of technical developments and the impact on society as a whole. Industrial technology conversely focuses on the "knowledge and skills used in contemporary industries," (p. 2) employing the task-analysis approach.

DuVall (1984) determined that because of the rapid changes taking place in industry in response to high technology inputs, the future will differ from the past. Significant to this change are flexibility and lower capital expenditures that permit industry to adjust their product, service, or process to meet society's needs. High technology companies typically locate near universities to establish a research link with the university, to have a reliable source for technically trained personnel, and to have the capacity to keep up with new technology. DuVall (1984) also recognized the potential these developments have for curriculum development. Some offerings in universities have changed in response to these developments. Representative courses include "CAD/CAM/CIM…more intensive offerings in computer technology, electronics, communications, and robotics" (p. 9). DuVall implied that curriculum change that anticipates the future will help students be prepared for careers that do not yet exist.

Goetsch (1984) postulated that high technology marked the birth of a new age potentially as significant as the Industrial Revolution. Impacts on industrial education include the need of new training programs for high technology positions, curriculum revision, equipment modernization, facility reorganization, and in-service education for personnel.

In deference to Vanderslice, Goetsch (1984) determined the birth of high technology coincided with the invention of integrated circuits in the late 1950s. Schuler (as cited in Goetsch, p. 17) defined high technology as:

The application of programmable integrated circuits and programmable systems based on integrated circuits to areas including, but not limited to, data processing, manufacturing, information management and transmission, education, national defense, entertainment, energy management, pollution control, safety, communications and efficient utilization of natural and human resources.

Six characteristics of high technology occupations have been identified by the Center for Occupational Research and Development (CORD). The characteristics:

1. require that workers have a broad knowledge base
2. involve heavy and frequent computer use
3. involve rapid and continuous change
4. are systems oriented
5. require an in-depth understanding of underlying principles
6. require a flexible workforce (as cited in Goetsch, 1984, p. 17)

To educate for high technology occupations, a four-part learning core "of applied math and science, communications, socioeconomics, and technical prerequisites" was recommended by CORD. The integral parts of the core are outlined in Goetsch (1984):

> The applied math and science portion of the curriculum includes algebra, trigonometry, analytical geometry, applied calculus, and physics. The communications portion covers technical communications and computer basics; socioeconomics includes economics and industrial relations. The technical prerequisites include electricity, electronics, properties of materials, mechanical devices, manufacturing processes, circuit analysis, heating and cooling, fluid power, instrumentation and control, computer applications, and industrial electrical power and equipment (pp. 17-18).

Upon completion of the common core, students specialize in an area of high technology. To meet the challenge of high technology developments, traditional industrial education programs must be updated. Goetsch (1984) proposed a two-part solution that included "developing, implementing, and maintaining new high technology programs, and updating and maintaining existing programs that are affected by high tech developments" (p. 18).

Cooperation between education and industry to pool resources and share financial burdens is required if a satisfactory solution of the high technology challenge is to be achieved. Strategies proposed to aid this process include formation of industry-education councils for decision-making about curriculum development, facilities, equipment, expert personnel, how to share expertise of each entity, how to share budgeting for high technology equipment, and methods by which educators can be updated about high technology (Goetsch, 1984).

Perception and Partnership

Since the inception and introduction of manual training into school curricula, the profession has been embroiled in controversy. Barlow (1967) noted that industrial arts was considered "…as an "upstart" trying to gain a foothold in the education structure where it was neither wanted or needed" (p.

239). Conversely, other educational leaders viewed "…the development of industrial arts as the vehicle through which the most precious values of education could be realized" (p.239). Another dogged problem has been one of unity. Part of that is tied to change and diversity of programs (Barlow, 1967; Diez, 1990) in determining a general or common curriculum. Most work has been accomplished through the efforts of groups led by strong leaders. Barlow (1967) outlined the problem of terminology surrounding the name of the profession. He noted that manual training was used after 1876, manual arts circa 1894 and about 1910 industrial arts began to be accepted. Industrial arts education was recognized until 1985, when the name was changed to technology education. Another influence was the management-oriented curriculum of industrial technology education. Hauer (1963) found 50 programs in 27 states in the mid-and-far west in departments of industrial education or industrial arts by 1963. These issues took root during the birth of the profession and still haunt the profession as it moves into the 21st century.

In retrospect, one can look historically at the profession and determine why these issues exist. Bennett (1926) wrote about how claims made by manual training advocates were related by educational conservatives because of such internal movements as the industrial schools for orphans, the industrial reform schools, the Ragged schools, and trade schools.

The evolution of industrial arts into technology education has not eliminated the public's view of it being vocational education (Zuga, 1995). This may also contribute to the idea that technology education is not for women. This is divergent from Bennett's (1937) observation that women were prevalent in industrial education and manual training in the early 1900s.

Dewey (Zuga, 1995) decried the control industrial arts was exerting over students. He believed that teacher mandated projects were eliminating the value of industrial arts education.

Zuga (1995) found that the renaming of industrial arts to technology education has been confusing. Part of that is attributed to the widespread use in society of the word technology. Technology is equated with computers by society and many times technology education is confused with instructional or educational technology in education use.

A review of various curriculum movements in industrial and technology education over the past 120 plus years has indicated that no one curriculum has been fully implemented by the profession. The elements of manual training, manual arts, industrial arts, education about technology and technology education can be found in programs across the United States. However, there is no one singular curriculum that has been implemented as general education or otherwise. Change to technology education curricula has been slow to reach the classroom even through the top-down efforts of professional associations and state departments (Zuga, 1995). This author has observed that classroom teachers fight the curricular change to technology education. Teachers do not want the curriculum forced into their classrooms. This resistance to change can possibly be traced to the fact that the beliefs, attitudes, and philosophies of the classroom teacher have not been adequately addressed (Zuga, 1995).

A shortcoming of technology education as general education is the missing link between mathematics, science, and other subjects. It is supposed to be a problem solving, innovating, and design-oriented curriculum that is integrated with and supported by other subjects in the curriculum (Zuga, 1995). The foundations of the profession were designed on the premise that manual training complemented and extended the influence and application of other subjects.

Zuga (1995) conducted an evaluation of nine studies that focused on student performance in mathematics (two studies), science (six studies), and language arts (one study) as a result of participating in technology education. She found that most results used technology as a method of instruction, not as unique content. This does not support the idea that technology is integrated with other subjects. This point is further supported by a statement at a National Academies of Science conference that when speaking about how technology is helpful in the education process, it is only as educational technology (1996).

Shaping the Future Conference

Several integrative and collaborative ideas were shared at the 1996 Shape the Future Conference. Opportunities in undergraduate education were identified as having a better understanding of pedagogical practices, course and curriculum design, and better information technology. Science, mathematics, engineering, and technology were challenged by industry to provide greater employee skills and increase the effectiveness of respective introductory courses for all students (majors, non-majors and future educators).

Reports about the most effective teaching methods emphasized that active collaborative settings for student learning were strengthened by multidisciplinary academic collaboration to solve socially and technically important problems, and that direct experiences with the practice and process of inquiry inspired students. It was postulated that comprehensive improvement in student learning will depend on the collaboration of science, mathematics, engineering, and technology faculty with colleagues from schools of education. Their charge will be to demonstrate disciplinary connections, promote the integration of research and education, and ensure that undergraduate introductory course pedagogy quality is strengthened. The Conference further challenged educators to work together to gain major improvements. Partnerships are needed among all schools from elementary through four-year colleges and universities. In addition, education is challenged to work more closely with industry and other college graduate employers (National Academy of Sciences, 1996).

Luther S. Williams (National Science Foundation) in his welcoming address spoke about the future of education:

> If properly configured, the centrality of undergraduate science, mathematics, engineering, and technology (SME&T) education is integral to the country's welfare. I am <u>not</u> talking about the traditional focus of undergraduate SME&T education – to prepare the next generation of scientists and engineers. The undergraduate sector is inseparable from the quality of the technological workforce, whose knowledge and skills grow from an understanding of these disciplines. It is also inseparable from any effort to improve K-12 math and science education because the undergraduate sector prepares a workforce that is increasingly critical to broad sectors of industry, education, and government (pp. 11-13).

He also noted that "…it is important to emphasize the connections between organized bodies of knowledge" (p. 13). Moye, in his closing comments, noted that "significant change is required…" (p. 15). He observed that "students must acquire life time skills such as critical thinking, quantitative reasoning, effective communication, along with such abilities as finding needed information and interacting with others" (p. 15). Lane believed it was time to pressure for institution wide reform (National Science Foundation, 1996).

Even though there was a great call for collaboration among SME&T at this conference, there also appeared to be only lip service given to technology education. For example, National Academy of Sciences President Bruce Alberts focused his comments only on science and talked about "shop." Exxon's Clarence Eidt, Jr. emphasized mathematics, science and engineering and made no reference to technology except that science and technology equals science literacy. He also voiced that technology was viewed as educational technology (National Science Foundation, 1996).

It was evident from the differing viewpoints of leaders at this Shaping the Future Conference that there are opposing viewpoints. Some view excellence in education as total collaboration and integration among SME&T at all levels of education. Others ignore technology completely, while others view technology as a method to teach other subjects. Technology education in some circles is only given lip service.

The future, however, holds hope for a change in attitudes and, hopefully, implementation and practice. The advent of education standards development in the fields of mathematics, science, and technology education indicate that recognition of the strengths of integrating the respective curricula can be beneficial to all. Partnerships forged with the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) in the development of the Standards for Technological Literacy underscore these efforts. An endorsement of the Standards by the Engineering Education Council further delineates the importance of technology education as general education.

Perhaps the controversy and issues can best be realized by what Woodward in 1877 suggested in a statement to Washington University officials "…that possibly the best of us have failed to realize is included in the term 'education.' In our desire to eliminate all narrow utilitarian motives, have we not sometimes run to the other extreme and excluded from our schools important and essential branches of study because they were suspected of being useful?" (as cited in Bennett, 1937, pp. 337-338).

Conclusions

To determine the perception and partnership of technology education in relation to science, mathematics, and engineering from the viewpoint of professional educators in each field, an informal survey instrument was constructed and select leaders in the fields of science, mathematics, and engineering were surveyed. Although not valid or reliable, this ad hoc research did confirm some insights into how technology education is viewed by related disciplines.

The results of the survey albeit not comprehensive in nature, underscore some of the perceptions that have been handed down from generation to generation of manual training, manual arts, industrial arts, and technology educators. Attitudes have not changed since the dawn of our profession. Technology education is:

1. Viewed as a secondary subject.
2. Understood as technical or vocational in nature.
3. Not accepted as general education.
4. Not design oriented.
5. Does not evoke teamwork ideals.
6. Does not encourage out of the box thinking
7. Only used as instructional or educational technology
8. Not viewed as an equal in decision-making about curriculum.

The technology education curriculum should be integrated with science, mathematics, and engineering, but only to the extent that these disciplines teach *with* technology, not about technology or how technology relates to their respective disciplines. Even though technology education should be integrated into science, mathematics, and engineering curriculums, very little integration has taken place.

One of the greatest perceptions the technology education profession must work to change is that it is still perceived as teaching technical skills and their applications. The profession must be able to demonstrate that in addition to the technical aspect, we also teach problem solving, teamwork, and thinking outside the box; that we are general education, not technical or vocational training. Even given this fact, the other three disciplines agree that technology is important to students who wish to further their education. It was disturbing, however, to discover that they don't believe students who enroll in postsecondary education are technologically prepared. It seems a dichotomy that the teaching of technology is deemed important to the teaching of science, mathematics, and engineering, but that technology education is ranked lowest in importance to the other three. It is perceived that our teachers are not prepared to teach technological literacy. It is also revealing that we are excluded to a great extent when it comes to making decisions about integrating the curriculums. Technology education is neutrally viewed as a basic and as a stand-alone subject in K-12 education. Once again we have conflict, because the respondents all believed that technology education was important to the lives of young people in the 21st century.

The final conclusion that can be drawn is that we, as technology educators, have much work to do to change the attitudes of other education professionals. We must strive to become a part of the decision-making process, integrate our curriculum with others, better prepare our teachers in technological literacy, develop strong innovation and design components in our curriculum, and instill teamwork ideals in our students. If we do these things, we will make a difference.

References

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

Bawden, T. (1916). *Historical file of the Mississippi Valley Conference.* In Barlow, M. L. *History of industrial education in the United States.* Peoria, IL: Chas. A. Bennett Co., Inc., 1967.

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

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

Bjorkland, L. R. (1988). Interpretation of industry approach. In W.H. Kemp & A.E. Schwaller (Ed.), *Instruction strategies for technology education: 37th yearbook of the Council on technology teacher education* (pp. 110-121). Mission Hills, CA: Glencoe Publishing Company.

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

Diez, C. R. (1990). Curricular trends in four-year baccalaureate degree industrial technology programs. Unpublished doctoral dissertation, University of Northern Iowa, Cedar Falls, Iowa.

DuVall, J. B. (1984). High technology: Dream or reality? *The Technology Teacher, 44*(2), 8-9.

Goetsch, D. L. (1984, March). Meeting the high tech challenge. *School Shop,* pp.17-18.

Holloway, H. D. (1987, May). Developing high technology curriculums. *Industrial Education,* pp. 12-13.

Householder, D. L. (1974). *Review and evaluation of curriculum development in industrial arts education.* Bloomington, IL: McKnight.

Lauda, D. P. (1988b). Technology education. In W.H. Kemp & A. E. Schwaller (Ed.), Instruction strategies for technology education: 37th yearbook of the Council on technology teacher education (pp. 110-121). Mission Hills, CA: Glencoe Publishing Company.

Lockwood, C. B. (1905). *The New Harmony movement.* New York: D. Appleton and Company. In C. A. Bennett. *History of manual and industrial education up to 1870.* Peoria, IL: The Manual Arts Press, 1926.

Lux, D. G. (1967, November). *Comparisons of theoretical bases and rationales of curricular innovations for secondary education.* Paper presented at the 54th Mississippi Industrial Arts Conference, Chicago.

Martin, G. E., & Luetkemeyer, J. F. (1979). The movements that led to contemporary industrial arts education. In G. E. Marftin (Ed.), *Industrial arts education: Retrospect, prospect, 28th yearbook of the ACIATE* (now the Council on Technology Teacher Education) (pp. 18-42). Bloomington, IL: McKnight *Publishing* Company.

McCrory, D. L. (1985). Technology or industry: Which shall it be? The Technology Teacher, 44(5), 2-3.

Manual education in the Polytechnic School of Washington University. (A pamphlet loaned by Dr. Woodward and parts of it copied). (1877). In C. A. Bennett. *History of manual and industrial Education 1870 to 1917.* Peoria, IL: Chas. A. Bennett Co., Inc., 1937.

National Science Foundation. (1996). Shaping the future: Strategies for revitalizing undergraduate education. *Proceedings from the National Working Conference.* Washington, D.C.: National Science Foundation.

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

Ricketts, P. C. (1914). History of Rensselar Polytechnic Institute. New

York: John Riley and Sons. In C. A. Bennett. History of manual and industrial education up to 1870. Peoria, IL: The Manual Arts Press, 1926.

Savage, E., & Morris, M. (1985). Technology systems matrix: Practical application for curriculum development. *The Technology Teacher, 44*(7), 8-10.

Snedden, D. S (1907). Administration and education work of American juvenile reform schools. New York: Columbia University Contributions to Education. In C. A. Bennett. History of manual and industrial education up to 1870. Peoria, IL: The Manual Arts Press, 1926.

Sterry, L. (1987). A relationship between technology education and trade and industrial education. *The Technology Teacher, 46*(5), 11-14.

Streichler, J. (1980). Ideals and practice: The profession's response to technology/society. In H. A. Anderson & J. A. Benson (Ed.s), Technology and society: Interfaces with industrial arts, 29th yearbook of the ACIATE (now the Council on Technology Teacher Education (pp. 71-108). Bloomington, IL: McKnight Publishing Company.

Sutton, J. R., & Carter, L. (1986). Industrial technology education: Goal setting for success. *ATEA Journal, 13*(3), 12-13.

Swanson, R. S. (1965). Industrial arts: What is its body of knowledge. In G. S. Wall (Ed.), Approaches and procedures in industrial arts, 14th yearbook of the ACIATE (now the Council on Technology Teacher Education (pp. 71-108). Bloomington, IL: McKnight & McKnight.

Warner, W. E. (1965). A curriculum to reflect technology. (Originally the feature presentation at the AIAA Convention 25 April, 1947). Columbus, OH: Epsilon Pi Tau.

Washburn, C. G. (1906). Technical education in relation to industrial development. *Journal of the Worcester Polytechnic Institute, 7*.

Bennett. History of manual and industrial education up to 1870. Peoria, IL: The Manual Arts Press, 1926.

Wilber, G. O. (1948). *Industrial arts in general education.* Scranton, PA: International Textbook Company.

Woodward, R. L., & Decker, H. S. (1967). Industrial arts education. In F. E. Connor, & W. J. Ellena (Eds.), *Curriculum handbook for school administrators* (pp. 141-159). Washington, D.C.: American Association of School Administrators.

Zuga, K. F. (1995, April). *Struggling for a new identity: A critique of the curriculum research effort in technology education.* Paper presented at the Annual Meeting of the American Education Research Association, San Francisco, California

Are Technology Education Teachers Prepared to Teach Engineering Design?

Presented at the 91st Mississippi Valley Technology Teacher Education Conference, 2004, Chicago, IL

Chapter 3

Brian K. McAlister
University of Wisconsin-Stout

Background

There has been a recent call for technology educators to integrate engineering content into the curriculum. This leads to several questions regarding requisites for such an initiative if it is to be successful. For example: Are technology teachers prepared to teach engineering design and analytical methods in high schools? Do technology teachers have the requisite math and science knowledge to effectively teach engineering content? If not, how best can they acquire such knowledge? Do technology education teachers have the requisite engineering design knowledge and skills to effectively teach engineering content? If not, how best can they obtain that knowledge and those skills?

Two separate studies were designed to address these questions. In the first study, technology teacher education programs were reviewed to determine the preparation that new teachers receive in science and mathematics. In the second study, current technology education teachers participating in a regional technology education conference were surveyed to determine their preparedness to implement engineering design concepts.

A Review of Technology Teacher Education Programs

The researcher chose to start by operationally defining the requisite math and science knowledge required to effectively teach engineering content. For the purpose of this paper, the researcher examined what is arguably the most successful pre-engineering initiative in the United States, Project Lead the Way. This fall Project Lead the Way (PLTW) launched a College/University Pre-Service Agreement for universities that showed interest in creating a PLTW curriculum option within their technology teacher education programs. Within this agreement they prescribed science and mathematics course requirements. By signing the agreement, universities agreed to design/realign their programs so as to require their pre-service teacher education candidates who were seeking a PLTW endorsement to take "one math course above college algebra" and "college level lab physics" plus "one additional lab science course." These guidelines became the criteria by which technology teacher education programs were measured in the first study.

Procedures

Do technology education teachers have the proper math and science preparation to teach pre-engineering/engineering concepts? Technology teacher education programs were reviewed to determine the current status of new teachers' science and mathematics preparation.

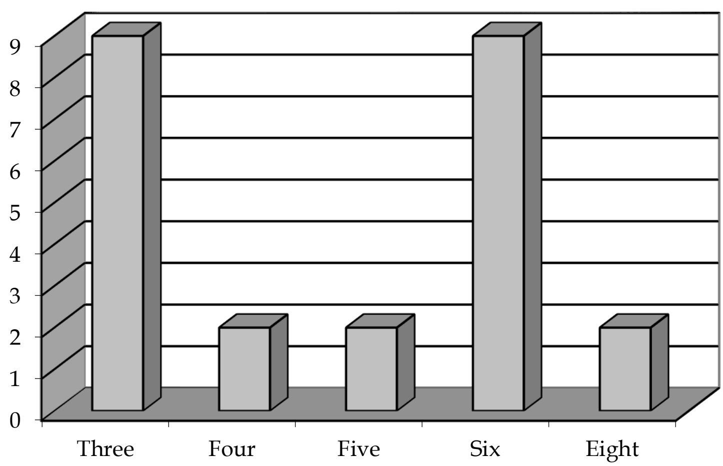
The CTTE/NAITTE directory was used to identify 44 technology teacher education programs that licensed 3 or more technology education teachers in the past year. A representative from those programs was mailed a letter soliciting copies of current program plan sheets. In addition they were asked to complete a survey instrument designed to help clarify the math and science requirements in their programs.

In addition to sending program plan sheets, respondents were asked to identify websites where information about their programs could be found. The researcher used the program plan sheets, the survey instrument, and program information available on the Internet to build an understanding of the math and science requirements in their programs. Of the 44 programs that were contacted, 24 (54.5%) returned information about their programs.

Mathematics Requirements

Technology teacher education programs very greatly when it comes to defining mathematics requirements. Future teachers may be required to take anywhere from 2 to 8 credits (Figure 1). The most common credit hour requirement was three or six credit hours (9 programs, 43%). This makes sense if you consider that many university level courses are offered for 3 semester hours of credit.

Figure 1: Required Math Credits



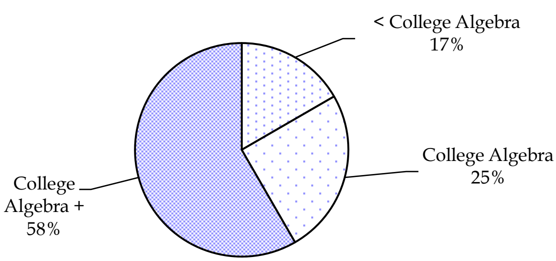
Once you get past credit hours, the analysis became more difficult to scrutinize. Mathematics is required in all technology teacher education programs and most require either one or two classes. But the requirements are not uniform across programs.

The following list provides a sampling of the types of phrases used to describe the requirements:

- Any college math
- Mathematical Reasoning
- Survey of Mathematical Ideas and Stats
- College Algebra
- College Algebra plus any Math
- Algebra and Trig
- College Algebra and Statistics
- Any Math above College Algebra
- Algebra and Trig or Pre-Calculus
- Pre-Calculus
- Applied Basic Math and Pre-Calculus
- Algebra for non-math majors and Calculus for non-math majors
- Calculus

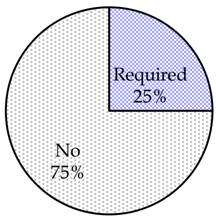
College algebra was chosen as the first point of reference. Most programs (83%) require at least college algebra while students in only 17% of the programs represented can complete their teacher preparation without taking it (Figure 2). Students in 25% of the programs can graduate with college algebra being the highest-level mathematics course completed.

Figure 2: College Algebra

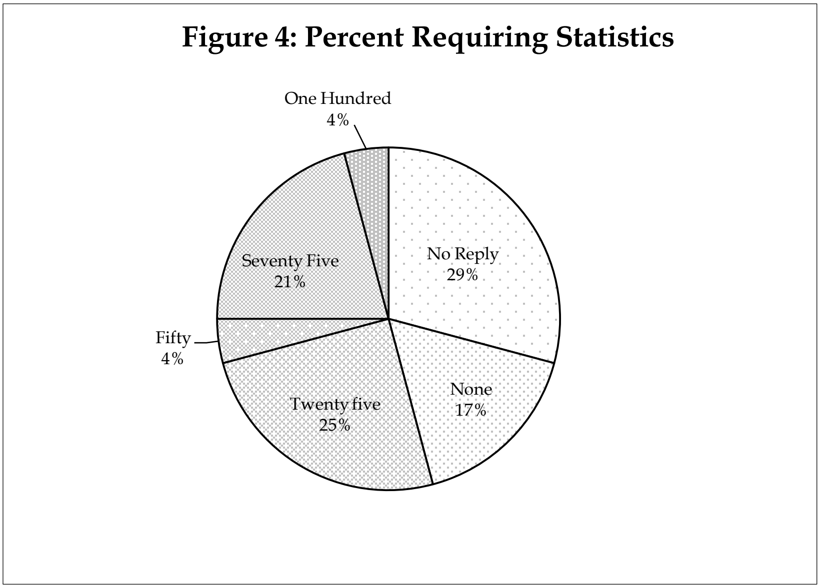


Project Lead the Way requires teacher education programs to require at least one course beyond college algebra. Using that standard, 58% of the participating programs offer a level of mathematics to prepare students to effectively introduce pre-engineering concepts under the PLTW model.

Figure 3: Statistics



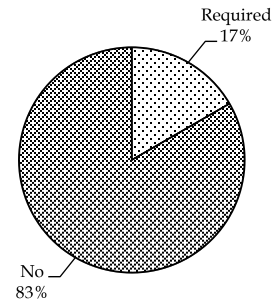
One of the next most common required courses was statistics. However, only 25% of the programs represented required a statistics course (Figure 3). Additionally, program representatives were asked to estimate what percentage of their pre-service technology teacher education candidates completed a given course. Only 29.1% of all programs indicated that approximately half or more of their students completed a statistics course (Figure 4).



Trigonometry was the next most commonly identified required course with 20.8% of the programs identifying it as a requirement. It was the highest level of mathematics required in 8% (3) of the programs.

Although calculus was the next most commonly identified required math course, only four programs (16.7%) indicated that they required it for their pre-service technology teacher education candidates (Figure 5). Half of the programs (12) reported that some of their students completed calculus. However, only four programs reported that half or more of their students took it. Representatives reported that few pre-service technology teacher education candidates complete calculus unless it is required.

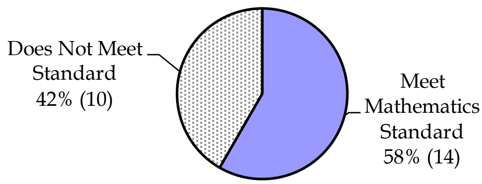
Figure 5: Require Calculus



Other courses listed as requirements by one or more programs include finite mathematics (2 programs, 8%), calculus 2 (2 programs, 8%) and pre-calculus (1 program, 4%). Other courses listed as electives were survey courses such as Survey of Math Ideas, Contemporary Topics in Mathematics and Foundations of Math in the Real World.

In summary, technology teacher education programs in the United States require a wide array of combinations of mathematics courses to prepare their students to be technology teachers. College algebra is the most commonly required mathematics course and most (83%) required it or another higher-level mathematics course. Over half (58%) of the technology teacher education programs represented in this study meet the mathematics preparation standards established by Project Lead the Way, college algebra plus one additional mathematics course beyond.

Figure 6: Programs Meeting PLTW Math Requirements

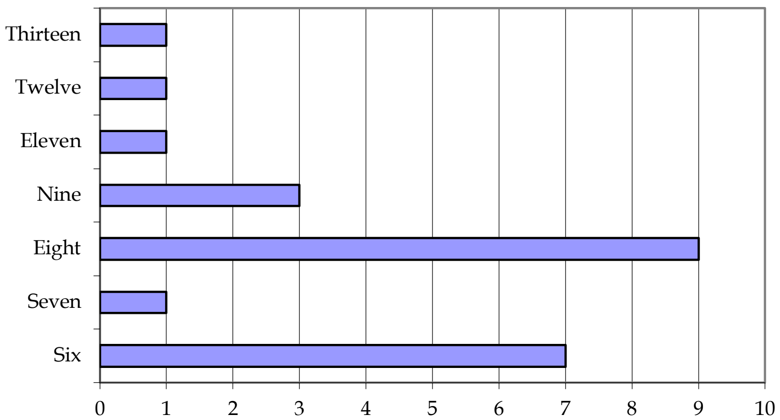


Approximately 21% of the programs require statistics and approximately 17% require calculus. Beyond that, the requirements become more difficult to track because of the flexibility within programs to meet mathematics requirements through different combinations of courses. One must conclude that there is no one consistent model for providing technology education teachers with the mathematics competencies.

Science Requirements

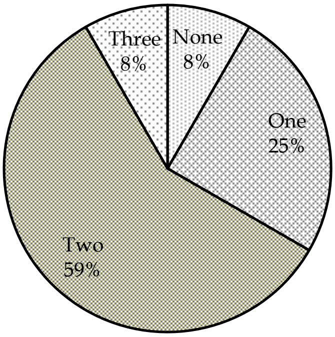
One might think that science requirements would be easier to summarize than mathematics. In some ways it is true, but in others it is not. Future technology education teachers are required to take anywhere from 6 to 13 credits (Figure 7). The most common requirement was 6 credits (7 programs, 29.1%) and 8 credits (9 programs, 37.5%).

Figure 7: Required Science Credits



In addition to credits, most programs (14 programs 58.3%) require their students to take at least two lab-based science courses (Figure 8).

Figure 8: Science Labs

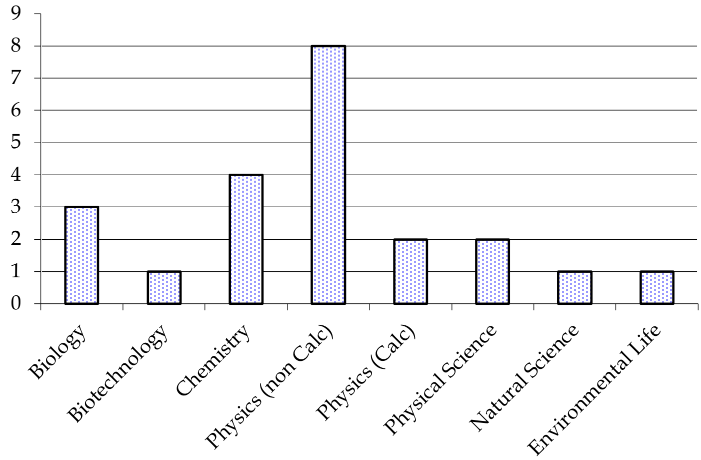


The most common approach to defining science requirements is to allow students to select two science courses from a list of courses. Beyond that, science requirements are no more consistent than mathematics requirements. The following list provides a sample of the types of descriptions given to describe the science requirements:

- Any 2 science course from a list
- 2 science course from a list, one from three categories
- 2 semester sequence in Biology—plus an additional science course
- 2 semester sequence in Biology, and Physics or Geology or Chemistry
- One Life Science and One Physical science
- Physical Science and Physics
- Chemistry and Physics
- Biology and Physics
- One Biology, One Physics, One Chemistry
- Physics plus one other science
- 1 lab Biology or Physics plus 2 other science courses
- Physics plus two other science courses

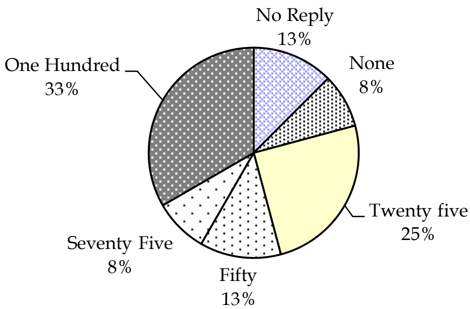
Physics was the most common science requirement identified by the technology teacher education programs participating in the survey (Figure 9). Chemistry and biology were the next most often required science courses.

Figure 9: Required Science Courses



Representatives of the technology teacher education programs were asked to identify the percent of their students who completed a range of different science courses. When asked about non-calculus based physics, one third of the programs reported that 100% of their students completed physics (Figure 10). Approximately 54% of the programs indicated that half or more of their students completed physics.

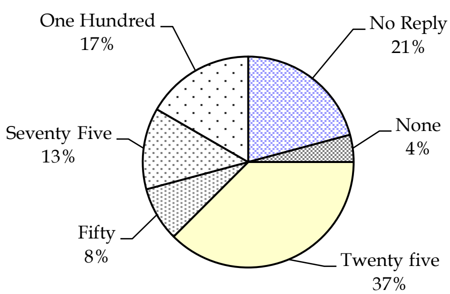
Figure 10: Percent of Students that Completed Algebra-based Physics



Calculus-based physic was a requirement in 2 programs. Only 4 (16.7%) of the programs reported that half or more of their students completed calculus-based physics. Roughly 41% of the programs reported that some of their students completed calculus-based physics.

Chemistry was another course identified as a requirement (Figure 11). Four programs (17%) reported 100% of their students took chemistry. Nine programs (37.5%) reported that 50% or more of their students completed chemistry.

Figure 11: Percentage of Students Completing Chemistry



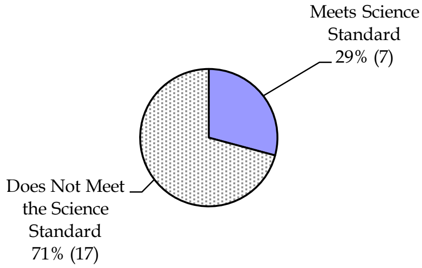
Biology was the second most popular science requirement with 5 programs (21%) reporting that 100% of their students completed it (Figure 12). But unlike physics, the numbers drop off dramatically after that. Only 21% of the programs report that 50% or more of their students complete biology.

The following science courses were also identified as requirements by at least one program: Biotechnology, Geology, Environmental Life Science, and Physical Science. The following were not listed as requirements but were listed as options: Astronomy, Earth Science, Nutrition, Weather and Climate.

Most technology teacher education programs (70.8%) require from 6 or 8 credits of science and almost 60% of the programs require two labs. The most commonly required science class is non-calculus based physics (33%). The next most popular requirements are biology and chemistry. But they are required in less than 25% of the programs. While physics is the most common class, most programs allow students to pick one or more of their science classes from a list of pre-approved courses. Therefore one must conclude, just as with mathematics, that there is no one consistent model across technology teacher education for providing students with the science competencies they need to teach. The only thing that is consistent is flexibility.

Project Lead the Way requires a lab based physics plus one additional lab-based science course. Only seven (29%) of the technology teacher education programs participating in this study would meet this standard. (Figure: 13)

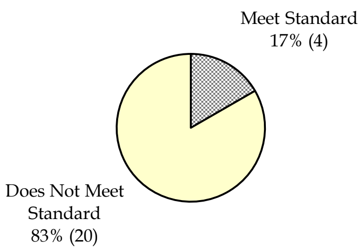
Figure 13: Programs Meeting PLTW Science Requirements



Findings

Do technology teacher education programs Meet Project Lead the Way Math/Science Standards? Do technology education teachers graduating from programs in the United States receive the requisite mathematics and science knowledge to effectively teach engineering content? No, not if one uses the criteria established by Project Lead the Way as the metric. Only four programs (16.6%) in this study currently meet both the science and the mathematics requirements outlined by Project Lead the Way (Figure 14).

Figure 14: Programs Meeting PLTW Math and Science Requirements



Pre-Engineering Option/Emphasis. Only one program indicated an area of emphasis designed to prepare teachers specifically to deliver engineering/pre-engineering concepts. But no teacher has graduated with that option and there are no additional math and science requirements. A second program indicated plans to add an engineering/pre-engineering education option in the near future.

Are Current Teachers Prepared?

Population and Procedures

Professionals attending the 51st annual Stout Technology Education Conference served as the population for the second study. The Stout Technology Education conference typically draws classroom teachers and professionals from North Central Wisconsin and the Minneapolis/St. Paul region of Minnesota. Attendees are typically alumni of the University of Wisconsin – Stout. Professionals attending the conference received a survey instrument with their registration materials. Participants were instructed to complete the instrument and return it to a file box located on a table in the registration area.

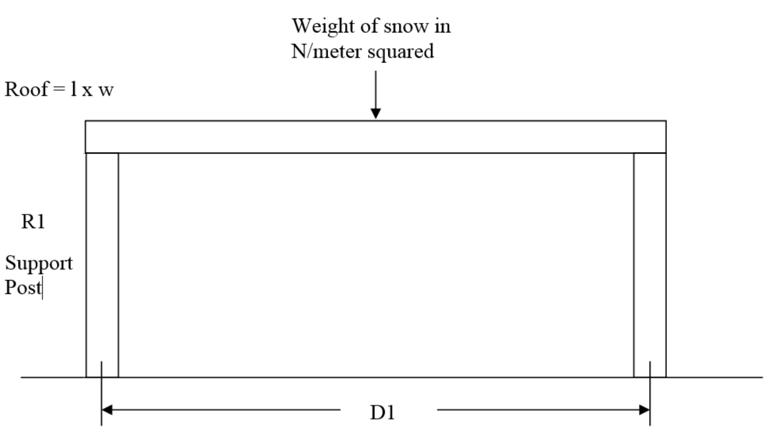
Instrument

The first five questions on the survey instrument solicited demographic information. In the next section each respondent was given an illustration of a problem and asked to read the background information provided. Then they were asked to answer two questions. The first question was designed to solicit an idea of how much training they believed that they would need to be adequately prepared to deliver similar types of content in a classroom. The second question was used to determine whether the participants could select the correct equation to solve the problem. The problems that were selected related to the forces acting on a structure.

A Rationale for Structures: An Underlying Assumption. It seems reasonable that if technology educators were to consider implementing engineering principles in schools, they might be inclined to start by modifying an activity that they already use. There are indicators that suggest the study of structures is relatively common in technology education programs. Many venders that sell modular equipment have units on structures. Venders that supply materials for technology education programs sell devices to test structures. Problem solving activities have been developed that ask students to design bridges and towers. The Technology Student Association has guidelines for Structural Engineering in their competitive events guide. Therefore two problems were developed that focus on forces applied to structures. The first was the following point load problem that requires a basic understanding of algebra (Figure 15).

Figure 15: Point Load Structure Problem

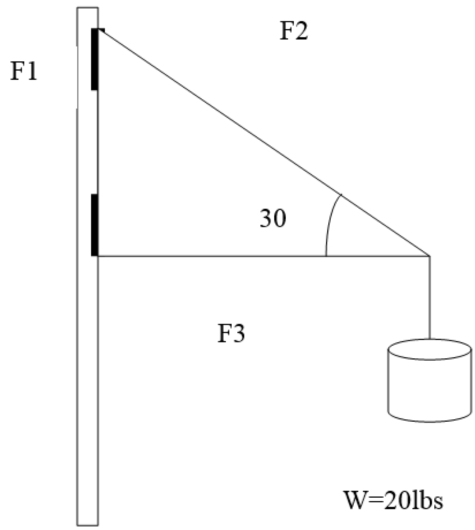
Background: Calculate Rx (the load on a support post) generated by an evenly distributed layer of snow given the weight of snow in N/meter squared, the dimensions of a flat roof and D1 (the distance of the support post from another support structure).



The second problem was a vector problem that required a basic understanding of trigonometry (Figure 16).

Figure 15: Vector Problem

Background: Given the following diagram, identify which members of the following structure (F1, F2, F3) are under compression and which are under tension. Calculate compression and tension forces on this structure. (Solve for forces F1, F2 & F3 given the suspended weight of 20 lb. and the 30-degree angle.)



The first problem was a logical place to start if one wanted to determine the load on a support. When trusses are added to a structure, it becomes important to be able to calculate directional forces. Selection of these two problems was further validated by the fact that similar problems can be found in design texts such as Hutchinson and Karsnitz's (1994) *Design and Problem Solving in Technology* and in physics texts such as *Physics* by Giancoli (1980).

Once they finished reading the problems, they were asked to complete the following statement: In order for the teacher to possess the level of understanding to successfully introduce this type of problem in a class, the teacher would require:

A. NO additional education or training
B. Time to brush up on my skills on my own.
C. Minimal outside help such as a single workshop or in-service
D. More extensive help such as a course or a series of workshops.
E. I do not believe this problem is within the scope of my abilities.

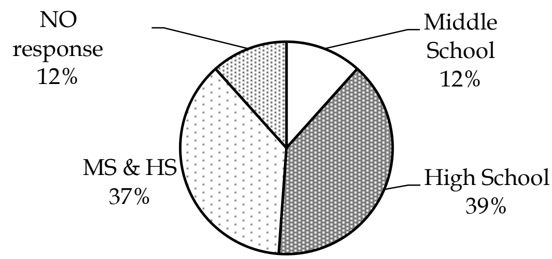
After reading the problems, participants were given specific information in the form of values and asked to select the equation that they would use to solve the problem from a list of five possible equations.

Findings

Of the 185 professionals attending the conference, 43 completed and returned a useable survey instrument for a response rate of 23.2%. No follow-up was conducted. Of the 43 respondents, 41 were fully licensed technology education teachers while one was a pre-service student and one was teaching technology education under an emergency license.

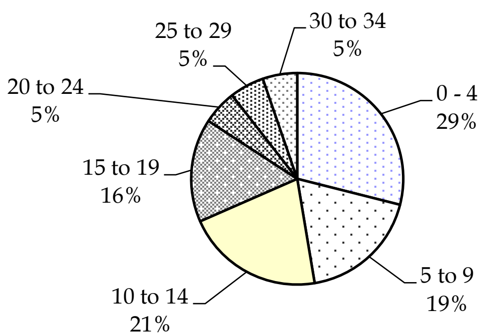
Most of the professionals choosing to participate in the study, 17 (39%), taught exclusively at the high school level (Figure 17). Sixteen (36%) taught at both the middle school and high school level, six taught at the middle school level only, and five did not indicate the level at which they taught.

Figure 17: Grade Level of Teaching Assignment



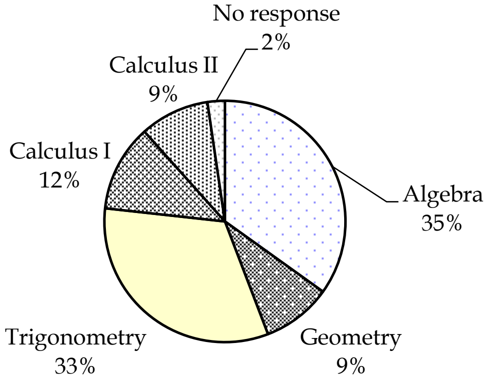
Almost 50% of the respondents (18) indicated they have been teaching less than 10 years (Figure 18). Only 15% (6) of the respondents indicated that they have been teaching over 20 years.

Figure 18: Years Teaching



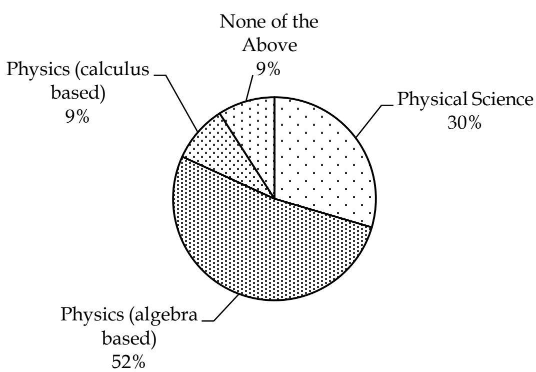
The next section of the instrument asked participants to indicate the highest-level mathematics and science courses they had completed. The largest percentage of participants indicated that algebra was the highest level of mathematics course they completed (Figure 19). The next largest category was trigonometry. Twenty one percent of the respondents indicated that they had completed a calculus course.

Figure 19: Highest Level of University Mathematics



Just over 50% of the respondents indicated that the highest-level science class that they had taken was an algebra-based physics course (Figure 20). Only 9% (4) of the respondents indicated that they had taken a calculus-based physics course. Physical science was selected as the highest-level science course

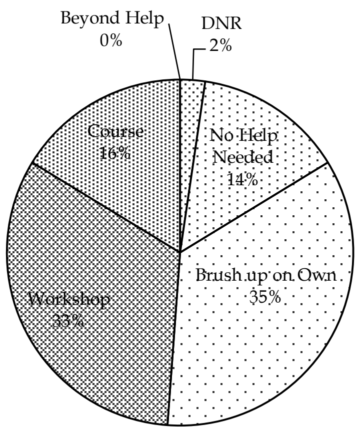
Figure 20: Highest Level of University Science



by 30% (13) of the respondents. Four indicated that they had not taken any of the science courses listed.

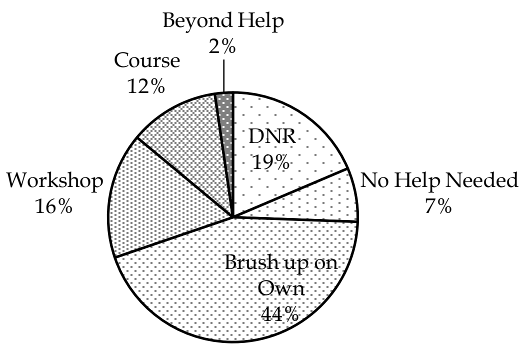
A small percentage (14%, 6) of the participants in the survey indicated that they thought they could implement the point load problem without any remediation (Figure 21). The majority of participants (35%) indicated that they thought they could implement this type of problem if they were given time to brush up on the content on their own. But almost half (49%) indicated that they would require either a workshop (33%) or more substantial training such as a course (16%). No one indicated that they thought this type of problem was beyond his or her abilities.

Figure 21: Point Load Help?



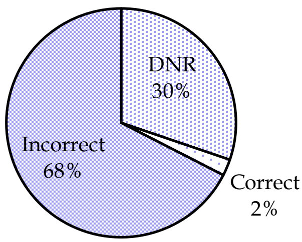
The vector problem requiring knowledge of trigonometry was actually more intimidating without training. Only 7% of the participants believed that they could implement the problem without any further remediation (Figure 22). But more thought it would be easier to get up to speed on this problem than the previous one. A larger portion (44%) thought they could implement the problem successfully if given a little time to brush up on their skills. A workshop was indicated as required by 16%, and 12% indicated they thought they would need a course or series of workshops. One participant indicated that this problem was beyond their abilities.

Figure 22: Vector Help?



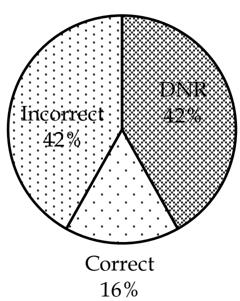
The Answers. Only 1 person (2%) was able to select the equation that would result in a correct answer (Figure 23). Sixty eight percent selected the wrong option while 30 % didn't even attempt it.

Figure 23: Answer to Point Load



Participants performed better on the second problem when seven (16%) were able to select the equation that would result in the correct solution (Figure 24). Forty two percent indicated an incorrect equation while fewer (42%) of the participants attempted to answer this item than did the first problem.

Figure 24: Vector Answer



Summary

Participants in this survey were typically certified technology education teachers that teach either full time at the high school level or split their time between the middle and high school levels. Only 12% taught at the middle school only. And while the results of this study cannot be generalized to the nation, it does represent a population of teachers in Wisconsin that would be likely candidates to implement engineering concepts into their curriculum.

Only one third of the participants indicated that they have had trigonometry. Only 21% indicated that they have had Calculus. Just under 40% indicated they have never had a physics course while 52% completed algebra-based physics.

Roughly half of the respondents believed that they need no further training or could successfully implement the types of problems in the survey if given time to brush up on their skills. The other half believe they would require at least a workshop or possibly a course in order to be prepared.

Regardless of their educational preparation, only a very small percentage of the participants could select the correct equation that would result in the correct solution to the problems. It is interesting to note that the participant that correctly identified the equation for the point load problem had completed two levels of calculus. And while 33 and 44% of the participants indicated they thought they could be successful on the respective problems if they had time to brush up on their own, it is unknown whether they would follow through or if such remediation would result in success. It would also be interesting to know how many of the participants would be willing to participate in a workshop or course. Further studies need to be done to determine the desire of technology education instructors to implement pre-engineering/engineering concepts in their curriculum and to what degree they would be willing to further their education if deemed necessary.

References

Giancoli, D. C. (1991). *Physics*. Prentice Hall, Englewood Clifffs, New Jersey.

Hutchinson, J and Karsnitz, J. (1994). *Design and problem solving*. Delmare, Albany, New York.

Technology Student Association (2003). *High school technology activities: The official TSA competitive events guide 2003-2004*. Reston, VA: Goodheart-Wilcox.

The Diversity Imperative: Attending to Gender Differences in Technology and Pre-engineering Education

Presented at the 91st Mississippi Valley Technology Teacher Education Conference, 2004, Chicago, IL

Chapter 4

Kenneth Welty
University of Wisconsin-Stout

Attending to Gender Differences in Technology and Pre-engineering Education

The study of technology in public education has undergone many changes since the inception of manual training. The laboratory facilities, courses of study, and teaching methods associated with exemplary practice today have very little in common with those used a hundred years ago. However, despite the dramatic changes throughout the history of technology education, one thing still remains a constant. Without the benefit of compulsory technology education course requirements, an overwhelming majority of the students participating in technology education are males (National Center for Education Statistics, 1991; Silverman & Pritchard, 1993). Ironically, the profession espouses to be an integral part of the general education of all students, yet it seems to specialize in preparing young men for life in a technologically sophisticated society (Brusic, 1990).

The following narrative will argue that women, as a population, bring a unique perspective to the study of technology that is woefully under-represented in the current curriculum. It will also provide some evidence that men and women may think about technology differently. Lastly, this paper will also describe some steps that can be taken to make the study of technology more gender inclusive.

It is important to note that gender equity, in any context, is an extremely complex issue that has many facets. Consequently, there is no single reform that will quickly transform the study of technology so it is more attractive and attentive to the needs and interests of girls and young women. Both the examination and reformation of technology education must be comprehensive and systemic due to the diverse factors that have shaped the current state-of-affairs over time.

Technology as a Male Endeavor

Historically, technology education was initially designed specifically to prepare young men for the roles that they would need to play in society as educated gentlemen. For the most part, the study of technology in our public schools has been a construct of the male psyche and experience. Technology education, as we know it today, gained momentum as a school subject in the United States around the turn of the nineteenth century. At that time, it was called manual training and it was designed specifically to prepare boys for adult life in an industrial age (Woodward, 1890). For much of its history, technology education was a subject that was taught exclusively by men for male students. The doors to the technology education classroom and laboratory have only been open to girls and young women for approximately 40 years.

Despite efforts to make the study of technology an integral part of all students' general education, it is still perceived to be a male subject (Gloeckner & Knowlton, 1996). In 1992, it was discovered that only 12.1% of female students were enrolled in technology education classes. That is a decline of over half the number of female students that participated in such courses over 20 years ago (Staff, 1994). In 1998-99, only 17% of the students enrolled in technology education in Wisconsin's secondary schools were female. Furthermore, their enrollment was concentrated in printing, drafting, and design classes.

One of the philosophical premises underlying technology education is the belief that technology is a human endeavor that is performed by both males and females. Furthermore, at least in principle, the content of the technology education curriculum should be derived from the ways in which both men and women utilize knowledge and resources to fulfill wants and needs and to extend human potential. Despite the intrinsic appeal of these fundamental ideas, there is compelling evidence that suggests men and women are not equal players in the enterprise we call technology.

In reality, men clearly dominated many technological endeavors. For example, at the professional level, only 11.6% of the architects and 10.8% of the engineers are women (U.S. Department of Labor, 2004). Similar demographics are apparent for many of the occupations commonly associated with technology (e.g., technicians, skilled trades, semi-skilled trades). The predominance of men at all levels of technological activity has created the common perception that technology is a male endeavor.

Despite the fact that women receive a majority (78%) of the education degrees, 97% of technology teachers are men (National Center for Education Statistics, 1991). With the exception of the important contributions made by a relatively modest number of leaders who happen to be women, the technology education curriculum has been defined by men. Due to the lack of female participation in the discipline since its inception and the predominance of men engaged in technological endeavors in the private sector, the technology education curriculum may be disproportionately attentive to male perspectives on technology. Although the use of gender neutral language, gender balanced media, and female role models has reduced gender bias in some technology education programs, the ways in which we ask young people to think about technology has remained essentially the same.

Eliminating gender bias in a male dominated subject requires a systemic reconceptualization of the curriculum based on the assumption that women account for half of the history and intellectual potential of humankind (McIntosh, 1984; Rosser, 1990; Rothschild, 1988). Therefore, eliminating gender bias from the technology curriculum will also require the integration of topics, examples, and pedagogical strategies that are consistent with the experiences, interests, concerns, and ways of knowing of girls and young women.

Under Valued Perspectives

From both a historical and anthropological perspective, the division of labor between men and women has often put men in the position of tool-makers and product producers while women have typically played the role of tool users and providers of basic human needs (e.g., food, clothing, home). For example, across time and cultures, men have traditionally used the tools of agriculture to work large sections of land to produce cash crops while women have used simpler tools on modest plots of ground to grow vegetables for family use (Pacey, 1983). The cash crops produced by men are typically transported to large and centralized facilities where they are processed and ultimately transformed into products for primarily economic gain. The fruits of their labor can be measured in bushels of grain and profits made. In contrast, the produce from the family garden is carried to the family kitchen where it is cleaned, canned, or prepared for family consumption and nutritional benefit. The results of their work can be measured in the quality of the meals and the health of the family. As technology developed it took the work traditionally performed by men and moved it further away from home (e.g., factories, construction projects, larger plots of land). However, women have been engaged in domestic work in the home up until the latter half of the 20th century when they, too, began joining the workforce.

The social gender roles played by both men and women over time have shaped how men and women perceive and subsequently think about technology. These differences have helped build different philosophical schools of thought. According to Frey (1987), Johnson (1988), Kline (1985), and Mitcham (1980), philosophical perspectives on technology typically emphasize one or more of the following themes: (a) technology as object; (b) technology as process; (c) technology as knowledge; and (d) technology as volition, or human will. It is in the area of technological volition that the gender differences begin to emerge.

Table 1. *Dimensions of Technological Volition*

	Virtuous Conquest	Economic Gain	Human Needs
Examples	NASA landing on the moon	Factory automation	Prenatal care for rural and urban poor
Pursuit	Status	Wealth	Wellbeing
Focus	To master the environment	To produce goods or provide services	To fulfill responsibilities
Measures of Success	A new capability or improvement in performance	An increase in gross national product and global competitive-ness	A decrease in birth defects, premature births, and infant mortality
Role of Risk	Risk is part of the challenge	Risk is weighed against potential gains	Risk is to be avoided or reduced

Popular definitions of technology often focus on exercising control over one's environment or nature. Such definitions are often used in the contexts of virtuous conquest and economic gain. One school of thought suggests that this is a male perspective on technology. Some authors suggest a more feminine perspective on technology emphasizes being in harmony with nature (Pacey, 1983; Rothschild, 1981). In practical terms, one perspective would appreciate increasing gross national product through factory automation while the other would identify with decreasing infant mortality through innovations in medicine, hygiene, nutrition, and prenatal care. Thus, it can be argued that a feminine perspective on technology focuses on managing the human condition, whereas a masculine perspective emphasizes extending human capability to meet challenges and generate wealth.

Looking at Differences

The following discussion will make frequent references to males and females, to boys and girls, and to young men and women. It is important to note that these references refer to populations in contrast to individuals. The author recognizes the fact that all students are unique individuals regardless of their membership in a group based on their gender. Furthermore, the author supports the theory that there is greater diversity within these two populations than there is between them. However, it is extremely difficult for teachers to account for all the unique characteristics of their students. To address the diverse needs of students, conscientious teachers often must think in terms of addressing the needs of different populations within a class. The author assembled these suggestions to help teachers address the diversity within their classrooms, based on gender. However, the ideas being presented should not overshadow the need to be attentive to individual differences regardless of gender.

A modest body of research suggests men and women do not think about technology the same way (Bank Street College, 1991).

Women tended to value and perceive technology as a means of facilitating collaboration, communication, and linkages between people. Men, on the other hand, tended to see technology as a means of extending their control over their physical environment. Men also tended to identify strongly with the technical details associated with a given technology, while the females were more attentive to its practical applications. Lastly, men often relate to technology through tinkering, while women connect with technology in the context of solving a problem from everyday life. These findings are consistent with the notion that a masculine perspective on technology values conquest and economic gain. Furthermore, they are also consistent with the idea that a feminine perspective on technology is attentive to addressing needs that are rooted in the human condition.

When asked to define technology, males tended to associate technology with the future and they described technology in the context of work more than the females (Welty, 1996). They also were more likely to equate technology with ideas than their female counterparts. In contrast, females tended to associate technology with computers and electronics more often than the males. Furthermore, they tended to equate technology with science more than males did. They also associated technology with advancements more than the male students. Lastly, both male and female students endorsed the idea that technology makes life easier.

There is also some evidence that suggests men and women have different interests when it comes to studying technology. Four hundred and twenty five new freshmen at the University of Wisconsin-Stout were asked to describe an impressive technology on index cards. The female students depicted examples of medical and communication technologies far more than their male counterparts. In contrast, the males tended to list examples of information, transportation, or military technologies more often than their female peers (Welty, 1996). It is interesting to note that these preferences run parallel with both masculine and feminine perspectives on technology.

Table 2. *Impressive Technologies by Categories*

Categories	Females	Males
Communication Technologies	82	38
Medical Technologies	58	26
Information Technologies	38	60
Entertainment Technologies	34	32
Transportation Technologies	13	26
Automation Technologies	6	12
Military Technologies	3	13
Space Exploration Technologies	3	4
Sports Technologies	0	4

In many ways, the examples of technology cited were as diverse as the 425 individuals sharing their preferences. However, there were reoccurring examples that were more frequent among respondents of one gender versus the other (see Table 3). For example, 12 female students specifically cited e-mail in comparison to eight males. Inversely, 19 males cited the Internet in comparison to only five females. What makes this modest finding thought provoking is the fact that these examples are essentially the same technology. The fact that more young women chose to describe their affection for telecommunications in the context of e-mail is consistent with an inclination toward viewing technology as a means of solving practical problems and connecting people together. In contrast, the males chose to describe telecommunications in the context of the Internet, which is an extension of themselves, it supports tinkering (a.k.a., surfing), and it is a source of information that can contribute to one's sense of power.

Table 3. *Impressive Technologies by Salient Topic*

Categories	Females	Males
Video Telephones	22	2
Virtual Reality	15	21
Fax Machines	12	4
Personal Computers	12	16
Electronic Mail	12	8
In Vitro Fertilization	8	1
Laser Surgery	6	7
Compact Disks	6	1
Fiber Optics	5	5
Internet	5	19
Automobiles	5	15
Factory Automation	3	8

Gender Inclusive Pedagogy

The subjects taught in school are often perceived as being either masculine or feminine. The gender schema attached to school subjects tends to be consistent with the gender stereotypes held by society at large (Whitehead, 1996). Subjects that address topics and skills that are thought to be masculine are perceived to be appropriate for male students. Inversely, school subjects that focus on topics and skills that are considered to be feminine are regarded to be appropriate for female students. For instance, the humanities and social sciences are often perceived to be especially appropriate for females because they focus on beauty, people, relationships, and society. In contrast, technology is thought to be especially appropriate for males because of its focus on tools, machines, industry, and doing work. Therefore, it is only logical that boys would enroll in technology classes to help them develop their gender identity. Inversely, it is not surprising that very few girls take technology classes while they are trying to define their gender identity.

According to Whitehead (1996), adolescence is "…a crucial period in the development of identity because individuals are transforming childhood identity into an adult one" (p. 149). During this stage of development, young people are testing and revising their concept of who they are and what roles they will play in society (AAUW, 1995). Adolescents devote a lot of attention to comparing who they think they are in their own eyes with who they think they are in the eyes of others. This is especially true for girls and young women. According to Gilligan (1982), females come to know themselves through their relationships and interactions with others. She also pointed out females evaluate themselves in terms of their ability to care about others. Furthermore, adolescent females tend to remove themselves from situations that can have consequences on their relationships with people contributing to their search for identity. More specifically, young women will choose to maintain a relationship at the expense of success if their success would be at the expense of the relationship. Thus, young women tend to gravitate toward situations that value cooperation in contrast to competition.

Laboratory Settings

Students, especially girls and young women, come to the technology education classroom with preconceived ideas about what the class and teacher will be like (Hill, 1993). Most of these perceptions are consistent with the biases and stereotypes that have been attached to shop classes over the years. The subtle look and feel of the classroom and laboratory, along with verbal and nonverbal forms of communication, can make girls and young women feel like they do not belong in a technology class. The physical environment found in technology education classrooms and laboratories is another element that can either welcome or turn off girls and young women. Females tend to avoid technology education classrooms because they find them to be dirty, cluttered, rough, and stressful environments. The misconception that physical strength is needed to operate equipment is often a barrier that needs to be overcome.

The fact that some technology classrooms and laboratories have become more contemporary environments is helping to offset the stereotype that surfaces in the minds of many girls and young women. While definitive studies have not been conducted, there is an abundance of teacher testimony that suggests female enrollment goes up when modular laboratories featuring contemporary workstations and table-top hardware are installed.

It is important to note that the physical space is only one consideration among many when addressing the teaching and learning climate. Despite the aesthetic appeal of the laboratory, teacher-student interactions and student-student interactions can create a chilly climate for females (Sandler & Hoffman, 1992). Teachers must carefully manage their interactions with students, as well as the interactions between students, to create a positive climate for all students. Gender specific language, sexist jokes, dominating male behavior, and competition at the expense of collaboration can all overshadow any gains made with a contemporary facility.

Looking at Engineering

Engineering is often equated with things like innovation, design, and production. All of these themes are consistent with a masculine perspective of technology. However, people use the products of engineering in everyday life and the interface between people and these products is a vital consideration in the pursuit of market share under global competition. For example, in an effort to gain a competitive edge, automobile manufacturers are deliberately tapping feminine perspectives on technology by hiring female engineers to design the controls, instruments, and ergonomics in automobile interiors. Unfortunately, most of the attention in schools of engineering is on the technical aspects of developing new technologies and little attention is given to the aesthetics associated with engineering design, understanding the social and cultural constraints associated with engineering design, or the ultimate management of technology.

The challenges facing schools of engineering are similar to those plaguing the study of technology at the secondary level. Only 1.7% of female high school seniors expressed an interest in pursuing a career in engineering, in comparison to 8.6% of their male counterparts (NSF, 1993). Less than 20% of the students entering engineering programs as freshman are women (Wulf, 1998). Once enrolled in an engineering program, women are more likely to drop out of the program than men (Owen, 1993). The women who dropped out of Michigan State University's engineering programs in 1990 reported that they withdrew from their program because they were not taken seriously in class, the labs were dominated by men, and there were few, if any, role models or supportive peer networks.

For women to join the ranks of engineers, there must be pathways to engineering careers that start when students' career aspirations and decisions begin to take shape. Young children make important gender role decisions based on the roles that they see men and women playing in society. Once girls and boys reach puberty, they usually resist thinking outside the gender roles that they have constructed for themselves based on subtle messages from parents, teachers, peers, and the media. Therefore, it is imperative that young women have access to the study of technology that is attentive to the needs, interests, and experiences of women during these formative years.

Cutcliffe (1981) argued technology is a "social process in which abstract economic, cultural, and social values shape, develop, and implement specific artifacts and techniques that emerge from the distinct technical problem-solving activity called engineering which is embedded in that process" (p. 36). Thus, the study of technology can serve as a funnel for engineering programs. It has the potential to provide a broad treatment of technology and its many manifestations that encompasses the unique perspectives that women bring to the study of technology.

Closing Thoughts

The popular portrayal of technology as being born out of the minds and hands of men paints a skewed picture of history and it perpetuates the unfortunate stereotype that technology is a male endeavor. The inclination to view technology as a male domain intrinsically alienates at least fifty percent of the population from an important school subject that can help prepare young men and women for work and citizenship in an increasingly technological society.

Once again, the study of technology in public education has undergone many changes since the inception of manual training. The laboratory facilities, courses of study, and teaching methods associated with exemplary practice have evolved over time with attempts to keep pace with the advancement of technology. However, despite these improvements, an overwhelming majority of the students participating in technology education are still males while the profession espouses to be dedicated to the technological literacy of all students under the auspices of general education. In practice, curriculum and instruction is often unduly attentive to male points of view in its efforts to prepare a predominantly male population for adult life in a technologically sophisticated society. This subliminal gender bias tempers the profession's representation of technology as a human endeavor that is practiced by all and misses opportunities to honor women's contributions and ways of knowing and doing.

To serve the technological literacy needs of young women, the discipline needs to integrate the perspectives, contributions, and learning styles of women into the study of technology. An increase in the voluntary participation of girls and young women at the middle school and high school levels will enrich and help balance technology education classes. The participation of girls and young women in our classrooms and laboratories will reap many benefits, not the least of which will be to inspire future technology education teachers.

References

American Association of University Women (1995). How schools shortchange girls. New York: Marlowe.

Bank Street College of Education (1991). Women and technology: A new basis for understanding. News from the Center for Children and Technology and the Center for Technology in Education. 1(2).

Brusic, S. (1990, April). And another thing the profession must attend to... The roles of Blacks, Hispanics, and Women in Technology Education. Paper presented at the meeting of Epsilon Pi Tau at the International Technology Education Association, Indianapolis, IN.

Cutcliffe, S. H. (1981). Technological literacy for the nontechnologist. In L. Smalley (Ed.), Proceedings of the Technology Education Symposium II (pp. 36-37). Menomonie, WI: University of Wisconsin-Stout. (ERIC Document Reproduction Service No. ED 206 915).

Frey, R. E. (1987, November). Is there a philosophy of technology? Paper presented at the meeting of the Mississippi Valley Industrial Teacher Education Conference, Chicago, IL.

Gloekner, G. W. & Knowlton, L. K. (1996). Females in technology education: The obligation of a democratic society. The Technology Teacher, 55, 47-49.

Hill, K. (1993). Controlling class fright: lessons from the theatre. Teaching Forum: The Undergraduate Teaching Improvement Council - UW System. 14 (2), 4-5.

Johnson, D. S. (1988). A philosophical base for developing technology education programs. Illinois Industrial Educator, 9 (3), p. 2-5.

Kline, S. J. (1985). What is technology? Bulletin of Science, Technology and Society, 5, 215-218.

McIntosh, P. (1984). The study of women: Processes of personal and curricular revision. The Forum for Liberal Education, 6(5), 2-4.

Mitcham, C. (1980). Philosophy of technology. In P. T. Durbin (Ed.), A guide to the culture of science, technology, and medicine (pp. 282-363). New York: Free Press.

National Center for Educational Statistics (1991). Digest of educational statistics 1990. Washington, DC: Department of Education.

National Science Foundation (1993). Indicators of science and mathematics education. Washington, DC: Author.

Owen, J.V. (1993, March). Women in manufacturing: engendering change. Manufacturing Engineering. pp. 42-49.

Pacey, A. (1983). The culture of technology. Cambridge, MA: MIT.

Rosser, S. V. (1986). Teaching science and health from a feminist perspective. Elmsford, NY: Pergamon.

Rothschild, J. A. (1981). A femisist perspective on technology and the future. Women's Studies International Quarterly. 4, 65-74.

Rothschild, J. (1988). Technology from a feminist perspective. Elmsford, NY: Pergamon.

Sandler, B.R. & Hoffman, E. (1992). Teaching faculty members to be better teachers: a guide to equitable and effective classroom techniques. Association of American Colleges.

Silverman, S., & Pritchard, A.M. (1993). Building their future: girls in technology education in Connecticut. Hartford, CT: Vocational Equity Research, Training, and Evaluation Center (VERTEC).

Staff (1994, March 14). Students move from voc. ed. to general ed. enrollments. Vocational Education Weekly.

U.S. Department of Labor (2004). Women in the labor force: A databook. Washington, DC: Author, Bureau of Labor Statistics.

Welty, K. (1996, March). Identifying women's perspectives on technology. Paper presented at the International Technology Education Association Conference, Phoenix, AZ.

Whitehead, J. M. (1996). Sex stereotypes, gender identity and subject choice at A-level. Educational Research, 38, 147-160.

Woodward, C. (1890). Manual Training in Education. New York: Scribners and Welford.

Wulf, W. A. (1998, Spring). The urgency of engineering education reform. The Bridge, 28(1).

Perceptions of Technology Education among Science, Mathematics, and Engineering Educators

Presented at the 92nd Mississippi Valley Technology Teacher Education Conference, 2005, St. Louis, MO

Chapter 5

Daniel L. Householder
Utah State University (Retired)

Introduction

As technology educators seek to work collaboratively with science, mathematics, and engineering educators, they frequently encounter a lack of support from colleagues in those fields for their efforts to foster and enhance technological literacy. This informal investigation sought to explore perspectives of a limited sample of stakeholders from the science, mathematics, and engineering education communities with the goal of developing a clearer understanding of their viewpoints on the roles and purposes of technology education. A specific effort was made to identify emerging trends in their support for the role of technology education in the development of technological literacy.

What images and messages relating to the technology education resonate most deeply with external audiences?

Technology educators rarely address their written messages to external audiences. Most of the materials in the field are written by technology educators and addressed to technology educators and their students, with little expectation that a more general audience will be interested. While there are exceptions, there is a paucity of information on technology education available to external audiences.

The most recent Gallup Poll to assess public perceptions of technology education (Rose, Gallup, Dugger, & Starkweather, 2004) reported that 68% of respondents thought of computers and 5% thought of electronics when the word “technology” was mentioned; only 1% thought of education. If only one percent of Americans associate technology education with technology, it is obvious that increasing public awareness of technology education is an even more basic problem than judging the comparative appeal of messages to external audiences.

What perspectives do NSF personnel have of the goal of technological literacy for all and of technology education as a school subject?

This section includes informal comments from NSF program officers during private discussions with the author. Program officers who are technology educators were not included in these discussions; also, comments were not sought from Gerhard Salinger, whose long-term advocacy for technology and technological literacy is well known.

Few incoming program officers coming to NSF from mathematics education and science education differentiate clearly between educational technology and technology education. One reported thinking about using technology to teach science and mathematics; but not being sure about the definition of technology education. This individual knew about vocational and technical education, but not about technology education.

It is clear that few program officers have direct experiences with exemplary technology education programs or with the preparation of technology education teachers. After concerted efforts to provide background information on the *Standards for Technological Literacy* and the recent emphasis upon technological literacy for all Americans, most (but not all) program officers develop a working understanding of technology education, particularly engineering and technology education for grades K-12.

One program officer whose background is mathematics and whose home institution prepares technology education teachers in the mid-South indicated that collaboration between mathematics education and technology education there is in its early stages; however other respondents did not point out synergy between the two fields.

Program officers in science education are more likely to recognize the importance of technological literacy as a component of scientific literacy, not as a separate field. If design research is included, they have a higher of opinion of technology; design under constraint is an important component of their work in science education. This is not surprising, since technology has been included in the standards for science education. An experienced program officer with strong credentials in science education noted that "there is growing awareness of technology education among science educators, but there is little about technology education in the literature of science education." Science educators see few effective curriculum examples that they identify as technology. Despite the gap in the literature, this program officer thought that technology education curriculum ideas offer fertile areas for important topics in science, including design experiences with interesting and relevant problems.

Two curriculum efforts that one program officer considered to be more promising than technology education are the Engineering Concepts Curriculum Project and the Science, Technology, and Society movement. However, the likely contributions of these efforts were quickly discounted when they were contrasted with contemporary standards-based science education.

The tendency to view technology primarily as applied science is pervasive. One program officer commented that a most promising possibility would be to develop interesting questions and activities that could lead to generalizations on the scientific concepts that provide the bases for technological activities. This program officer indicated that technology education would be more appealing to science education if it did not "get stuck in the gizmos."

A number of program officers are puzzled by a definition of technology that includes ideas or a knowledge base within the realm of technology. It seems that many such people find the terms "technology" and "knowledge" to be mutually exclusive, even upon reexamination. Notably, one science educator felt that "there is no room in the curriculum for an additional subject, though it might be possible for technology education and science education to collaborate in some areas, such as ecosystems."

How do the mathematics, science, and engineering communities view technology education and the goal of technological literacy?

The relationship between technology and science received support from the report of a Project 2061 panel (Johnson, 1989). The volume on technology was one of five panel reports intended to provide a foundation for the reform of science, mathematics, and technology education. The others dealt with biological and health sciences; mathematics; physical and information sciences and engineering; and social and behavioral sciences. Only two of the consultants who worked with the technology panel were from the technology education profession. Project 2061 published *Science for all Americans* (1990), *Benchmarks for Science Literacy* (1993), and *Atlas of Science Literacy* (2001). Technology assumes visible roles in each of these publications under the science umbrella. George (Pinky) Nelson, physicist and astronaut, Fernando Cajas (2001), and Andrew (Chick) Algren, three science educators at Project 2061, were instrumental in organizing two conferences on research in technology education.

In recent years, an increasing number of engineers and their professional associations have shown an active interest in K-12 technological literacy. The National Academy of Engineering was involved in the review and validation of the *Standards for Technological Literacy* (International Technology Education Association, 2000), played a leadership role in the development of *Technically Speaking* (Pearson & Young, 2002), and is currently completing a project on the assessment of technological literacy.

Engineering colleagues are among the strongest outside proponents of technology education. William Wulff of the National Academy of Engineering (on leave from the University of Virginia); Elsa Garmire of Dartmouth College, Ioannis Miaoulis of the Museum of Science (formerly at Tufts University), M. David Burghardt of Hofstra University, Larry Genalo of Iowa State University, and Gary Benenson at City College of the City University of New York are engineers who have made significant contributions to the reform of K-12 technology education, despite the fact that they are not affiliated with an institution that prepares teachers of technology education. Engineers currently associated with the National Center for Engineering and Technology Education include Christine Hailey, Bruce Bishop and Paul Schreuders, Utah State University; Ronald Terry, Brigham Young University; Mark Tufenkjian, California State University – Los Angeles; Ali Abul-Fadl, North Carolina A&T State University; David Gattie and Sidney Thompson, University of Georgia; Bruce Litchfield and Ty Newell, University of Illinois; Karl Smith, University of Minnesota; and Danny Bee and Richard Rothaupt, University of Wisconsin – Stout.

In truth, it should be noted that many, if not most, of the engineers named above have a different perspective on technology education than that held by more traditional engineering educators. In talking with engineers and engineering educators, it is rare to encounter an advocate of technological literacy for all; it is rarer yet to find individuals who place a high value upon the work of technology educators in the schools. Indeed, the perception of technology education held by many engineers is not far from the "plane-pushing, shaving-making" image of the manual arts era. It is unusual to find an engineer who values technology education for college-bound students, much less as an area of study for future engineers – or for their own children and grandchildren!

In moving forward, engineering and technology education needs to consider political issues, curriculum issues, professional development issues, teacher preparation issues, and implementation issues as reforms require collaboration among science, mathematics, and technology teachers.

How do the mathematics, science, and engineering communities view technology education and the goal of technological literacy?

Perspectives on technological literacy tend to be closely related to the respective levels of educational programs. Technological literacy seems to be a goal that is compatible with the goals of elementary education, but this congruence diminishes as students move through middle school into the high school. The relationships between science, technology, engineering, and mathematics seem to have more appeal with younger learners, even though this emphasis represents a major shift in educational practice. Teams of teachers, curriculum developers, and administrators seem to work together more effectively, especially at the elementary level. As one supervisor noted, working in teams "helped the participants better complete the activities in the training due to varied backgrounds. The teams of people were more cooperative in completing the activities."

One state supervisor of technology education reported that it has been very difficult to have the state technology education group and the educational technology group to recognize technological literacy as the umbrella, with educational technology and technology education as parts under this umbrella even though the State Board of Education adopted standards in that structure. The educational technology people want to have educational technology as the umbrella. The state technology education association maintains that technology education is different than computer and information technology and wants the two fields to be recognized separately.

One respondent said that "there needs to be stronger alignment between technology education lessons and activities in the classroom and academic areas such as math, science, and language arts literacy. There is a need for more school reform to have time for teachers to plan joint activities. Statewide assessments promote silos of discrete information and testing vs. project oriented portfolio assessments."

When asked whether there is evidence that the science education, mathematics education, and technology education communities are working together more effectively, one state science supervisor responded, "I don't see this happening. Elementary teachers don't know much about technological literacy or how to incorporate it into their over-packed school day; middle school teachers seem to rely on the technology education specialist and hence avoid dealing with it."

In response to the question, "How could technology education improve its messages and approaches to be more effective in working with other areas in education?" a state supervisor of technology education suggested that "technology education experts need to develop learning units that incorporate state standards in science and mathematics and infuse the technology aspect. Teachers cannot be expected to develop these learning units on their own with their limited expertise. You need to put teaching materials into their hands that focus on the 'accountable' knowledge that shows up on state tests – reading, math and science – and infuse technological literacy standards within those critical contexts."

Summary

It is difficult to discern the good news and the bad news, but it may be most useful to concentrate on the good news and work on making it better news when we meet again next year. To paraphrase the bad story about the half-full glass of water, it is clearly the case that many of today's professionals in science, mathematics, and engineering are unaware of the potential contributions of technology education in the development of technological literacy – and they may even be unaware of the *Standards for Technological Literacy.* It is also true that the science, mathematics, and engineering communities appear to be more supportive of technology education today than ever before.

While few science educators seem to have an in-depth understanding of technology education, it is important to note that there are notable exceptions. Gerhard Salinger, formerly a research physicist at the Rochester Institute of Technology, has been a major champion of technology education at the National Science Foundation for the last decade. In his role as "self-appointed advocate of technology education," (to paraphrase Thoreau) Salinger has been an ardent advocate for efforts to develop standards for technological literacy, to develop rigorous standards-based instructional materials, and to prepare teachers who could implement exemplary instruction in technology education. He and his NSF colleagues have been instrumental in bringing a series of technology educators to NSF, where they have facilitated the consideration of proposals and monitored technology education projects that transcend a wide range of NAF programs. His recent analyses of the trend toward the inclusion of engineering content and activities in technology education are particularly enlightening (Salinger, 2002; 2003).

One distinguished science educator who has been a strong and consistent supporter of technology education for a number of years is Rodger Bybee of Biological Sciences Curriculum Studies (BSCS). During the American-Australian Education Forum held in Australia in January 2003, he described the uniquely American set of problems associated with the reform of technology education on a national level. Bybee (2003) provided one of the most insightful commentaries on the constraints facing the technology education profession as it attempts to confront the problems of moving the U. S. educational system toward the capability of ensuring the technological literacy of all its citizens. His thoughtful analysis looked at the relevant stages involved in effecting meaningful changes in the purposes of the program, the establishment of policies to put the program in place, the actual development of the program at the local and state levels, and the professional practices required to implement the new program and to prepare teachers to carry it out.

Rogers (2003), in the most recent update of his classic generalized change theory, has pointed out the complexities that must be overcome to accomplish major paradigmatic transformation. Engineering and technology educators would do well to revisit this classic work as they set about the challenging task of educational reform.

Teacher education also deserves attention in the reform agenda. NCATE (CAEP) guidelines for technology teacher education (ITEA/CTTE, 2003) do not appear to require prospective teachers to complete specific university requirements in mathematics, physics, chemistry, or biology. If teachers are to be effectively prepared to provide standards-based instruction in engineering and technology education, states must move promptly to require appropriate preparation for their teachers.

It is imperative for the engineering and technology education profession to expand its vision and develop communications for much broader audiences, including the general public; parents; national, state, and local policy makers; state and national legislators; K-12 curriculum developers in the full range of school subjects; teacher educators; school administrators; teachers in the full range of school subjects; K-12 students; and a complex array of professional associations who view themselves as stakeholders in the K-12 arena.

References

Bybee, R. W. (2003). Achieving technological literacy: Educational perspectives and political actions. Paper given at the American-Australian Technology Education Forum, Gold Coast, Australia. In G. Martin & H. Middleton (Eds.). *Initiatives in technology education: Comparative perspectives*. Technical Foundation of America and the Centre for Technology Education Research, Griffith University, pp. 171-180.

Cajas, F. (2001). *Proceedings of the AAAS technology education research conferenc*e. Retrieved September 7, 2005 from http://www.project2061.org/meetings/technology/default.htm.

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

International Technology Education Association/Council on Technology Teacher Education. (2003). *ITEA/CTTE/NCATE Curriculum Standards: Initial Programs in Technology Teacher Education*. Reston, VA: Author.

Johnson, J. R. (1989). *Technology: Report of the Project 2061 Phase I technology panel*. Washington, DC: American Association for the Advancement of Science.

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

Project 2061, American Association for the Advancement of Science. (2001). *Atlas of science literacy.* Washington, DC: Author.

Project 2061, American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Project 2061, American Association for the Advancement of Science. (1990). *Science for all Americans.* New York: Oxford University Press.

Rogers, E. M. (2003). *Diffusion of innovations.* (5th ed.). New York: Free Press.

Rose, L. C., Gallup, A. M., Dugger, W. E., Jr., & Starkweather, K. N. (2004). The second installment of the ITEA/Gallup Poll and what it reveals as to how Americans think about technology: A report of the second survey conducted by the Gallup Organization for the International Technology Education Association. *The Technology Teacher, 64*(1), (Insert).

Salinger, G. (2002). Foreword. *Journal of Industrial Teacher Education, 39*(3), 6-8.

Salinger, G. (2003). Engineering in the K-12 curriculum. Paper presented at the American-Australian Technology Education Forum, Gold Coast, Australia. In G. Martin and H. Middleton, (Eds.) (2003). *Initiatives in technology education: Comparative perspectives*, pp. 86-96. Nathan, Queensland: Technical Foundation of America and the Centre for Technology Education Research, Griffith University.

The Soul of Technology Education: Being Human in an Overly Rational World

Presented at the 93rd Mississippi Valley Technology Teacher Education Conference, 2006, Nashville, TN

Chapter 6

Scott A. Warner
Millersville University of Pennsylvania

Introduction

Technology is an expression of the human experience, and as such reflects through its many artifacts and systems the spirit and humanistic qualities and values of its designers, makers and users (Norman, 2004). In *Standards for Technological Literacy* (International Technology Education Association, 2000), four of the standards are devoted specifically to technology and society. These four standards (4, 5, 6, and 7) explore the non-technical aspects of technology and the relationships between technology and the social/cultural milieu in which it exists. Unfortunately, even in those four standards the role of humanistic qualities and values such as emotions, intuition, and aesthetics in the development and use of technology is generally overlooked. In the first chapter of *Standards* the definition of technological literacy states:

> Technological literacy is the ability to use, manage, assess, and understand technology. A technologically literate person understands, in increasingly sophisticated ways that evolve over time, what technology is, how it is created, and how it shapes society, and in turn is shaped by society…. A technologically literate person will be comfortable with and

> objective about technology, neither scared of it nor infatuated with it. (pp. 9-10)

If technology does indeed reflect the spirit and humanistic qualities and values of its designers, makers and users, then the ability of a technologically literate person to be objective about technology may be difficult at best. It is important to recognize that historically humanistic qualities and values have played an integral part in both the creation and the use of technology. Furthermore, a review of the history for the profession of technology education illustrates that such qualities and values have also provided both an overt and subtle role in the study of technology.

Once again referring to *Standards*, the study and use of design is clearly a cornerstone toward building technological literacy. Design, in its various forms, is the explicit focus on four of the standards (8, 9, 10, and 11), and an underlying component of the other sixteen standards. In discussing design, *Standards* address the creative act again and again. However, it is done so with a clinical detachment. Arguably, creativity and design are human activities that are heavily laced with emotions and subjectivity (Norman, 2004). This matter-of-fact presentation of creativity and design in *Standards* may be indicative of an attitude toward the study of technology that is significantly different than the approaches taken by progressive educators of the past, or of educators in other countries. This paper will argue that should technology education ignore or reject the value of studying the role of humanistic values related to the creation and use of technology it would do so at its own peril.

Have we abandoned the emotional, the spiritual, the aesthetic, and the intuitive aspects of the human experience in our contemporary technology education curriculum, as we pursue linkages with engineering?

To answer the question of whether technology education curriculum has abandoned the emotional, spiritual, and intuitive aspects of the human experience with technology it is first necessary to determine if those humanistic characteristics and values ever existed in the curriculum. An investigation of the area of educational philosophy is one place to start such a determination. Two recent publications have specifically addressed the philosophical struggles that have fundamentally shaped the nature of American education over the course of the last century. The struggles have been between educational philosophies that represent a humanistic view and those that represent a mechanistic view to the processes of teaching and learning. A recent article written by Gibboney (2006) for the *Kappan* was entitled *Intelligence by Design: Thorndike versus Dewey.* A second document was written by Lewis and Zuga (2005) and was entitled *A Conceptual Framework of Ideas and Issues in Technology Education*. Each of these documents provided a window of understanding as to how contemporary models of both general education and technology education have taken their current form.

In the opening passage of Gibboney's work a quote from Lagemann (1989) summarizes the main point of the article. Lagemann's quote stated: "One cannot understand the history of education in the United States during the twentieth century unless one realizes that Edward L. Thorndike won and John Dewey lost" (p. 170). Most technology educators would have a working familiarity with the educational philosophy of John Dewey. Gibboney described Dewey's humanistic approach to teaching and learning by stating:

> Dewey believed subject matter in schools exists to make the quality of democratic life as good as it can be under given conditions. He asserted that a teacher ought to try to arouse a continuing interest in learning throughout a student's life…. [Dewey] argues that the goal of schools ought to be developing an attitude – the love of learning. And ultimately, schools should be judged on how well they meet this difficult goal. In other words, what is transferred when a student

> learns something that is truly important is intangible and immeasurable by test. It is an attitude, the desire to learn. (p. 170)

Arguably, Thorndike's work is not as well recognized by technology educators. At best, his name may be one that is vaguely remembered from a long past college course on educational psychology. However, his approach to understanding intelligence and the processes of teaching and learning could very well claim to be the foundation of contemporary public education, most notably in recent years with the *No Child Left Behind* legislation and the extensive use of standardized tests to measure what has been achieved. In short, Thorndike's perspective on the proper approach to teaching and learning was very mechanistic in nature. Gibboney summarized Thorndike's beliefs in this area by stating:

> [Thorndike] believed in the possibility of a science of education so powerful that experts alone would be able to decide what to teach, how to teach it, and how to evaluate it…. [He also] believed that such value-laden matters as setting the aims of education could be done efficiently by experts, using the kind of science he was developing. (p. 170)

Gibboney later drew the distinctions between Dewey and Thorndike in very succinct terms by stating "Thorndike saw humans in the image of the machine; Dewey saw them in the image of life" (p. 170).

Several factors may have contributed to Thorndike's mechanistic approach winning this struggle for the compass of American education. Though the ideals of progressive education that were espoused by Dewey were actively embraced by academics, they did not easily fit into the broader American culture that was being driven by the measurable and mechanistic paradigm of the 20th century industrial revolution, the simplified world of politics, and the increasingly prevalent sense of progress that was defined by the rules of science. Gibboney described this effect by stating, "Thorndike and his successors surely won the minds and hearts of their countrymen. Dewey, ignored in the rough and tumble of legislative halls and teachers' meetings, has lived on in a few protected scholarly havens" (p. 171). In the second half of the century other social-cultural forces came into play such as the political climate created by the Cold War. As an example, in the late 1950's and through the 1960's the space race between the United States and the Soviet Union resulted in a major drive in public education to produce engineers and scientists (Lopez & Schultz, 2001). Those efforts compressed the educational efforts of American public schools as well as colleges and universities with science and engineering programs to produce graduates that would enter these respective fields quickly, thus addressing the needs for the market place as perceived by the general public (Flemming, 1960). In both subtle and obvious ways, the curriculum and the philosophies of schools at all levels were changed by these many forces (Herschbach, 1997). In short, the mechanistic view of Thorndike slowly overwhelmed the progressive, humanistic views of educational leaders such as Dewey.

A natural question that would come from this brief overview of American education in general is how did these philosophical struggles manifest in technology education? Even a brief review of literature for manual arts and industrial arts, the immediate predecessors of technology education, reveals that influential writers and thinkers from those fields had a deep investment in the worth of teaching about technologies within the context of humanistic qualities and values. Selected examples of this type of philosophical foundation, beyond John Dewey, have included Calvin Woodward (1887) who stated:

> The word "manual" must, for the present, be the best word to distinguish that peculiar system of liberal education which recognizes the manual as well as the intellectual. I advocate manual training for all children as an element in general education. I care little what tools are used, so long as proper habits (morals) are formed, and provided the windows of the

> mind are kept open toward the world of things and forces, physical as well as spiritual. (p. 202)

Almost 40 years later, with the transition from manual arts to industrial arts fully underway, Frederick Bonser and Lois Mossman (1924) (as cited in Miller and Smalley, 1963) stated that:

> Since the desire for beauty in all that we possess or produce is so fundamental, it is readily seen that the industrial arts and the fine arts are closely and vitally related. Any attempt to separate them completely is artificial. (p. 72)

This passage clearly indicates that Bonser and Mossman understood that there are connections between the study of technology and the humanistic values of beauty and aesthetic pleasure, values so prevalent in the fine arts. In succeeding passages, Bonser and Mossman went on to discuss in detail the values and objectives of industrial arts which included "(1) a health purpose; (2) an economic purpose; (3) an art or aesthetic purpose; (4) a social purpose; and (5) a recreational purpose" (p. 72). Though each of these values and purposes had varying degrees of measurability, a significant component of the mechanistic approach advocated by Thorndike, at their core they were designed to help students become "efficient in the selection, care, and use of the products of industry, and to become intelligent and humane in the regulation and control of industrial production" (p. 72) and were thus primarily humanistic in their goals and objectives.

In the four decades between 1940 and 1980, the humanistic qualities and values espoused by Dewey were still on the front page of the professional discussions in the literature. Wilber (1948), Hornbake (1957), and Maley (1973) were examples of leaders in the field who advocated the study of industries and their processes and products within the scope of general education. Time and time again, they discussed the importance of the values learned by young people who took industrial arts classes. At the top of the list of values that were discussed in the writings of these individuals and their peers was the importance of learning the principles of democracy. Like Dewey, each of these authors felt that the use of industrial arts education in the general education curriculum contributed toward the overall development of a young person's ability to grow and mature into a fully informed and participating member of a democratic society. Bode (1942) (as cited in Miller and Smalley, 1963) perhaps summed it up best when he stated, "The task confronting our teachers of industrial arts is to make their subject-matter a gateway to a philosophy of life in an industrial democracy" (p. 100).

However, these progressive voices were not the only ones being heard throughout the first half of the 20th century. One individual in particular who seems to have had a rather twisting philosophical journey was William E. Warner. Warner left a rather large footprint on the profession through such activities as the founding of the Epsilon Pi Tau honorary society and the American Industrial Arts Association, the mentoring of numerous graduate students over the course of a long career, and the development and presentation to the profession of *A Curriculum to Reflect Technology* (Warner et al., 1953). This curriculum project was released to the profession in 1947 and represented one of the first major efforts to specifically address the study of technology using industrial arts curricula as the means. Interestingly enough, early in his career Warner had college courses at Teachers College, Columbia University with both Dewey and Bonser (Lux, 1981). With such mentors, it would be a natural assumption that Warner would also advocate industrial arts curricula that was humanistic in nature. However, as Lewis and Zuga (2005) noted, "Perhaps, it [was] because of his essentially conservative nature that he was able to promote a view of industrial arts as a technology based field of study and ignore the social prescriptions for the curriculum which were so evident in the work of Bonser and Mossman" (p. 22). Warner's curricular efforts, and the work of his protégés, lead to a broad acceptance of a mechanistic thinking toward the teaching and learning processes developed and used by industrial arts. As an example, Wilbur, one of Warner's protégés, is credited as being the first to define and apply the concepts of behavioral psychology to the field of industrial arts (Thorndike was a behavioral psychologist). Lux (1981) asserted that a "review of standard practice today would document that most industrial arts teachers indeed start their syllabi with lists of behavioral objectives. [Wilbur] heavily impacted upon theory, [and] affected the documentation teachers produce to describe their courses and curricula…" (pp. 215-216). As noted earlier, Wilbur still had humanistic qualities in much of his writings. However, like Warner, he contributed to the steady march away from the humanistic approach advocated by Dewey and Bonser.

Beginning in the 1950's, the tide began to change significantly for industrial arts. Lewis and Zuga (2005) described the reaction of the leaders in industrial arts toward the social-cultural milieu of that time when they stated:

> Given the backdrop of society and culture in the United States during the 1950's and 1960's, it is easy to see how the leaders in industrial arts education began to distance themselves from the work of Dewey and social reconstruction. Dewey had come into question during the McCarthy era and his ideas were not in favor. Tradition in industrial arts leaned towards industry as a result of many years of alliance with vocational education. Even Warner and his followers, who fought to establish an industrial arts organization separate from the American Vocational Association, did not separate themselves from industry and corporate America, nor did Warner and Olson's students who became the next generation of leaders in industrial arts. Maley, DeVore, Lux, and Ray, all had ties to William Warner and his influence by either being his students, being students of Warner's students, or working with him. So, as innovation in industrial arts took hold, many of the ideas of Warner and Olson made their way into the thinking and prescriptions for the field by the leaders who

created their own curriculum plans and collaborated on the Jackson's Mill compromise. (p. 26)

With perhaps the notable exceptions of Maley and DeVore, the shift in industrial arts away from the humanistic approach to education advocated by Dewey would continue unabated. Lewis and Zuga (2005) described Maley as "the most Deweyan of the new generation of leaders" (p. 26). His focus was unquestionably on the student and how the industrial arts curriculum could aid his or her intellectual, social, and cultural development. The program that bore his stamp was *The Maryland Plan*. It set the standards for a generation of student-centered industrial arts programs (Kirkwood, Foster, & Bartow, 1994; Rudisill, n.d.). DeVore could be described as a standard bearer among his generation of professional leaders for the value of the study of technology. As early as the 1960's DeVore was calling for the organization of the content of the study of technology into categories that described the human activities of production, communication, and transportation (Kirkwood, Foster, & Bartow, 1994; Lewis & Zuga, 2005). DeVore's humanistic credentials were found in his writings which "re-introduced into the literature of the field, ideology and sociology with respect to the study of technology" (Lewis & Zuga, 2005, p. 28). Though the influence of these individuals toward the transformation of industrial arts into technology education would be significant, their Deweyan perspectives seemed to diminish with the compromises that were needed to facilitate that transformation.

The Jackson's Mill Industrial Arts Curriculum Theory (Snyder & Hales, 1981) represented a benchmark in the creation of content organizers for the study of technology. These organizers included manufacturing, construction, transportation, and communication. Ultimately, the document represented a compromise between various interpretations of industrial arts curriculum and the study of technology. Lewis and Zuga (2005) identified the three primary factions of compromise being between the interpretations of the group advocating the *Industrial*

Arts Curriculum Project (IACP), Devore, and Maley (represented by his colleagues at the Jackson's Mill gathering). From the humanistic perspective, the *Jackson's Mill* document presented the profession with a conceptual framework that encompassed the adaptive systems of ideology, sociology, and technology, any one of which could be used as the platform for the exploration of technology. However, the real importance of the *Jackson's Mill* document, and later *A Conceptual Framework for Technology Education* (Sterry & Savage, undated), is that these documents started the process of moving industrial arts toward the study of technology as the subject material for the field.

Perhaps the most significant movement to formalize the study of technology was initiated through the release of the document *Technology for All Americans: A Rationale and Structure for the Study of Technology* (International Technology Education Association, 1996) which served as the conceptual precursor of *Standards for Technological Literacy* (International Technology Education Association, 2000). The increasing acceptance of *Standards* as the de facto measure of technology education curricula across the United States (Russell, 2005) indicates a profession that has embraced the mechanistic perspectives to intelligence, learning, and teaching advanced by Thorndike. The perception that the profession even needed a set of standards indicates that the educational culture of the last twenty years has taken a conservative path; a path that is mechanistic in its expectations of accountability by measurements (Herschbach, 1997). The humanistic view of these matters seems, for the most part, to have been relegated to between the covers of history books about progressive education. The mechanistic influences on the development of *Standards* can be seen in the funding agencies, *The National Science Foundation* and the *National Aeronautics and Space Administration* (Lewis, 2004), and the individuals who reviewed the document while it was under development, members of the *National Academy of Engineering* (Pannabecker, 2004).

Though *Standards* represent an important contribution to the intellectual and philosophical underpinnings for the content of technology education, they also represent a significant departure from the humanistic origins of technology education. Therefore, the answer to the first part of the question, *Have we abandoned the emotional, the spiritual, the aesthetic, and the intuitive aspects of the human experience in our contemporary technology education curriculum*, would have to be yes.

The second part of the question deals with the qualifier of, *as we pursue linkages with engineering*. Pannabecker's (2004) interpretation of the results of the influence of engineering toward *Standards* put forth cautions for our profession. His analysis found the mechanistic model of teaching and learning, as controlled by experts and endorsed by Thorndike, separating technology from the humanistic values upon which they should be built. Pannabecker stated:

> How might the influence of engineering relate to the ideological emphasis on the "effects" of technology in *STL* standards 4, 5, and 7? By designing these standards around "effects," the development of technology can be separated conceptually from social values, thus reinforcing the evaluation of technology as "end result." The artifacts can then be controlled and fixed by engineers. It might be government agencies that employ engineers to evaluate the technologies and recommend "fixes," but engineers remain in control of fixing, redesigning, or retrofitting the technology. This approach contrasts with an instructional model that integrates social conscience or responsibility within the design and construction process, and that sanctions the expression of critical reflection (such as "whistle-blowing") for both engineers and the public.
>
> Instead, *STL*'s dominant tone is one of implied neutrality, but with the "engineer in control." Although ethics is mentioned a few times in the *STL* narrative of standards 8-13 (pp. 97, 98, 104, 111), it is clearly not central to the standards

> of design and development. This is subtle politics that isolates the discourse of social responsibility from the design and construction process, focusing social responsibility at the end use, or "effects stage. Historians labor to uncover and understand these kinds of politics, the study of which should be included in teacher preparation and graduate programs in technology education. (p. 76)

If Pannabecker's observations are correct, then technology education should move with caution in developing closer ties with engineering or run the risk of completely severing all ties to its humanistic heritage.

One final caution on this matter comes from the field of engineering itself. Florman's (1994) work entitled *The Existential Pleasures of Engineering* discussed how that profession had lost some of its own humanistic anchors. The author described the difficulties that engineering schools had in keeping promising students in their programs. He also described how the culture of engineering school had evolved a mentality that advocated engineering education be organized as a type of filtering mechanism. Florman observed that:

> Young people are dropping out of engineering school for the same reason they shunned it in the first place: The program is laborious and in many respects disagreeable. The "hands-on" approach is largely gone, increasingly replaced by scientific theory. "Research" is in while "teaching" is out, a casualty of the way engineering education has been funded for several decades….
>
> Once the major problem has been identified, the solution seems stunningly obvious. We should stop looking at engineering school as a boot camp designed to eliminate all but the most dogged recruits. We should stop making the first two years the obstacle course they have become – consisting of calculus, physics, and chemistry. We should bring practical, creative, "fun" engineering into every year, particularly the first, and teach mathematics and the sciences

> as enabling complements to engineering rather than isolated afflictions to be endured. We should help young people perceive how important technology is in the scheme of things. We should advise and nurture the students at every step along the way, paying particular attention to the needs of women and under-represented minorities. Thus will we attract talented young people to engineering, keep them from dropping out, and at the same time improve the quality of our graduates. (p. xv)

This passage reads like a list of all the things that technology education should try to avoid. His suggestions for how the culture of engineering school should reform also sounds like the types of things that a humanist like Dewey would have encouraged. In light of this, perhaps the tables should be turned and the conversation should be about how engineering education would benefit by adopting the humanistic models of the study of technology instead of how technology education would benefit by being more like engineering education.

Where does the non-analytical aspect of learning fit into technology education curriculum?

The following section of this document comes from an article in *The Technology Teacher* (Warner, 2006). The article specifically focused on the emotion of joy, but a broader interpretation of the spirit of the article would allow the reader to substitute the term *non-analytical aspect of learning* for the word *joy*. The intent of the article, as it was originally written, was to start a conversation within the profession about the changing nature of American education. The focus on the emotion of joy was chosen because it was a factor that could be easily identified, and identified with, by the readers. The emotion of joy is only one of the many non-analytical aspects of learning that John Dewey would have readily accepted as an important component of a liberal education; one that contributes to the intellectual, moral, spiritual, social, and cultural growth of a young person in a democratic society.

In the opening decade of the 21st century, technology educators face the daunting challenge of finding a balance between the educational expectations imposed by governmental mandates and the individualized needs of the developing intellect of students. Even today the debates continue within the profession about the proper types of lab facilities, curriculum content and structure, and the nature of the types of learning experiences that are appropriate for technology education. Within such a turbulent environment, it may be difficult, though not impossible, to provide opportunities for joy to be an ingredient that goes into the daily mix of what takes place in one's classroom. Though there are no easy formulas that a teacher can put to use to bring joy into a classroom; a review of the literature provided the following collection of general guidelines that can help make learning a joyful experience.

Just as enthusiasm is contagious, so is joy. The first guideline for promoting joy in a technology education classroom focuses on the teacher. The teacher should feel joy about what he or she does. The attitude of the teacher about the topic, the classroom environment, the students, and technology in general will significantly influence the attitude of the students. Goodlad (1984) discussed the influence of these subliminal messages; he called them the implicit curriculum, which included:

> ...all those teachings that are conveyed by the ways the explicit curriculum is presented–emphasis on acquiring facts or solving problems, stress on individual performance or collaborative activities, the kinds of rules to be followed, the variety of learning styles encouraged, and so on. (p. 197)

Teachers with a joyful approach to teaching will, through example, also encourage joy in their students. (Amabile, 1989; Noddings, 2003)

The classroom environment is the focus of the second guideline. A classroom that functions in an oppressively authoritarian manner is a sure way to kill the spirit of joy in learning. Joy is more likely to take root and prosper in a learning environment that is safe, comfortable, and friendly. Amabile (1989) referred to such an environment as one that encourages intrinsic motivation in students through a setting where "teachers believe that children should be relatively autonomous in the classroom" (p. 129). Amabile later described an ideal classroom environment as being "non-controlling but directed" (p. 131). The author noted that research has found that students in such a classroom condition seemed to do best because "they were interested, they did not feel pressured or tense, and they did well on both rote learning and conceptual learning" (p. 131). In a technology education program, a non-controlling but directed climate would provide the necessary structure for maintaining safety, and yet allow the freedom for individual exploration, creativity, expression, and joyful involvement in learning about the many aspects of technology.

The third guideline deals with the various learning styles of students. According to Armstrong (1994), since ancient times there have been many theories of intelligence. Modern examples have included Jung's psychological types, Guilford's Structures of the Intellect (SOI), and Gardner's Multiple Intelligence Theory (MI). Armstrong defined a person's learning style as "the intelligences put to work" (p. 13). As an example, one learning style model that is commonly used by educators is the 4-MAT System. It divided learning styles into combinations of concrete or abstract perceivers, and active or reflective processors (McCarthy, 1987). Though Reed's (2001) research, using the 4-MAT system, found most technology teachers tended to be common sense learners, it is important that the technology educator always remember to provide opportunities for learning that appeal to as many learning styles as possible (Funderstanding, 2001). The more students the instructor can take along on the joyful learning experience, the more joyful the learning environment becomes for all.

Finally, the fourth guideline addresses the ongoing struggle of finding a balance between what is mandated for all and the intellectual needs of the individual. Teachers who are trying to maintain a joyful learning environment must also have flexibility with curriculum and its delivery. Teaching is as much an art as it is a science. Arguably, the science of teaching can, in part, be represented by the measurable output from testing. These results can provide teachers, administrators, parents, and the general community with quantifiable indications of the learning that has occurred in the schools. However, the recent push for accountability through adherence to standards, and the measurements of that adherence through standardized tests, can also have negative consequences. Brulle (2005) reminded us that the numbers from these tests only have meaning in the context of large groups and that even then the statistical meaning is often misunderstood and misused. Unfortunately, in the current educational environment the needs of the individual student can get lost or forgotten. The art of teaching, the other half of the equation, recognizes that each student has unique developmental patterns and needs for intellectual growth. As Amabile (1989) stated, “Children learn better if the level and pacing of the curriculum fits their strengths and weaknesses” (p. 133). The challenge to the teacher is to find the balance between meeting the mandated expectations and still allowing for individual student interests and passions. Amabile’s research found that “the best approach seems to be one where children are directed toward overall goals, but encouraged to learn in whatever way is best for them. Always, the emphasis should be on learning, and not on testing” (p. 131).

Keeping the joy in learning should be a priority of every school and for every teacher. Technology educators have a long history of providing students with opportunities to experience the joy of learning and the joy of involvement with technology. As American public education moves into the standards-based curriculum of the 21st century, technology educators would be wise to follow the advice of Loris Malaguzzi, the Education Director of the Italian District of Reggio Emilia who said:

> What we like to do [as teachers] is to accompany a child as far as possible into a realm of the creative spirit. But we can do no more. At the end of the path is creativity. We don't know if the children will want to follow the path all the way to the end, but it is important that we have shown them not only the road, but also that we have offered them the instruments–the thoughts, the words, the rapport, the solidarity, the love–that sustain the hope of arriving at a moment of joy. (Goleman, Kaufman & Ray, 1992, p. 83)

So where does the non-analytical aspect of learning fit into technology education curriculum? It should fit everywhere. It should be an integral part of the curriculum. If technology education is for everyone, then it should address the full spectrum of human characteristics in its curricular designs from emotional to logical, intuitive to reasoned, aesthetic to functional and spiritual to physical.

If we are abandoning these aspects, will we be able to attract a diverse student body?

To answer this question properly it becomes necessary to first ask, have we ever attracted a diverse student body to manual arts, industrial arts, or technology education? Though the profession has advocated the inclusion of manual arts, industrial arts and technology education into general education, and has promoted the value of these subject areas for all students, the historical application has not always met up with the ideals. As an example, for most of the 20th century, girls were traditionally excluded from taking manual arts or industrial arts courses. The typical curricula structure had boys taking industrial arts and girls completing courses in home economics. As a result, approximately 50 percent of the students who went through American public schools were excluded from exposure to a study of this subject area, inversely; the other 50 percent were excluded from a valuable study of home economics (Zuga, 1998). However, this type of overt exclusion of a cultural group or a gender has not been a major factor for several decades. Generally speaking, in contemporary public high schools that have technology education programs, students who want to take courses on the study of technology have been able to do so. Therefore, the prerequisite of allowing the door to be open so that we *can* attract students of all types into technology education programs has been met.

A current factor that determines whether a student *must* take a technology education course is the student's grade level. Many states, though not all, require a technology education experience during the middle school years. This requirement effectively provides all students in those states with some degree of technology education experience. However, after middle school, technology education becomes an elective in just about every high school across the country, with the lone exception of the State of Maryland where all students are required to have one credit in technology education at the high school level (Maryland State Department of Education, 2003). Therefore, it becomes necessary to recruit students to take a technology education course. Being an elective course places the burden on the subject area and the local instructor to make the study of technology valuable enough for a student to make room in his or her already overloaded schedule. Several factors influence the perceptions of the value of a technology education course to a typical high school student. These factors include: 1) How he or she perceives the culture of a technology education course, 2) The academic fit of a technology education course toward his or her career goals and interest, 3) Local curricular restrictions such as scheduling conflicts with core courses which inhibit the ease by which a student can take a technology education course, and 4) Other influences such as pressure from peers, parents, teachers, and guidance counselors. At this point in the process, the student has had to have maintained a strong interest in the subject matter; an interest that sustains the individual through the maze of restrictions and social-cultural pressures. For women, minorities, and other non-traditional students to the technology education area those forces can be additional obstacles to overcome.

Once the young person has managed to become a student in a technology education course, he or she will have to deal with another series of issues related to the content and method of instruction used to teach the course. If the instructor is progressive and up to date on his or her understanding of the processes of learning and teaching, then the student will have instruction, regardless of the content, that reflects the wide variety of human characteristics in thinking and learning styles. If, on the other hand, the instructor is mechanistic in his or her approach to teaching technology education, then automatically significant percentages of the class will be forced to adapt to, and focus on, the analytical aspects of the study of technology.

Even in our overly rational world, using such a mechanistic approach to teaching about technology is questionable in its value. Caine and Caine (1991) argued that the role of emotion toward the learning process was essentially ignored by the traditional school organization, teaching methods, and testing practices. They, like the progressive educators from technology education's past, advocated the value of making connections between the material being taught and student interests. Johnson (2006) noted that with the changing landscape of the global marketplace the emphasis ought to be on helping students to develop right brain thinking patterns instead of the analytical, logical patterns that are the primary focus of an engineering education. Johnson noted that, "Successful players in this new economy will increasingly be required to develop and use the right-brain abilities of high concept (seeing the larger picture, synthesizing information) and high touch (being empathetic, creating meaning)" (para. 3). The author then builds on the writings of Daniel Pink in his book *A Whole New Mind: Moving from the Information Age to the Conceptual Age* (2005) to elaborate on how schools can teach students to become successful players in this new economy:

> [Pink suggested] we work toward developing in ourselves (and by implication, in our students), six right brain 'senses' to complement our left-brain, analytic skills. We need to realize the value of:
>
> - not just function, but also *design*.
> - not just argument, but also *story*.
> - not just focus, but also *symphony*.
> - not just logic, but also *empathy*.
> - not just seriousness, but also *play*.
> - not just accumulation, but also *meaning*.
>
> And I would add a final conceptual age skill to Pink's list: not just knowledge, but also *learning*.
>
> In the age of educational accountability, we seem to be designing all of our instructional efforts to help student's master left-brain skills, because that's what the tests measure. To what extent should we also be helping students develop design sense, storytelling abilities, synthesis, feelings for others, humor, and the ability to detect the importance of the information they learn?
>
> Sadly, our society and educational system view many of these opportunities that develop conceptual-age skills as extras – frills that often are the first to be cut in times of tight budgets. It's tragic that by doing so, we are doing a disservice to our students as future workers and citizens. (para. 4, 5 & 7)

The message offered by Johnson to education is especially pertinent to the field of technology education. The list of conceptual age values is laced with terms and concepts that would resonate with a progressive educator such as Dewey. The list could almost be identified as a comparison between engineering education and the ideals of a humanistic approach to technology education. Reflective educators should recognize that issues such as diverse thinking, learning, and teaching styles are important variables in determining the value of a subject matter and a program. The more receptive the instructor and the program are to facilitating these types of issues, the more likely students will find ways around the many other obstacles that the system of public education puts in their way.

If technology education is to become a vital part of the general education curriculum it will need to attract a diverse population of students into its courses. To achieve this goal, it will need to examine the story it wishes to tell. If we chose the storyline written by Edward Thorndike then we will never achieve the level of diversity we desire. An alignment with engineering could result in our profession going in the opposite direction of the goal of having a diversity of students in our courses. If we chose the storyline written by John Dewey we will certainly capture the interests of a diverse population of students into our programs. In the larger conflict for the heart of American education, currently Thorndike may be winning, but in the battle for the soul of technology education we have to ask, do we want to embrace the machine or the human?

References

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

Armstrong, T. (1994). Multiple intelligences in the classroom.

Funderstanding (2001). Learning styles. Retrieved February 9, 2005 from http://www.funderstanding.com/learning-styles.cfm

Gibboney, R. (2006, October). Intelligence by design: Thorndike versus Dewey. Phi Delta Kappan, 88(2), 170-172.

Goleman, D., Kaufman, P. & Ray, M. (1992). The creative spirit. New York: Dutton.

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

Herschbach, D. (1997, Summer-Fall). From industrial arts to technology education: The eclipse of purpose. The Journal of Technology Studies, 24(2), 20-28.

Hornbake, R.L. (1957). Philosophical viewpoints. In C. Gerbracht & G. Wilber (Eds.), A sourcebook of readings in education for use in industrial arts and industrial arts teacher education (pp. 1-52). 6th Yearbook of the American Council on Industrial Arts Teacher Education, Bloomington, IL: McKnight & McKnight.

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

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

Johnson, D. (2006). Are 21st century skills right brain skills? Education World. Retrieved from http://www.education-world.com/a_tech/columnists/johnson/johnson006.shtml

Kirkwood, J., Foster, P. & Bartow, S. (1994, Fall). Historical leaders in technology education philosophy, Journal of Industrial Teacher Education, 32(1), 1-21.

Lagemann, E. C. (1989, Summer). The plural worlds of educational research. History of Education Quarterly, 29(2), 183-214.

Lewis, T. & Zuga, K. (2005). A conceptual framework of ideas and issues in technology education. Washington, D.C.: National Science Foundation.

Lewis, T. (2004, Fall). A turn to engineering: The continuing struggle of technology education for legitimization as a school subject. Journal of Technology Education, 16(1), 21-39.

Lopez, R. & Schultz, T. (2001). Two revolutions in K-8 science education. Physics Today Online. Retrieved from http://www.aip.org/pt/vol-54/iss-9/p44.html

Lux, D. (1981). Industrial arts redirected. In R. Barella & T. Wright (Eds.), An interpretive history of industrial arts (pp. 205-225). 30th Yearbook of the American Council on Industrial Arts Teacher Education, Bloomington, IL: McKnight.

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

Maryland State Department of Education. (2003). Technology education. Retrieved October 30, 2006, from http://www.marylandpublicschools.org/MSDE/divisions/careertech/career_technology/docs/fact_sheets

McCarthy, B. (1987). The 4MAT system: Teaching to learning styles with right/left mode techniques. Barrington, IL: Excel.

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

Norman, D. (2004). Emotional design. New York: Basic Books.

Pannabecker, J. (2004, Fall). Technology education and history: Who's driving? Journal of Technology Education, 16(1), 72-83.

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

Rudisill, A. (n.d.). Leadership series: Donald Maley. National Association of Industrial Technology. Retrieved from http://www.nait.org/foundation/maley.html

Russell, J. (2005, Winter). Evidence related to awareness, adoption, and implementation of the Standards for Technological Literacy: Content for the Study of Technology. The Journal of Technology Studies, 31(1), 30-38.

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

Sterry, L. & Savage, E. (undated). A conceptual framework for technology education. Reston, VA: International Technology Education Association.

Warner, S. (2006, April). Keeping joy in technology education. The Technology Teacher, 65(7), 6-11.

Warner, W. E. [with Gary, J. E., Gerbracht, C. J., Gilbert, H. G., Lisack, J. P., Kleintjes, P. L., and Phillips, K.]. (1953). The industrial arts curriculum: Development of a program to reflect American technology [Proposal]. Columbus, OH: Epsilon Pi Tau. (Original work presented at the American Industrial Arts Association Conference in 1947)

Wilber, G. O. (1948). Industrial arts in general education. Scranton, PA: International Textbook.

Woodward, C. (1887). The manual training school. Boston: D.C. Heath.

Zuga, K. (1998). A historical view of women's roles in technology education. In B. Rider (Ed.). Diversity in technology education (pp. 13-35). 47th Yearbook of the Council on Technology Teacher Education, New York: Glencoe, McGraw-Hill.

Technology, Innovation, Design, and Engineering (TIDE) Education

Presented at the 93rd Mississippi Valley Technology Teacher Education Conference, 2006, Nashville, TN

Chapter 7

Anthony F. Gilberti
Fairmont State University

Introduction

This paper will follow a historic practice that exemplifies the strength of the Mississippi Valley Conference papers of years past. During those papers presented by scholars in our field, presenters illustrated what they believed, what they valued, and their professional opinions on topics that they were compelled to address. This author fondly remembers reading the papers from the Mississippi Valley Conference as a graduate student at Eastern Illinois University and the University of Maryland. The presenters spoke with conviction and steadfastness regarding their values and beliefs of the changing nature of Industrial Arts Education and Technology Education. Having attended several of these conferences as a graduate student, this author was also impressed by the discourse and debate that resulted. If nothing else, participants learned quite a great deal about the presenters and their opinions about pressing issues before our field. Therefore, this paper will serve as a reflection of beliefs and position regarding the use of TIDE as a descriptor for our curriculum area.

What Does a Name or Tagline Reflect?

The International Technology Education Association (ITEA) has been promoting the Tagline of '*teaching excellence in technology, innovation, design, and engineering.*' Further, the ITEA is the professional organization for technology, innovation, design, and engineering educators. Its mission is to "promote technological literacy for all by supporting the teaching of technology and promoting the professionalism of those engaged in this pursuit" (ITEA, 2005). While reflecting on this statement, this author found himself drawn to several key words in the sentence. These key words are 'to promote technological literacy for all.' Thus, these key words are essential to what our curriculum area should reflect.

A tagline is an alternative form of a branding slogan that is typically used in marketing materials or advertising. The concept behind a tagline is to create a memorable phrase that will sum up the outstanding characteristics of a product, or it can be used to reinforce the audience's memory of a product. A tagline quickly illustrates a product or an organizations position. Examples of effective or memorable taglines include: AT&T: *Your World Delivered,* Kodak: *100 Million Years in the Making,* Ford Motor Company: *Quality is Job One,* and Microsoft Corporation: *Where Do You Want to Go Today?* The most successful taglines may even become part of our popular culture. An example of such a tagline that has been elevated to this status would include the phrase stated as part of every Star Trek episode: *To Boldly Go Where No Man Has Gone Before.*

The descriptors that an organization uses are important to its members and constituents. These descriptors illustrate to the members and others what an organization stands for, what it values, and what it attempts to provide (whether this is a product, good, or service). The key point for any organization that develops a tagline or descriptor is that it meets some basic criteria. These criteria can include:

- A representation for what the organization stands for (i.e., orientation, philosophy, or values)
- Uniqueness (e.g., Bundy Very Used Cars changed to Rent-a-Wreck)
- Listing benefits to clients or customers
- Being pronounceable and easy to spell
- Being concise
- Pleasant to the ear

Besides the criteria listed above, a good tagline should always follow the organization or company name, and it must be used correctly and consistently. We will return these attributes of a tagline later. For now, let us turn our attention to one of the important questions: Does TIDE provide a brand identity for technology education?

A Historical Perspective of Technology Education

The curriculum area of technology education has a very rich history with regard to curriculum transformation. Each of us is aware that technology education had its roots in the earliest forms of what many referred to as 'industrial education' or 'manual training.' Historically, industrial education and manual training had their beginnings in the very early forms of trade, technical, and engineering education.

Perhaps the most famous of the early schools to teach different forms of trade, technical, and engineering education were the School for Roads and Bridges (École des Ponts et Chaussées, founded in 1774) and the Central School of Trades and Industries (École Centrale des Arts et Manufactures, founded in 1829) in France. These schools had a primary purpose of educating youth to the industrial nature of society, as well as trade and engineering skills (Bennett, 1937). Within the United States, and influenced heavily by the 'The Russian Tool System' of manual training and engineering concepts promoted by Victor Della Vos at the Imperial Technical School, a number of schools were opened to teach design, the manual arts, and engineering. These schools included:

- West Point (starts to focus on engineering), 1817
- Franklin Institute in Philadelphia, 1824
- Gardiner Lyceum in Maine, 1827
- Sheffield Scientific School of Yale College, 1847
- Lawrence Scientific School at Harvard College, 1847
- Massachusetts Institute of Technology (School of the Mechanic Arts), 1876
- The St. Louis Manual Training School, 1879 (Bennett, 1937).

The point of the above listing of schools is to illustrate that our curriculum area of technology education evolved from the early manual training and engineering focus that was taking place in Europe. Perhaps Charles R. Richards (1904) best illustrated the need for these new educational endeavors when he wrote:

> When we consider that 'the dominant tendency in the world to-day is the industrial,' and that industrial problems constitute the gravest aspects of our social life, does it seem wise to eliminate the study of these problems from our scheme of general education? Furthermore, when we consider that a large share of the prosperity and progress of this nation is dependent upon the efficiency and intelligence of our industrial workers, whose preparation must come largely thru the training of the common schools, would it not seem that the necessity for including a study of some of the basic elements of these problems in the elementary curriculum were beyond argument? . . . It should hardly be necessary to state that this idea does not mean any more of an attempt to teach trades than heretofore . . . But it can give an insight into the basic operations of a great number of trades and occupations; it can give a wide variety of

> experiences in the manipulation of tools and materials, and a considerable knowledge of typical methods and principles of construction. It can go farther, and trace the course of invention in the primary arts; it can bring out the intimate dependence of industry upon science; it can develop an insight with the economic relations of industry to social life and give some idea of the laws governing those relations; in short, it can do much to advance an understanding of, and interest in, the facts and forces fundamental to all human art and industry, and to define the place of these activities in the life of to-day (pp. 371-372).

The above comments would still have relevancy today by substituting the word industrial with technology.

The early forms of industrial education in the United States had both an associated economic and social element. Further, the early proponents of industrial education and manual training promoted the concepts of 'industrial intelligence' and 'social efficiency' as a means of educating youth to the industrial nature of society (Addams, 1910, 1930; Commonwealth of Massachusetts, 1906; Fish, 1907; Stebbins, 1902). These concepts were often associated with the necessary skills needed for society with regard to moral and social education, design, mathematics, science, and engineering. The concepts of industrial intelligence and social efficiency can be viewed as similar to the concepts behind technological literacy today. One can also find connections to the Project Lead the Way movement that has taken hold in many states across this nation. Thus, it can be written that technology education has always had a connection with design, engineering, mathematics, science, and the study of technical means.

TIDE as a Brand Identity

The purpose of this session was to explore and answer two specific questions. These questions were:

1. To what extend is technology, innovation, design, and engineering (TIDE) education an accurate descriptor for the curriculum area of technology education?
2. Does TIDE provide a brand identity for technology education?

TIDE education *could be* and accurate descriptor for the curriculum area of technology education. This is not an attempt to make a separation of engineering from the word technology. Many (cf., Bugliarello, 1973; Florman, 1968) believe engineering to be merely an extension of technology. Where engineering is highly specialized and relies on the knowledge of science, innovation, and creative design, technology is more comprehensive in that it relies on artifacts, design, innovation, processes, science, systems, and influences from the social infrastructure and environmental concerns.

Technology education has always had a connection with the problems and promises that result from the application of technical means. Technology shapes our world, and it makes possible our very existence. However, if we were to examine the history of the curriculum area, it would be correct to note that technology education has been dominated by three main themes. These themes are:

- A study of technical processing of materials
- A study of tools and skill development
- The making of projects

While the above may have served our profession well in the past, the focus on these three themes has limited the ability of educators to teach effectively about technology in the robust manner needed in a technologically based society. TIDE *could* be an accurate descriptor of our curriculum area of the future if technology educators embrace a greater emphasis of innovation, design, and engineering concepts into the curriculum area. Clearly, the profession is making progress in this direction, evidence can be documented by reviewing the growing list of curricula materials being published by the ITEA, Project Lead the Way, and a host of other organizations associated with science, technology, engineering, and mathematics (STEM) education. Examples of curricula materials that are available from the ITEA include:

- Technological Systems: A Standards-Based Middle School Model Course Guide
- Invention and Innovation: A Standards-Based Middle School Model Course Guide
- Engineering Design: A Standards-Based High School Model Course Guide
- The ProBase Curriculum: Engaging Technology

Again, the profession is making progress in the right directions to position TIDE as an emphasis area of our curricula and teaching methodology. Thus, this could result in TIDE being a good descriptor for the profession of technology education. However, there are problems with this future direction.

Project Lead the Way

One curricula endeavor that is quickly taking hold in many States is the adoption of Project Lead the Way (PLTW). PLTW works with schools to implement an instructional plan to prepare students for postsecondary careers in engineering and engineering technology. This curriculum is educationally sound, and it has created a degree of excitement among educators, administrators, and students. Yet, this curriculum would not address all of the standards outlined in the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000). Further, if one examines the courses that are part of the Project Lead the Way curriculum, one would find an intense study that would emphasize:

- A study of engineering and technology concepts
- Innovation and design
- A study of technical processing of materials
- A study of tools and skill development
- The making of projects

This curriculum is highly technical and specialized, and it would address the concepts of TIDE education, but at what cost? PLTW is quickly establishing itself as a major curriculum movement in technology education. Yet, this endeavor has some rather grave consequences for technology education. For example: Indiana has embraced PLTW as a part of Career and Technical Education, and a large number of schools are already offering the curriculum or preparing to do so in the near future. Indiana is in the top tier of States that provides PLTW instruction. This researcher contacted 20 schools at random from the list of PLTW schools and asked two questions:

- What are your plans to continue offering technology education classes that are based on the standards to promote technological literacy (i.e., state adopted courses approved for technology education and based on the standards promoted by the ITEA)?
- How many students do you see yourself teaching in the future with the PLTW curriculum as compared to technology education courses adopted by the state of Indiana?

The results of this poll indicated that 65% of the instructors believed that they would no longer offer technology education classes that addressed the standards to promote technological literacy. The reason for this response was that instructors were limited in faculty resources. Where there is only one technology educator, and due to intense nature of the instruction to deliver PLTW classes, the curriculum was transitioned into a PLTW curriculum. Regarding how many students an educator would be teaching in the future, 85% stated that they would likely teach fewer students in the future. This belief was illustrated with the idea that the curriculum was specialized to those who had an interest in becoming a future engineer or industrial technologist. While further research is needed in this area, it does raise concerns about our ability to teach technological literacy skills to *all students*.

Teaching Innovation and Innovation Capabilities

Technology education has a role in teaching both innovation and fostering students' innovative capabilities. This could achieved with an emphasis on TIDE education. However, a different approach might be more effective. This approach should move beyond a study of the technical processing of materials, a study of tools and skill development, and the making of projects. These strategies to teaching about technology have been our historical mainstay. Rather, technology education should be a reflection of its original purposes and within the contexts of a technologically based society.

If we consider that the dominant organization of society has been centered on the use and development of technology, and that technological development constitutes both problems and benefits to society, then it would seem appropriate to focus the teaching of technology on this organizational structure and its resulting problems and benefits. This can be achieved with TIDE education, but it must make a greater connection to the concepts of innovation, invention, and design to address the economic, social, and environmental problems faced by society.

The idea of providing an authentic or experiential approach to teaching technology and engineering should be presented as a dimension of the *social application of technology*. As an important aspect of the nature of technology, technological knowledge is applied in cultural traditions (i.e., commerce, work, recreation, etc.) and in the social and personal life of citizens of all countries. Thus, the study of technology or TIDE education could be undertaken by:

- Having an orientation towards a relevant problem (i.e., social, technical, etc.)
- Being concerned with realistic situations and problems
- Elaborating on the alternatives that exist for situations and the skill of selecting between competing alternatives
- Utilizing purposeful activities as an integral component of learning
- Using the school, local community, and the natural environment as a context for learning
- Involving value clarification skills
- Increasing the ability of students to contribute to improving their own technological or environmental situations

If one examines the above list for learning about technology and engineering from its social application, a rich body of curricula endeavors comes to mind. These include the developments of units of study around the content areas of:

- The Interactions of Technology and Society
- Consumption and Conservation of Resources
- Technological Development and the Environmental Predicament
- The Role of Technology and Engineering in Ecological Destruction
- Using Technological Fixes to Solve Social Problems
- Assessing and Managing Technology
- Ethics, Engineering and Technology
- Appropriate Technology
- Technology and Sustainable Development

- Energy Production and Conservation

Technology education and TIDE educational approaches have an unprecedented opportunity to critically examine the relationship of technology and engineering to environmentally sound development. This examination would promote social responsibility among citizens, and it would make a true connection to the original concepts that have always been fostered by the curriculum area of technology education.

Technology education has a vital role to play with the inclusion of engineering concepts to promote democratic duty and personal development of citizens. Technology education is unique in our ability to take this holistic view of teaching technology and engineering concepts via an authentic or experiential approach. No other discipline in the current school environment has this same ability to teach via these perspectives.

What Must the ITEA do to Capitalize on TIDE as a Brand Identifier and Tagline?

If one examines the original list offered earlier in this paper regarding the components that make a good tagline, the ITEA has missed the mark on two key aspects. These aspects are a representation of what the organization stands for and the ineffective use of a tagline. Clearly, the profession is not yet ready to embrace the TIDE tagline. However, the ITEA leadership is moving the profession in a positive direction by suggesting a tagline. Personally, this author prefers the following tagline: *Fostering Technological Literacy for All*; as this phrase seems more reflective of what our profession stands for and is trying to achieve.

Regarding the inefficient manner in which the tagline is used, the ITEA must consistently use this tagline on all publications and correspondence with its constituents—a current shortcoming of the professional association. Lastly, the ITEA should adopt this tagline for at least five to ten years.

Research suggests the public requires at least five years before constituents make a connection with a tagline or branding to the organization. In the past ten years, we have moved from a number of unofficial taglines: *Technology: The New Basic, Anything is Possible,* and *Technology is Human Innovation in Action.* The consistent and repeated use of TIDE as a tagline can be effective, if it is used on all publications and correspondence, and if it is used for an extended time.

References

Addams, J. (1910). *Twenty years at Hull-House.* New York: Macmillan.

Addams, J. (1930). *The second twenty years at Hull-House: September 1909 to September 1929.* New York: Macmillan.

Bennett, C. A. (1937). *History of manual and industrial education 1870-1917.* Illinois: Chas. A. Bennett.

Bugliarello, G. (1973). The engineer and the historian. In G. Bugliarello and D. B. Doner (Eds.), *The history and philosophy of technology* (pp.50-56). Urbana, Ilinois: University of Illinois Press.

Commonwealth of Massachusetts. (1906). *Report of the commission on industrial and technical education.* Boston: Wright and Potter.

Fish, F. P. (1907). *Address.* Bulletin of the Proceedings of the Organization Meetings of the National Society for the Promotion of Industrial Education, 1, 24-30.

Florman, S. C. (1968). *The existential pleasures of engineering.* New York: St. Martins.

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

Richards, C. R. (1904). Is manual training a subject or a method of instruction? *Educational Review, 27*, 369-374.

Stebbins, H. W. (1902). Industrial education as a social force. *Educational Review, 23*, 462-467.

Highly Qualified Technology Education Teachers—Their Attributes, Competencies, Assessment and Preparation for Tomorrow's Schools

Presented at the 94th Mississippi Valley Technology Teacher Education Conference, 2007, Chicago, IL

Chapter 8

John L. Iley & Susan E. Bastion
Pittsburg State University

What Constitutes a Highly Qualified Technology Education Teacher?

To answer this question, the authors identified several studies that acknowledged attributes, characteristics, and/or qualities one should possess to be a highly qualified teacher. These characteristics took the form of personal qualities, teaching competencies, technical competencies, and professional attributes.

Additional literature, more closely related to technology education, included articles and studies in technology education, career and technical education, design and engineering, science and mathematics, and physical education. These publications cited additional attributes or qualities that a teacher should possess that were related to the manipulative and kinesthetic activities, experiments, experiential learning, and design activities associated with these disciplines.

In April 2007, the National Association for Sport and Physical Education published a position paper entitled: *What Constitutes a Highly Qualified Physical Education Teacher?* (NASPE). (2007). By adapting ideas originally generated in this report, the authors have proposed a list of qualities that should be exhibited in highly qualified technology education teachers. Using this technique, the authors propose that highly qualified technology education teachers would exhibit the following attributes:

1. **Possess the skills (performance), knowledge, and values (dispositions) necessary for teaching technology education, as outlined in: (1) the *NCATE/ITEA/CTTE Program Standards (2003)*:** *Programs for the Preparation of Technology Education Teachers;* and (2) *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* (ITEA, 2003). These standards are guided by the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000). Technology teacher education (TETE) programs are to facilitate preservice teachers' progress toward being deemed "highly qualified" upon entrance into the profession. Technology teacher education programs should provide preservice teachers with substantial pedagogical and content knowledge bases; afford many opportunities for preservice teachers to participate in an array of field experiences where they can interact with veteran teachers and diverse students at all grade levels while seeing the application of classroom principles; and develop, nurture and reinforce specific professional behaviors that facilitate student learning.
2. **Base their teaching on the national standards, *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000)** in order to provide

students a foundation of skills and knowledge that can apply to many activities so that students are willing, able, and interested in embracing a lifetime of technology-related activity. Highly qualified technology education teachers understand the importance of meeting the needs of all types of learners and will use the outcomes provided in the national standards to elicit ideas for a variety of instructional strategies to do so. By relating the national standards to developmentally appropriate technology activities, highly qualified teachers give a purpose to their curriculum and illustrate that technology education has meaningful, educational, and significant content.

3. **Establish high expectations for learning within the psychomotor, cognitive, and affective domains, and support student learning through the creation of an environment that is conducive to learning.** Highly qualified teachers manage the day-to-day functions that are necessary for classes to run smoothly, as well as plan and deliver instruction of the technology education content. This content includes appropriate practice opportunities that contribute to attainment of specific learning goals. Students are encouraged to engage in technology-related activities inside and outside of the school setting.
4. **View assessment as an integral component of the teaching-learning process.** Regular, ongoing formative and summative assessments provide students with adequate feedback regarding progress towards the specified learning goals. Additionally, regular assessment provides valuable information about student achievement of the content standards and guides the program evaluation process to affect meaningful curriculum change.

5. **Demonstrate professionalism and ethical behavior in the learning environment through positive interactions with students, parents and guardians, colleagues, administrators, business and industry constituents, and community members.** Highly qualified technology education teachers use sound teaching practices to deliver curricular content, keep abreast of new information in the discipline, and assume leadership roles while advocating for the importance of technology education (technological literacy) within the educational process. They effectively work with colleagues, administrators, and business-industry constituents (e.g., advisory council members; mentors for students) to further the goals of the program and meet the educational needs of students. They seek opportunities to educate members of the family and school community of the value of technological literacy to maintain productive and fulfilling lifestyles.
6. **Engage in reflective practices while systematically reviewing their curriculum, teaching practices, and assessment tools.** They constantly seek to update and refine their professional credentials. Highly qualified technology education teachers welcome professional development opportunities such as: workshops, conferences, field research, and professional projects to increase their knowledge in the field, preserve their abilities as quality teachers, and work with colleagues to the benefit of their students and their profession. They are members of a professional technology education organization and often serve as leaders within the organization (NASPE, 2007).

What Characteristics Describe a Highly Qualified Technology Education Teacher?

As noted previously, the quality technology education (TE) teacher teaches appropriate technology subject matter for developing technologically literate students. Ideally, one's students obtain the appropriate level of knowledge, skills, and dispositions associated with the *Standards for Technological Literacy* (STL). The quality TE educator also serves as an excellent role model for students, fellow teachers and TE teacher candidates. Some of the characteristics used to describe the quality TE educator are:

1. **Enthusiastic and enjoys teaching young people.** The teacher's enthusiasm for teaching, working with children, and teaching technology is evident to others (Polich & Goodell, 2007).
2. **Committed and passionate about the TE field and the success of their students.** The TE educator believes strongly that what he or she is teaching is important; he or she is passionate about technological literacy and students becoming technologically literate (Center for Advancement of Teaching and Learning, 2007).
3. **Enjoys learning, embraces change, and keeps up with trends.** The TE teacher is genuinely excited about learning how things work; learning other ways of doing things; learning the latest software; using the latest in technology; embraces these changes; and keeps up with trends in the field, (e.g., integrated academics; interdisciplinary approaches; Scarcella, 2007). These teachers also practice reflective teaching to facilitate personal and professional change to provide students with the best possible learning experiences (NASPE, 2007).
4. **Positive attitude.** "The glass is half full" definitely describes this individual; he or she regularly looks forward to making things work, rather than constantly

dwelling on the negative and focusing on reasons why some idea won't work or cannot be done (Polich & Goodell, 2007).

5. **Sense of humor.** This person appreciates humor and is able to incorporate laughter into presentations and demonstrations; recognizes that people tend to remember things more if laughter is associated with it; and is willing to laugh at oneself. (Garner, 2005; Thompson, et al, 2004).
6. **Philosophically grounded and balanced.** The instructor is not easily disrupted by change; he or she keeps things in perspective; and addresses various technologies equally as opposed to focusing on pet projects and technical areas. The teacher can also objectively present various points of view to stimulate students to make personal decisions with a strong educational basis (Polich & Goodell, 2007).
7. **Possesses a strong set of values and ethics.** Scarcella (2007) identifies honesty and integrity (doing the right thing even when no one is watching) as paramount to this teacher. He or she can be counted upon to keep promises, do what most would consider the right thing, and have ethical interactions with students.
8. **Excellent work ethic and serves as a good role model for students.** This TE teacher uses time wisely; completes tasks in an efficient manner; is a self-starter; works cooperatively with others; and serves as good role model for students (Scarcella, 2007).
9. **Professional.** Professional is the word that best describes the quality TE teacher. Dress and actions are appropriate. He or she regularly engages in professional activities--conference participation, service to the professional organization, is well-read, contributes to the profession through presentations and writing, etc. (New Mexico Public Education Department, 2007). The teacher

candidate also has professional interactions with his or her students, and collaborates with colleagues (Berry, 2002). A professional TE teacher is fair, genuine, and relaxed during interactions with students, administrators, and parents (Fortier et al., 1998).

10. **Caring, listens to students, is inviting.** One who genuinely cares about students and others; cares about their needs and their success; takes steps to enhance opportunities for their success; and listens to the concerns and ideas of students, etc. (Morgan, 2003, Alexander, 1992).
11. **Confident.** These teachers are confident in their teaching abilities, technical knowledge and skills, and are confident that they are teaching appropriate content for their students. "They convey confidence in others and instill it in their students" (Morgan, 2003).
12. **High expectations.** He or she sets the bar realistically high for students based on their abilities; and is not content with mediocrity (Connors & Mundt, 2001; Morgan, 2003; & NASPE, 2007).
13. **Futurist, forward thinker—eye toward the future, and risk-taker.** The TE instructor has an appreciation for the past, but is regularly looking toward the future and plans accordingly. He or she is willing to take risks and try new things (Morgan, 2003).
14. **Adaptive.** Although one plans well, he or she adapts well to changing situations, as opposed to being constantly frustrated and unwilling to adapt. This teacher is prepared to teach or do what is necessary regardless of the challenge (Center for Advancement of Teaching and Learning, 2007).
15. **Possesses thinking skills necessary for success.** Quality TE teachers are problem-solvers and engage in the systematic process of solving problems (ITEA, 2007). They are creative thinkers and use a variety of strategies

to break mental locks and develop creative ideas and solutions (Etkina, 2005; Warner, 2003). These teachers are good decision-makers, using a variety of tools and strategies (Greer, 2000; US Department of Labor, 1991).

16. **Excellent communicator.** Whether using oral or written communication, the quality TE teacher effectively conveys the appropriate message to the audience, free of distracting mistakes or misinformation (Darling-Hammond & Youngs, 2002; Fortier et al., 1998; & New Mexico Public Education Department, 2007).
17. **Possesses necessary technical knowledge and skills.** The quality TE teacher is typically:
    - **Well-rounded in technical competence** - technologically literate and possesses the knowledge, skills, and appropriate beliefs associated with STL (Darling-Hammond & Young, 2002 & ITEA, 2003).
    - **Typically possesses at least one area of expertise** - usually there is some area of expertise for which the TE teacher is identified (Glass, 2002).
    - **Quality in craftsmanship** - does work to the best of one's ability and is professional in appearance as appropriate; not content with sloppy, inaccurate, mediocre work, especially when quality craftsmanship is the appropriate expectation. In addition, a quality TE teacher should provide a clean, uncluttered, and safe facility, which has equipment that supports the TE curriculum (Fortier et al., 1998).
18. **Possesses pedagogical knowledge and skills and uses them appropriately.** This includes the:
    a. ability to implement a variety of instructional strategies (Berry, 2002 & Scarella, 2007)
    b. knowledge and ability to develop and implement appropriate assessment tools (formative and summative) (Fortier et al., 1998; ITEA; & Polich & Goodell, 2007)

c. ability to evaluate individual student needs and implement accommodations when necessary or required (Fortier et al., 1998; Polich & Goodell, 2007; & Scarella, 2007)
d. understanding of how and why students learn (Berry, 2002 & Etkina, 2005)
e. ability to create an environment conducive to learning (Etkina, 2005)
f. ability to develop/design materials and curriculum of high quality (Scarella, 2007)

19. **Motivated to be a good teacher.** The quality TE instructor is motivated to improve the TE program, student learning and the school (Berry, 2002). He or she uses reflective practices to evaluate and improve teaching (Scarella, 2007).
20. **Certified.** Quality instructors have successfully completed a TE teacher preparation program that certifies them as a qualified technology education teacher. The literature noted that the quality of instruction and success of students positively correlates to the certification of the instructor. Teachers who are teaching outside of their field and more likely to have students who perform lower on assessments of student performance than those teachers who are certified in the teaching field (Darling-Hammond & Youngs, 2002 & Fortier et al., 1998).
21. **Teaching experience.** The amount of experience a teacher has is also linked to the positive performance of students (Darling-Hammond & Youngs, 2002).
22. **Leadership.** Not all quality teachers are gifted leaders. However, leaders are needed in the profession to continually provide direction and move the profession forward (ITEA, 2007).

Types and Roles of Technology Education Teachers

To understand the qualities of a good technology education teacher, one must understand the various types or roles these educators assume in producing technologically literate students. Their abilities and giftedness—including their degree of creativity and innovation and their teaching environment define the type of instructor or role they perform as a teacher. Quality, effective teachers fulfill one or more of the following roles: *researcher*, *innovator*, *implementer-manager*, and/or *maintainer*. Marginal or ineffective teachers assume the roles of *settler*, *squatter*, and/or *destroyer*. The type of teacher and the role he or she assumes impacts students and their level of achievement.

Researchers or investigators. These educators are constantly conducting research and investigating the latest technological breakthroughs, the latest in educational psychology and educational theory, the societal needs for technological literacy, etc. They investigate phenomena, not unlike the scientist that researches natural phenomena. The researcher often comes from the ranks of teacher-educators or from professional organization leaders related to the field.

Innovators. An innovator takes the new knowledge or direction provided by the researchers and does something to improve upon that knowledge. Not unlike an engineer taking the latest breakthrough in material science and applying it to a new product design, the innovator educator takes the information provided by the research and develops new programs, new activities, etc. that benefit students.

Implementers-managers. Programs and instructional materials developed by innovators are embraced by other educators, designated as *Implementers-managers*. These educators do what is necessary to replicate these programs and materials in their TE programs or schools. These implementer-managers may be fellow teachers, teacher educators, administrators, state supervisors, professional organization leaders and members, and/or possibly vendors. Today, we are seeing innovative pre-engineering curriculum projects, such as *Project Lead the Way*, being successfully implemented by implementer-manager educators throughout the country.

Maintainer. Once innovative programs have been implemented, a maintainer educator can successfully teach students. The maintainer may be a solid educator who is not gifted as an innovative curriculum developer nor one that is adept at navigating the politics to get an innovative program implemented in his or her school. However, they are still a quality TE teacher that can do an excellent job of teaching the curriculum and educating their students. These teachers are not unlike the highly skilled technicians and technologists that make things work and produce quality products in industry. Many successful "maintainers" are also teaching in *Design and Technology* programs and *Project Lead the Way* programs throughout the country.

Settlers. Settlers are teachers without an adequate TE background to be truly effective teaching technology education subject matter. They require continual direction and assistance from other TE educators in order to be successful. They are only marginally effective, despite their sincere and honest efforts. During the 1990's as modular-based TE programs were sweeping across the nation, many teachers fulfilled the role of settlers, whether they were from a traditional industrial arts backgrounds or transplanted from another discipline. Some of these teachers evolved into maintainers, while others sunk to the non-productive educator roles of *Squatter* and even *Destroyer*.

Squatters. These teachers may spend time in the classroom or lab, but they appear to make little or no effort to educate their students. They do not appear to have a passion for teaching. These individuals are the antithesis of quality TE teachers. In some cases, squatters may have been foisted into teaching situations that they did not desire, so their response has been to be unproductive. In other cases, the squatter may need a break from teaching, a new assignment, and or a recharge.

Destroyers. These individuals not only lack knowledge of TE nor embrace the concept of technological literacy, they oppose it by purging the curriculum, equipment, and materials for which they have no personal interest. They pursue their own interest to the detriment of the TE program and the technological literacy of its students.

The types or roles of an educator are summarized in Table 1. It provides a description, industry counterpart, and example for the various roles of an effective, quality TE educator — *Researcher, Innovator, Implementer-Manager*, and *Maintainer*. The less effective role of *Settler* and the detrimental roles of *Squatter* and *Destroyer* are also summarized.

Table 1

Summarization and Examples of Educator Roles

Type or Role of Educator	Industry Counterpart	Description	Example
Effective Quality Educator			
Researcher	Scientist	Research and investigate fields of technology and education; provides direction.	Dr. William Dugger and STL; Don Maley; others
Innovator	Engineer	Take new ideas and directions and develops new programs and instructional materials, etc.	Brad Thode; Michael Neden; others
Implementer/ Manager	Engineering Technologist/ Industrial Technologist	Successfully implements and/or replicates the innovative programs and activities, etc. in their school, district or state; make it happen.	Ron Barker (Georgia); Dr. Harvey Dean (Pitsco); others
Maintainer	Skilled Technician	Successfully teaches and manages TE programs; and develops technologically literate students.	Most quality TE teachers that are engaging in the field

Marginally Effective			
Settler	Machine Operator	Lack sufficient background in TE to be truly successful, despite their best efforts; require continual direction and instruction to have success.	Often a transplant from a related or unrelated teaching field; or marginally-prepared
Detrimental			
Squatter	Non-Productive employee	The null employee; makes little or no effort to teach; lacks passion for TE and teaching students; strictly there to collect a check; interests are elsewhere; the antithesis of a quality teacher.	The transplant or unmotivated teacher that has little interest in the profession.
Destroyer	Saboteur	Not only does not support the direction or philosophy of technological literacy, but may even take it in a wrong direction; makes changes in programs and facilities that are detrimental to future continuance of a TE program.	The unsuccessful transplant that diminishes the TE lab to implement a marginally related or favored project.

How Are Highly Qualified Technology Education Teachers Prepared?

In general terms, the following initiatives or activities should be undertaken to prepare quality teachers in technology education:

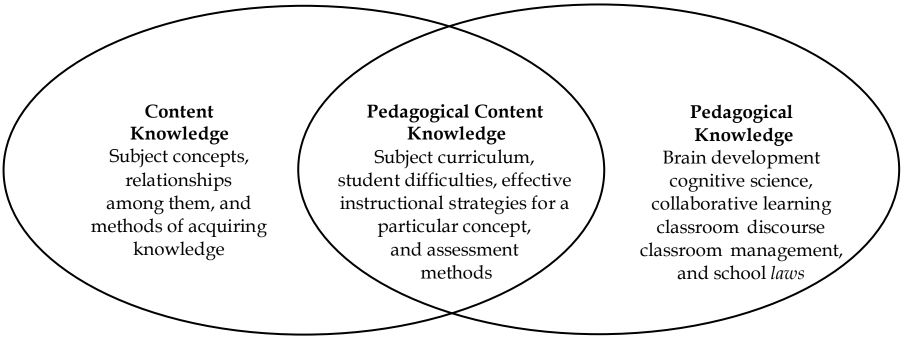
1. Teach appropriate technology education subject matter and content. This can be derived from the *Standards for Technological Literacy* and ITEA/CTTE/NCATE

Standards. The first five program standards for TE teacher preparation are noted below.

- Subject Matter *Standards for Technological Literacy*
- Standard 1—The Nature of Technology
- Standard 2—Technology and Society
- Standard 3—Design
- Standard 4—Abilities for a Technological World
- Standard 5—The Designed World (ITEA/CTTE/NCATE, 2003)

2. Teach appropriate pedagogical and assessment strategies as noted in ITEA/CTTE/NCATE Standards. Standards #5-#10 address effective teaching and are listed as follows:
   - Effective Teaching *Standards for Technological Literacy*
   - Standard 6—Curriculum
   - Standard 7—Instructional Strategies
   - Standard 8—Learning Environment
   - Standard 9—Students
   - Standard 10—Professional Growth (ITEA/CTTE/NCATE, 2003)
3. Prepare TE teacher candidates to meet minimum academic standards associated with the program, including general education course work, education and psychology support courses, specific math and science support courses, and TE technological and pedagogical courses. High quality TE teacher candidates should not only acquire this knowledge but should also understand the relationships between the areas of knowledge as shown in Figure 1.

Figure 1. The Structure of Teacher Knowledge (adapted from Etkina, 2005)



4. Teach TE teacher candidates the types of laboratories and classrooms that they *should* find in secondary schools when they graduate. These laboratories should reflect current best practices. Students should have experiences in broad-based labs (e.g., general technology lab) and focused labs (e.g., CAD; materials science and manufacturing). Teacher educators should model best practices in instruction and management. Provide students with teaching opportunities and practicum field experiences that provide them experiences they *should* encounter or find when they graduate and pursue their teaching careers.
5. Pre-professional experience. This should provide observations and experiences in a *model* technology education program with highly qualified technology education teachers. Many new teachers consider these experiences as the most important in the teacher preparation program (Ingersoll, 2007).
6. Pre-service technology education candidates should work with candidates from other teaching disciplines to develop thematic or unit activities that can be presented to students in a team-taught integrated environment.

7. Use videoconferencing or online platforms to work with individuals or groups of students on special projects or activities (e.g., electric vehicle competition). TE teacher candidates work with TE students in secondary schools and provide services (e.g., output models on rapid prototyping systems; complete analysis of design; etc.).
8. Actively participate in student organizations that not only provide model experiences of a professional organization but also interacts with student organizations in the public schools. For example, TECA chapters working with TSA Chapters.
9. TE teacher candidates should engage in professional teaching experiences in schools with high-quality technology education programs and exemplary TE teachers (Hill & Wicklein, 2000). Teacher preparation programs vary greatly in the duration and requirements during the professional semester, but the amount of experience is positively correlated with a teacher's effectiveness to facilitate student performance (Darling-Hammond & Youngs, 2002).
10. TE teacher candidates as well as practicing TE professionals should develop an on-going professional development plan and engage in activities associated with it.

Assessing Teaching Candidates

No one type of assessment or assessment tool is sufficient to evaluate all technology education teacher candidates. The assessment used should provide evidence that the student possesses the knowledge, skills, and dispositions that assures the teacher educator that the university is graduating qualified technology education teachers; and at the same time assuring an administrator and search committee that they are hiring the best candidate for their school. They should be competent in the four domains of teaching responsibility: planning and preparation, the classroom environment, instruction, and professional responsibilities (Danielson, 1996). Evidences or assessment components that would be beneficial in making a selection are noted in the following narrative, and more specifically in the listing under portfolio.

Authentic Assessment

Authentic assessment measures should be used in addition to traditional assessment measures to provide a more comprehensive evaluation of teacher candidates. Authentic assessment refers to a wide variety of measurement tools and techniques (e.g., checklists, rubrics, portfolios, interviews, etc.) that correspond more closely to real-world teaching experiences. It is an ongoing and integral part of the teacher preparation process (Custer, 1994). Although traditional paper-pencil examinations are by far the most commonly used assessment measures, they are not positively correlated with successful teaching performance. However, teacher candidates' general academic verbal ability has been linked to successful teaching performance (Glass, 2002). Therefore, authentic assessment measures are recommended in addition to traditional assessment techniques.

Portfolio (Electronic or Print)

Portfolios are an excellent assessment tool for documenting student performance. Portfolios provide a record of growth and development and consist of a variety of technology and education-related artifacts that document student performance. (Petrina, 2007). These portfolios may be electronic, for example e.g. *FolioLive* (McGraw-Hill, 2007), or in print form, which candidates may share with potential employers.

The following are components a teacher educator might require teacher candidates to include in his or her portfolio.

1. **Personal Information.** This could include the following:
   a. **Resume or Vita.** This would be a summation that includes career goal statement, educational experience, work experience, activities, etc.
   b. **Philosophy of Education.** Narrative provides opportunity to share the candidate's philosophy about education in a paragraph or one-page format. It also provides someone assessing it to have a better idea as to the beliefs of the teaching candidate as well as his or her writing ability. An alternative to this would be a *Personal Practical Theory* that includes: beliefs about learners; beliefs about instructors; beliefs about subject matter; beliefs about classroom climate; and beliefs about learning.
   c. **Philosophy of Technology Education.** Candidate expresses his or her philosophy regarding technology education. One can determine if the candidate embraces *STL*, engineering education, favors a traditional industrial arts philosophy, favors engineering education, etc. It also provides evidence of written communication skills.
2. **Evidence of Instructional Material Development.** Items to include are:
   a. **Syllabus.** A summation of all courses elements and facts that can serve as a contract between the student and the teacher.
   b. **Course of instruction**--quarter, semester or year-long. This includes course objectives, instructional resources, activities, instructional plan matrix.
   c. **Instructional module**-- three-day to ten-day unit appropriate for a module delivery-type system
   d. Sample: **PowerPoint Presentation**

e. Sample: **Activity sheet**
f. Sample: **Lesson Plan**
g. Sample: **Objective Test** (50 questions; variety of questions)
h. Sample: **Rubric** for assessing performance in technology education activity
i. Sample: **On-line development activity**
j. Sample: **Electronic grade book** (using MicroGrade, ANGEL, BlackBoard or other)
k. Sample: **Design brief and problem solving activity**
l. Sample: **Visual aid** (photo with description of use)
m. Sample: **Display** (photo of bulletin board or desktop display)

3. **Evidence of Teaching**
   a. **Micro-lesson** A recorded lesson plan and self-evaluation form
   b. **Demonstration** A recorded lesson plan and self-evaluation form
   c. **IDL teaching activity** A recorded lesson plan and self-evaluation
   d. Sample: Completed ***Teaching Internship Evaluation Form*** (student copy)
4. **Evidence of Organization and Management**
   a. **Classroom management plan** – instructional plan for conveying information about policies, procedures, assessments, code of conduct, laboratory management, etc.
   b. **Safety plan** – includes plan regarding instruction in general laboratory safety, housekeeping, MSDS, sharps, emergency procedures, specialized equipment safety, etc.
   c. **Facility design** – includes a laboratory floor plan with equipment location, furniture location, utility locations, instructional spaces, storage spaces, etc.

Also, includes planning matrix for equipment, hardware, software, furniture, etc.

d. Sample: **Completed requisition** for classroom supplies, including quantities, description, unit cost, total cost, shipping, etc.
e. Sample: **Purchase order** for piece of equipment, including specification, accessories, etc.

5. **Evidence of Technical Knowledge and Skills**
    a. ***Technical Competency Check Sheet*** (student copy) – listing of competencies associated with the *Standards for Technological Literacy*. Checklist includes scale of proficiency for knowledge and skill components, including proficiency in use of software and equipment.
    b. Sample: **Engineering and design project and report** (photo, CADD drawings, analysis, and narrative)
    c. Sample: **Communication activity** – e.g., Storyboard and video production (DVD); brochure; web page design; etc.
    d. Sample: **Transportation activity** (photo, drawings, and description)
    e. Sample: **Manufacturing activity** (photo, drawings, and description)
    f. Sample: **Construction activity** (photo, drawings, and description)
    g. Sample: **Bio-technology activity** (photo, drawings, and description)
    h. Sample: **Technology forecasting and/or technology social/cultural impact activity** (photo, drawings, and description)
    i. Sample: **Technical report**
    j. Photos of other projects or activities

6. **Evidence of Professional Development and Involvement**
    a. Summary of **professional activities**
    b. Summary of **TECA participation**
    c. Copies of **certificates or evidence of conference participation**, etc.
    d. Copies of **licenses or certifications** earned
    e. Copies of **articles submitted** (if any)

Traditional Assessments

In addition to authentic assessment measures, traditional summative evaluation measures are used to assess TE teacher candidates. Several states and countries have technology education teacher preparation program standards in place. The structures of several of these instruments and articles describing them were reviewed, as part of this study. Most of the subject matter specific instruments reviewed were based on the *Standards for Technological Literacy*. Older or previous efforts were based on the Jackson's Mill Curriculum Theory.

Preparing Technology Education Teachers for Tomorrow's Schools

To determine how to best prepare individuals to be technology education teachers for tomorrow's schools, the technology education profession must first determine who they are; what they are to teach; and then prepare teachers to teach it. The literature and general observations reveal a technology education field that ranges from teachers of traditional industrial arts to teachers embracing a pre-engineering component exclusively. This is also reflected in individual state education departments and teacher education institutions. In some cases, there is a disconnect between the state department, the local school districts, and the TE teacher education preparation programs in the state. It is imperative that all three entities initiate efforts to collaborate philosophically with regard to the purpose of the technology education discipline.

The *ITEA/CTTE/NCATE Program Standards (2003) for the Preparation of Technology Education Teachers* (ITEA 2003) and the *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* (ITEA, 2003), which are both based on STL, provide a solid foundation for preparing teachers for Technology Education now and in the future. The nature of NCATE is to review standards every eight (8) years, with the current standard remaining in place until 2012 (NCATE, 2007). As changes in technological content take place and new methods of instructional delivery are developed, the standards should change to reflect these developments. The foundation for technology education teacher preparation is in place.

Although the foundation is in place, the profession faces several challenges in to prepare highly qualified technology educators. These include:

1. **Addressing *Technology Education's* internal and external identity**. As noted, there is a wide range of practitioners in "technology education." As part of the internal identity problem, there are those who would change the name from technology education to industrial technology or engineering education. At the same time, there is an external identity problem that one faces. In surveying the literature using "technology education" as a descriptor, one finds that information technology and other related technology fields have latched on to this title to describe their education programs. It is crucial that the profession have an identity that the general public, educators and administrators, and government officials all recognize and understand. The field of technology education is well-defined and documented as a result of efforts associated with STL. Within the umbrella of technology education, there is sufficient rationale for the

inclusion of pre-engineering education for increasing and promoting technological literacy (Rogers & Rogers, 2005). This should not be at the exclusion of other areas associated with technological literacy. "The common sense of educational reform and the improvement of the technological literacy begin with the implementation of the standards—now, at the beginning of the 21st century" (Dugger, 2000, p. 138).

2. **Attracting and retaining quality candidates.** The quality of the input greatly influences the quality of the output. The best candidates typically come out of strong secondary programs that are teaching bona fide technology education curriculum. Unfortunately, the number of technology education teacher candidates is limited; and top quality candidates are even more limited. These candidates are attracted to engineering, engineering technology, and industrial technology programs that provide more lucrative salaries for their graduates. The retention of quality candidates and ultimately the retention of quality teachers are imperative.
3. **Providing up-to-date TE teacher education facilities.** The literature points out the need to prepare prospective teachers, whether they are physics, physical education, or technology education, in similar learning environments that they will teach in and instruct them using the techniques they should use in their teaching (NRC, 2001). Many teacher education programs are not only ill-equipped to address this recommendation in their facilities but also find a lack of sufficient secondary programs that have adequate facilities.
4. **Providing quality mentors and cooperating teachers.** A similar scenario exists regarding finding top quality cooperating teachers. It is disheartening for a technology education teacher to instill the philosophy of technology

education reflected in STL, and have students return from practicum experiences saying their cooperating teacher told them to forget that stuff and take more wood classes or go into industry and not be a teacher. Sometimes, pre-service students find themselves practice teaching in a modular-based facility with a teacher that has never had a technology education course. Their supervising instructor is the product of retrenchment and only had a workshop about the instructional system they are teaching. The old axiom: "You teach the way you are taught," still holds true.

5. **Developing model K-12 technology education programs.** Programs need to be developed in local school districts that are in proximity of undergraduate TE teacher education programs. These models need to have facilities, equipment, curricular materials, and quality TE teachers. Each program needs to serve as a benchmark for the profession in providing examples of best practices for teacher candidates. These could then be replicated in other school districts by these teacher candidates upon entrance into the profession. In-service and workshop opportunities at these model sites should be provided for currently practicing TE teachers. These models should also host administrators, legislators, and other decision makers wanting to provide the best possible programs in technological literacy for their constituencies.

Summary

The quality teacher's attributes and characteristics are well documented in the literature. Quality teachers exhibit the following attributes:

- Possess the skills (performances), knowledge, and values (dispositions) outlined in standards for preparing technology education teachers (i.e., AETL and ITEA/CTTE/NCATE Program Standards);

- Base their teaching on national standards (i.e., STL);
- Establish high expectations for student learning; and provide an environment conducive to learning;
- View assessment as an integral part of the teaching-learning process;
- Demonstrate professionalism through positive interaction with students, parents and guardians, colleagues, administrators, business and industry professional, and community members; and
- Engage in reflective practices while systematically reviewing their curriculum, teaching practices, and assessment tools.

These teachers should possess characteristics such as: enthusiasm; genuine care and desire for teaching young people; a commitment to the profession; a positive attitude; changing and adapting positively; a sense of humor; and a good work ethic. These teachers are certified to teach TE, possess a strong set of values and morals, are excellent communicators; and are competent technically and pedagogically to teach TE. Ultimately, they are caring, competent, committed, professional teachers of technological literacy.

Technology education teaching candidates are assessed using both traditional and authentic assessment measures. Paper and pencil tests over cognitive and pedagogical knowledge associated with STL and AETL, as outlined in ITEA/CTTE/NCATE, are recommended. The literature noted that performance on comparable written tests in other disciplines is NOT closely linked to the teacher candidates' future students' success. However, teacher candidates' verbal abilities are linked to their future students' performance.

Authentic assessment measures such as portfolios, checklists of observed successful competency completion, practicum evaluations, and interviews should also be used to determine the competency level of teacher candidates. These assessments should also reflect the nationally-recognized standards for technological literacy and TE teacher preparation.

A TE teacher entering the profession should aspire to fulfill the role of one or more of the five types of effective educators identified: researcher, innovator, implementer-manager, and/or maintainer. They should avoid becoming one of the three less effective or undesirable types of identified teachers--the settler, the squatter, or the destroyer.

Several concerns related to providing quality technology education teachers were noted. Specific concerns and challenges associated with TE include:

- Addressing technology education's internal and external identity;
- Attracting and retaining quality TE teacher candidates;
- Providing TE teacher education facilities;
- Providing quality mentors and cooperating teachers;
- Developing model K-12 technology education programs.

Recommendations

The following are recommendations concerning the identification of quality TE teachers, the preparation of TE teacher candidates, the assessment of these candidates, and preparation of TE teachers and TE candidates for future schools.

1. Base the identification of quality TE teachers not only on the basis of personal qualities and general characteristics associated with quality teachers but also on their adherence to addressing content associated with STL and receiving certification.
2. Develop a database of quality TE teachers and best practices associated with them.
3. Align TE teacher preparation programs with STL, AETL and the ITEA/CTTE/ NCATE program standards.
4. Prepare teachers in facilities using instructional tools, equipment, and software that should be found in quality

TE programs in the public schools that are aligned with STL.
5. Develop resource libraries as clearinghouses of current TE resources in teacher education facilities for pre-service teacher candidates and in-service instruction of teachers, and establish opportunities for these educators to review these instructional materials and resources.
6. Develop checklists of specific technical and pedagogical competencies that are based on STL, AETL, and ITEA/CTTE/NCATE program standards that can be used to document teacher candidate performance.
7. Provide TE teacher candidates quality field experiences in secondary schools that are aligned with STL; and with instructors that embrace a philosophy aligned with STL and the development of technologically literate citizens.
8. Utilize both standard assessments (based on STL and AETL) and authentic assessment tools, such as portfolios, rubrics, and checklists that provide an accurate picture of teacher candidates. In preparing TE teachers for tomorrow, quality assessments must be very high on the profession's agenda (Schwaller, 2000).
9. Develop model K-12 technology education programs in local school districts that are in proximity of undergraduate TE teacher education programs. These models can serve as benchmarks of quality and examples of best practices for teacher candidates that can be replicated in other school districts by these future teachers.
10. Address technology education's internal and external identity in light of well-developed and well-documented *Standards for Technological Literacy* and TE teacher preparation programs and be committed to it.

It is imperative that the profession have an identity that the general public, educators and administrators, and government officials all recognize and understand. All education-related constituencies need to collaborate with regard to the professions name, description, mission and standards. The field of technology education is well-defined and documented as a result of efforts associated with *STL*. Technology education will be no stronger than the commitment of the people who call themselves technology educators (Martin, 2000, p. 231).

References

Alexander Jr, W. A. (1992). Inviting teacher characteristics and teacher. *Journal of Invitational Theory and Practice, 1*(1), 6-15.

Berry, B. (2002, October 1). What it means to be a "Highly qualified teacher" [Southwest center for teaching quality] (p. 6). Chapel Hill, NC.

Center for Advancement in Teaching and Learning. (2007). *Characteristics of the superior college teacher*. Retrieved from Kansas State University: http://www.k-state.edu/catl/effectv.htm

Connors, J. J., & Mundt, J. P. (2001, December 12). *Characteristics of preservice teacher education programs in agricultural education in the United States.* Presented at the 28th Annual National Agricultural Education Research Conference.

Custer. R. *Performance based education: implementation handbook*. Columbia, MO: Instructional Materials Laboratory.

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

Darling-Hammond, L., & Youngs, P. (2002, December 1). Defining "Highly qualified teacher": What does "Scientifically-based research" actually tell us? *Educational Researcher, 31*(9), 13-25.

Dugger, W.E. (2000). *Standards-based reform for technology education*. In E. Eugene Martin (Ed.), Technology *education for the 21st century: Forty-ninth yearbook of the Council on Technology Teacher Education.* (pp. 133-138). New York, NY: Glencoe McGraw-Hill.

Etkina, E. (2005, Fall). Preparing tomorrow's physics teachers. *Forum on Education of The American Physical Society.* Retrieved from http://units.aps.org/units/fed/newsletters/fall2005/preparing.html

ETS (2007). *The praxis series: Teacher licensure and certification.* Retrieved from http://www.ets.org/portal/site/ets/menuitem.fab2360b1645a1de9b3a0779f1751509/?vgnextoid=48c05ee3d74f4010VgnVCM10000022f95190RCRD

Fortier, J. D., Albrecht, B. D., Grady, S. M., Miller, K. D., & Starkman, K. J. (1998). *Wisconsin's Model Academic Standards for Technology Education*. Retrieved https://dpi.wi.gov/sites/default/files/imce/standards/pdf/teched.pdf

Garner, R. (2005). Humor, Analogy, & Metaphor: H.A.M. it up in teaching. *Radical Pedagogy, 6*(2).

Glass, G. V. (2002). Teacher characteristics. In *School reform proposals: The research evidence* (pp. 8.1-8.28). Greenwich, CT: Information Age Publishing, Inc.

Greer. D.E. (2000). Teachers for tomorrow. In E. Eugene Martin (Ed.), *Technology education for the 21st century: Forty-ninth yearbook of the Council on Technology Teacher Education.* (pp. 141-146). New York, NY: Glencoe McGraw-Hill.

Hill, R. & Wicklein, R. (2000). Great expectations: preparing technology education teachers for new roles and responsibilities. *Journal of Industrial Teacher Education*. *37*(3).

Ingersoll, R. M. (2007). The preparation and qualifications of the teaching force in the United States. In R. Ingersoll (Ed.), *A Comparative Study of Teacher Preparation and Qualifications in Six Nations* (pp. 95-106). Philadelphia, PA: Consortium for Policy Research in Education.

International Technology Education Association (ITEA). *Middle & High School Teacher Excellence Award - General Information*. Retrieved from http://www.iteaconnect.org/Resources/AffilRepBook/MSHSTeacherExc.pdf.

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

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

International Technology Education Association (ITEA). (2003). *Programs for the Preparation of Technology Education Teachers.* Reston, VA: Author.

International Technology Education Association/Council on Technology Teacher Education/National Council for Accreditation of Teacher Education. (2003). *ITEA/CTTE/NCATE curriculum standards.* Reston, VA: Author.

Kemp, W.H, & Schwaller, A.E. (Eds.). (1988) *Instructional strategies for technology education: Thirty-seventh yearbook of the Council on Technology Teacher Education.* New York, NY: Glencoe McGraw-Hill.

Lee, S. S. (2002, March 14-16). Development of technology teacher education certification examination in Taiwan. Paper presented at the annual conference of International Technology Education Association Columbus, OH

Martin, E. (Ed). (2000). The new millennium: a time for change. In E. Eugene Martin (Ed.), Technology *education for the 21st century: Forty-ninth yearbook of the Council on Technology Teacher Education.* (pp. 231-235). New York, NY: Glencoe McGraw-Hill.

McGraw-Hill. (2007) *FolioLive.* Retrieved from http://www.foliolive.com/

Morgan, C. (Visiting Scholar and Senior Educational Development Advisor). (2003). *The qualities that make a good teacher.* Teaching and Learning Centre.

National Association for Sport and Physical Education (NASPE). (2007). *What constitutes a highly qualified physical education teacher?* [Position paper]. Reston, VA: Author.

National Council for Accreditation of Teacher Education (NCATE). (2007). *Program standards and report forms: technology education.* Retrieved from http://www.ncate.org/public/programStandards.asp?ch=4

National Research Council (NRC). (2001). Educating teachers of science, mathematics, and technology. Washington, DC: National academy Press.

New Mexico Public Education Department. (2007). *Competencies for Entry-Level Technology Studies/Education Teachers.* Retrieved from http://www.sde.state.nm.us/newthismonth/dl07/ProposedRuleChanges/6.64.16.pdf

New York State Education Department. (2003). New York State Teacher Certification Examinations. Author.

Petrina, S. (2007). Advanced teaching methods for the technology education classroom. Hershey, PA: Information Science Publishing.

Polich, S., & Goodell, Z. (2007). Sidebar: Characteristics of an effective teacher. In *New faculty resources.* Retrieved from http://www.vcu.edu/cte/resources/nfrg/09_05_characteristics_effective.htm

Ritz, J.M., Dugger, W.E., & Israel, E.N. (Eds.). (2002). *Standards for technological literacy, The role of teacher education: Fifty-first yearbook of the Council on Technology Teacher Education.* New York, NY: Glencoe McGraw-Hill.

Rogers, S. & Rogers, G. E. (2005). Technology education benefits from the inclusion of pre-engineering education. *Journal of Industrial Teacher Education, 42*(3), 88-95.

Scarella, J. A. (2007). *Engineering and technology education teaching tips.* Retrieved from www.acteonline.org/about.division/ete_teachingtips.cfm

Schwaller, A.E. (2000). Knowing where you're going! In E. Eugene Martin (Ed.), *Technology education for the 21st century; forty-ninth yearbook. Council on Technology Teacher Education.* (pp. 189-193). New York, NY: Glencoe McGraw-Hill.

Texas State Board of Educator Certification. (2007). *Texas educator certification program.* Retrieved from http://www.texes.ets.org/

Thompson, S., Greer, J.G., & Greer, B. B. (2004). Highly qualified for successful teaching characteristics every teacher should possess. In *Essays*. Retrieved from http://www.usca.edu/essays/vol102004/thompson.pdf

U. S. Department of Labor, The Secretary's Commission on Achieving Necessary Skills. (1991). *What work requires of schools, A SCANS report for America 2000.* (DOC Publication No. PB92-146711). Springfield, VA: National Technical Information Service.

Warner, S.A. (2003, December/January). Teaching design: taking the first steps. *The Technology Teacher.*

Perspectives on the Future of Technology Education

Presented at the 94th Mississippi Valley Technology Teacher Education Conference, 2007, Chicago, IL

Chapter 9

Barry N. Burke
International Technology Education Association

Introduction

The future of the profession and technology education as it is known today may undergo significant changes in the next ten years. As history has shown and as the current educational climate dictates, the profession has adapted and/or adopted changes in content and philosophical understandings. Federal and state efforts to improve schools (school reform) through *No Child Left Behind (NCLB)* has, and continues to have a major impact on the educational landscape. The traditional certification methods for teachers in the profession is changing rapidly as school districts experience a critical shortage of teachers for technology education classrooms and other subject areas. Has the profession adequately addressed the concepts of *NCLB*? High school reform? Assessments? Standards-based instruction? Professional development through learning communities? As education continues to look at standards and assessment as the impetus for school reform initiatives, the technology education profession has but one choice to either get involved or face extinction.

Does the Past Predict the Future? What will Technology Education Look Like in 2017?

In the last 30 years, technology educators have experienced the transition from industrial arts to technology education. In 1985 the American Industrial Arts Association changed its name to the International Technology Education Association. The transition in the classroom at first clearly seemed to be a change in name – but not much action in terms of the way content was delivered. The field continued to teach content through hands-on learning, using the construction of artifacts as the primary source of learning. In the early 1990's and with the introduction of the *Rationale and Structure for the Study of Technology* (ITEA, 1996) a movement began to take hold that integrated the concepts of mathematics and science while solving authentic problems. This problem-solving approach was embraced by some – but did not take the nation by storm. By the end of the 1990's, teachers being hired to teach the hands-on, minds-on approach to problem-solving were often re-trained by school districts to implement a new "*technology challenge*" approach to learning. Some school districts found that teachers from technology teacher education institutions embraced this methodology, while others hardly addressed the process at all.

With the release of the Standards for Technological Literacy (ITEA, 2000, 2003) and Achieving Excellence in Technological Literacy (ITEA, 2003), the content for the study of technology made its debut. School districts began looking for teachers that could implement this content. As in the 1990's, it was clear to some districts that many of the new teachers being hired understood the *Standards for Technological Literacy*, and that much progress was made that showed that they could teach the technological problem-solving process. However, a new problem, which began in the late 1990's, and continues today, is the shortage of new highly qualified teachers able to deliver technological literacy. Enterprising states began to implement emergency certification procedures that allowed architecture and engineering degrees to count as the content for Technology Education. What started out as a stop-gap measure turned out to be productive and perhaps began a transition to yet another development in the profession. However, while these architects and engineers were experts in the content, they did not always understand education – or the developmental needs of children. Even so, this certification/teacher shortage solution unknowingly provides insight and a predictor of the future.

The Present – A Profession in Transition and Searching for an Identity

Looking at the present, the profession looks to be in transition and is clearly searching for an identity. With the release of the *Standards for Technological Literacy* (ITEA, 2000, 2003) there has been a great deal of emphasis placed on standards-based curriculum, instruction and assessment. However, in seven years only a handful of teachers nationwide appear to be implementing standards-based instruction, while a significant number are implementing instruction that would be considered standards-reflective. With each passing year, more and more schools are looking for ways to improve student achievement, and technology education provides an environment that seamlessly uses problem-based learning to enhance student achievement in mathematics and science.

What is most alarming about the present is the rate at which programs in schools and technology teacher preparation departments are closing. For a profession that is constantly defending itself (do you mean "computers?"), competing for facility space, program funding, and continually in search of qualified and certified teachers, it is a slippery slope for which the current educational landscape has no patience. After so many years of two or more teachers in a school, most schools have reduced the staff to one teacher, or closed the program altogether because of the lack of teachers that are a "fit" for the school improvement plan. At the same time, school reform/improvement efforts are desperately trying to change the way schools are organized, and technology educators are often unprepared to cope with this change. Not all is lost. School reform/improvement efforts have been creating smaller schools around career themes, and academies that focus on blending instruction across content silos. With this in mind, technology education professionals play an important, if not critical role in school redesign. Embracing these reform efforts continues to change how educators view the profession, including how technology educators view workforce development. Many in the profession view workforce development as vocational education and must not interfere with the content of study of technology. While this point of view may not be valid in the current educational landscape, it does provide the opportunity for technology education to take the lead on preparing students to be technologically literate citizens. What does the workforce require of schools? It is easily argued that having workers that can use, manage, assess and understand technology is a need for the global workforce of tomorrow.

There are other forces at work in the profession. With the introduction of online learning in the early 2000's, degree programs are available in the convenience of one's home. The profession, long committed to the use of tools and equipment struggles to understand how teachers can be prepared to teach technical skills and earn a degree using this new method. Furthermore, there is a struggle to understand how online learning can be used when it will replace a teacher in the classroom. Perhaps over time the strategy will be embraced and enhance the way that technology education content is delivered.

Technology improves online course popularity

New technology is transforming once staid online classes. In the fall of 2006, 3.5 million students were taking online classes and while much of the growth is at the college level, nearly half of high school students and about a third of middle school students are interested in enrolling in courses online that are not offered in their own schools (Berger, 2007; Regan, 2007).

No Child Left Behind (NCLB) has brought data driven decision-making to the forefront of school improvement. Scores on state assessments – and improving those scores consumes school districts and states. Meeting *adequate yearly progress* (AYP) so as to not be designated as under-performing, has schools focusing resources and staffing. Because, under *NCLB*, children in schools that struggle year after year can move to better-performing schools there is continued pressure to provide a highly rigorous program for *all* students.

Far more intriguing is the fact that engineers and architects are now being certified to teach within the discipline. No longer is the technology teacher education pathway the only path by which a teacher can be certified. Some states have implemented emergency certification procedures that allow career changers to receive their teaching certificate. This change alone has schools and districts re-thinking program closures – citing the mathematics background of architects and engineers as a way to find highly qualified teachers in areas of critical need. Teacher shortages continue, but not to the same level as the early 2000's because of the alternate licensure route.

The philosophical debate of the present continues to be in the name and the influence that engineering has on the profession. Some argue that the profession is pre-engineering. After all, the National Research Council of the National Academy of Sciences and a special focus group of engineers from the National Academy of Engineering passed a rigorous review of the *Standards for Technological Literacy*. In early 2000, the National Academy of Engineering issued a report in support of the Standards (Dugger, 2004). The dilemma of the profession vacillates between accepting engineering as an integral component of technological literacy, to change the name to reflect engineering concepts and whether engineers will embrace technology education as the place in the educational landscape that can develop the next generation of engineering majors and engineers. “Engineers. There are 400,000 of them, but they are in acutely short supply” (Compton, 1951).

This recurring theme makes one wonder what can be done by technology educators that has not been tried in 56 years. Using the little “e” (as a verb) to describe the way engineering concepts are taught to all children is one way that technology educators can address this issue. If thoughtfully planned and implemented, it addresses the needs of Engineering with a big “E” (used as a noun). That is to teach students to pursue Engineering as a career.

The debate and energy behind creating STEM (Science, Technology, Engineering and Mathematics) and/or TIDE (Technology, Innovation, Design and Engineering.) programs continues to take center stage. The engineering community as well as corporations that focus on innovation for their bottom line have made significant efforts to work in schools and work politically to create new educational and legislative programs. STEM centers are taking shape throughout the country with funding to increase the number of students entering engineering schools. While these centers are creating their infrastructure, they are engaging schools, school districts, post-secondary institutions and the business community to strengthen STEM. However, one important ingredient to success is not always considered. Often, the technology and engineering are not included, making the initiative all about more mathematics and science. In the report *Preparing for the Perfect Storm* (Coppola & Smith, 2007) the following findings and recommendations emerged as a result:

- An overarching STEM framework is needed to map standards, programs, and curricula at the K–12 and undergraduate levels to critical skill needs.
- A strong focus on design, a core part of engineering, must become integrated into academic instruction at the K–12 and undergraduate levels. Learning design is a means by

which students can learn innovation. It is also a motivator that uses discovery, exploration, and problem-solving.

- Global engineering approaches, being used by business and government professionals, must be integrated into academic preparation at the K–12 and undergraduate levels. Students need to learn how to work collaboratively in geographically distributed teams to prepare for their roles in a global economy.
- Employers want technicians and engineers with excellent academic preparation and 7–10 years of real-world experience. Providing real-world opportunities for K–12 and undergraduate students could cut workforce preparation time by a decade.
- While it is important for all students to be technologically "literate," for the United States to succeed in a highly competitive global economy, we should aim to have all students become technologically "fluent."
- Rigorous research-based approaches to teaching and learning should be the foundation of K-12 and undergraduate T&E programs.
- Traditionally underrepresented groups, including women and minorities must be engaged and recruited into T&E jobs to have enough people to meet the workforce needs, to spark creativity and innovation through diverse perspectives and approaches to problem-solving, and to communicate and connect with various partners, clients, and members of the supply chain in a global economy. Programs should be designed to involve these populations.
- Assessments and certifications are needed to create a baseline and to benchmark achievements toward our national STEM workforce goals (pp. 16).

All of these issues have shaped the past and the present and provides background for a Perspective on the *future*.

Perspective on The Future – What will technology education look like in 2017?

As discussed previously, technology education is going through a transition phase. In 10 years, the profession will continue to go through some transition, after all, changes in education take 10-20 years. Predicting what technology education will look like 10 years from now is much like trying to identify what careers will be "hot" in 10 years. Who would have thought in 1967 that in 2007 people would buy bottles of water, or that almost every person in the United States would carry a portable cellular phone, or that technology would enable a global economy? The contention here is that the rate of change continues to multiply and 2007 – 2017 will hold some of the same surprises as 1967 – 2007. What follows is a perspective on the future that links yesterday's lessons and today's issues.

Perspective #1 – Technology Education Programs Change (for the most part)

Programmatic changes. Programs that deliver rigorous technological literacy / engineering concepts will survive the windstorm of activity that existed in 2007. The name will change to provide the public with a clearer view of the content of the profession from *technology education* (TE) to *design & engineering (DE)*. The debate between the content for the study of technology and the use of technology to deliver instruction will have come to an end. Programs will have a strong relationship to standards, focusing on the knowledge *and* skills needed for students to use, understand, manage and assess technology. Schools finally get the message that stand-alone courses do not make a program and begin to add staff (but not facilities) to support the revitalized program. As a result, teachers link with the community to identify meeting sites for students to develop *Innovation, Design & Engineering Application Skills* (IDEAS).

Innovative practices. In addition to the name, innovation will be valued in the profession and by communities that are screaming for the *design & engineering* curricula in their schools and districts. Research from 2008 – 2015 has identified *design & engineering* as the primary source for improving student achievement in mathematics, science, and English/language arts. Corporations and chambers of commerce make a strong connection between the authentic problem-based curriculum and workers that have a commitment to ethics, community and the future of the company – strong *IDEAS*.

Classrooms and technology teacher education programs will be looking at different delivery models than were used in 2007. *Blackboard*®, *Moodle*® or other online delivery classware are used to communicate with students – with teachers meeting with their students three or four times a semester. Those classroom facilities that do survive look dramatically different, including an emphasis on virtualization, modeling and simulation. Research and design hubs link virtual design labs with schools across the country. Global design and modeling, long used in industry to design products is implemented through major funding by companies that focus on innovation for defense, homeland security, and consumer products. A very high value will be placed on design, and how we help students and teachers "design tomorrow" (Hansen, 2007).

Same old, same old! Some programs will look identical as they do today. It would be important to note that these programs look the same as they have for the last 30 years.

Perspective #2 – Technology Education Teachers – Demographics

Certification procedures change. With the closure of technology teacher education programs, and with schools having found a renewed emphasis on *design & engineering* programs, state certification departments take drastic measures to ensure a continued flow of highly qualified teachers. Very few universities continue to offer a program to prepare teachers beyond the virtual degree program. Focus has shifted from certifying up and coming new teacher candidates to retraining the retiring workforce to utilize online learning to become teachers. The percentage of women entering the profession will increase to the point where there are an equal percentage of males and females teaching the *IDEAS* content.

Online certification. Pilots and doctors go online to re-certify most of their skills. Teachers will utilize this same web-based modeling and simulation environment to certify and re-certify as highly qualified. Post-secondary institutions quickly catch on (as much as anything in education is "quick") and offer teachers a host of online certification and re-certification opportunities. Teachers find the online professional learning community to be the place to maintain contact with others to continually upgrade and hone their knowledge and skills.

Workforce sharing of teachers. The workforce, noting the critical shortage of teachers begins sustaining a practice that began in the 1990's, where it provided qualified employees to schools for ½ days. The practice guarantees that students are receiving instruction around *IDEAS* that their future employers require. Because education is always one or two generations behind industry when it comes to technology, this infusion of high-tech knowledge helps jump start students to consider *IDEAS* and the possibility of teaching as a career. The most intriguing construct of this model is that the teacher communicates with students from the local school, the school district, across the United States and internationally from the desk at his or her own jobsite. Once a week, the teacher (or rotating teacher from the home school district) holds a school-based videoconference where students and on-site teachers are able to communicate visually and clarify important or more difficult concepts.

Same old, same old! Teachers look the same, teach the same – have not changed in 50 years.

Perspective #3 – Educational infrastructure changes

School reform initiatives result in changes to the school infrastructure. Given the continued emphasis on school reform/improvement significant progress has been made towards breaking down the barriers (silos) between content areas. It is quite feasible that high schools will begin to find themselves in an organization that mirrors middle school than the departmental silos currently in place. In this organization, *IDEAS* through *Design & engineering* is team taught at the school and via online learning. However, the teacher is responsible for students from outside the school, the school district, the state and the country, making the *Design & engineering* program using internet social networking as the basis for global design. *YouTube* and *MySpace* become the preferred method of teaching learning communities for the future.

Despite early failures in the smaller schools' federal grant program, a new initiative based on creating a greener future will be similar in nature. Schools will look at themes that will sustain earth, and organize schools around singular themes, with all teachers leaving their silos to co-teach conceptual knowledge and skills that will yield the most innovative solutions to technological problems to date. Without the barriers of time and space, these future citizens will make informed decisions about the use, management and assessment of technology. *Design & engineering* teachers find this new infrastructure a comfortable fit, and, after 30 years, move up the career ladder in schools to administration where they maintain high visibility for the re-engineered profession. These leaders also become the next generation of university personnel, linking practice, supervision, and pre-service to the actual needs of educators.

Same old, same old! Seven period day, silos for each department, same facilities with students continuing to build artifacts to support the crafts economy. Nothing has changed in 50 years!

Perspective #4 – Technology Teacher Education and Technology Education Supervision

The need? Will there still be a need for technology teacher education? In the *design & engineering* model, teachers implementing *IDEAS* from remote desktop locations changes the way teacher educators and supervisors provide pre-service and in-service training. Pre-service training will focus more on the developmental needs of students, online safety and security, virtual knowledge and skills (modeling and simulation) rather than technical skills (which the new breed of teachers will have). A need will still exist to provide endorsements for teaching certification, and it is provided in a different context using technological strategies.

TIDE / STEM. The impact of TIDE and STEM legislation will provide technology teacher education programs the opportunity for major curriculum projects that focus on *Design & engineering* and *IDEAS.* Over time funding opportunities had diminished, and with renewed interest by legislators and business and industry, collaborative curriculum, pre-service and in-service projects take on a different structure than they had in the past, using online and virtual communities to leverage the large numbers of teachers that will be trained and the geographic diversity that will be managed.

Design. Design will transcend the issue of STEM in the long term. While the profession debated the changing of its name from technology education to engineering (or some derivation of engineering) design and innovation is the subset that bubbles to the top of most lists. The corporate community embraces design and innovation (back in 2012) and education, always lagging behind, looks seriously at how design and innovation contribute to engineering, and the long-term effects for the economy and the marketplace.

Same old, same old! Some programs – if they survive the shakeout, will look the same in 2017 as they looked in 2007. Same old, same old!

Closing Perspectives

As the profession transforms itself for the future, teachers, teacher educators and supervisors, finally (after 50 years of same old, same old) understand the "New Reality." Survival is not about saving teacher jobs but about what is good for students and the global workplace. As the corporate world would say "it is about the future and the bottom line – not about saving jobs! It is about sustaining life in a global environment where the target changes daily and not about saving teachers in "silos." They might also say that we should be thinking about how we implement a new piece of legislation or mindset called "*No Design Left Behind" (NDLB)* that the "ingenuity of children is untapped, unrealized potential, that when properly motivated will lead to the next generation of technologists, innovators, designers and engineers" (Burke, 2006).

References

Berger, J. (2007, October 31). The classroom of the future is virtually anywhere. *The New York Times*. Retrieved from http://www.nytimes.com/2007/10/31/education/31education.html?WT.mc_id=SmartBriefs-Newsletter&WT.mc_ev=click&ad-keywords=smartbriefsnl

Burke, B.N. (2006) *Engineering byDesign™, A national standards-based solution for delivering technology, innovation, design & engineering,* Reston, VA.

Compton, K.T. (1951). Engineers. *Scientific American,* 185(3), 65-68.

Coppola, R.K., & Malyn-Smith, J. (2006). *Preparing for the perfect storm, A report on the forum, taking action together: Developing a national action plan to address the "T&E" of STEM*. Reston, VA: PTC-MIT Consortium.

Dugger, W.E. (2004). *A historical perspective of ITEA's Technology for All Americans Project*. Reston, VA: International Technology Education Association.

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

ITEA (2006) *Technological literacy for all: Rationale and structure for the study of technology*. Reston, VA: Author.

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

ITEA (2003) *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards.* Reston, VA: Author.

Regan, T. (2007, October 31). Online learning grows more popular. *Christian Science Monitor*. Retrieved from http://www.csmonitor.com/2007/1031/p17s01-stct.html

STEM Education: The Potential of Technology Education

Presented at the 95th Mississippi Valley Technology Teacher Education Conference, 2008, St. Louis, MO

Chapter 10

John G. Wells
Virginia Tech

Disciplinary perspectives on science, technology, engineering, and mathematics (STEM) education afford an opportunity for insights into how these respective fields of education view their roles in the schooling of American children within the current context of STEM education reform. In each case one must first recognize that these Mississippi Valley Technology Teacher Education Conference responses are but microcosmic perspectives in that they are based on limited time and resources. And as a result, though drawn from valid sources, their interpretations are therefore subject to disciplinary bias. In an effort to address these limitations and challenges to presenting the Technology Education perspective on STEM education, an intentional effort was made to corroborate data gathered through a broad sweep of valid sources, including published reports and articles, research results from personal projects and courses, and personal experience gained from more than three decades of teaching, integrating, and learning about science and technology education with students PreK-20.

A Century of Educational Reform – Prelude to STEM Focus

World economies, international connections, rapid continuous technological changes, the explosion of available information, threats to national security, and a plethora of other pressures are all forcing education to rethink how teaching and learning take place in the current educational system and to search for new, effective approaches to schooling. The promise of establishing STEM education as an educational reform movement portends some novel educational concept having the potential for affecting change in the educational process. The underpinnings of STEM education in the US however, are not at all new.

The current focus on STEM education is following literally decades of educational reform initiatives throughout the past century beginning as early as 1892 when the National Education Association established the Committee of 10 to study schools and recommend standards for secondary education (NEA, 1894; Ravitch, 2000). As it was at the turn of the 20th Century, the main causes of educational reform continue to be large societal changes brought about by real and/or perceived threats to America economically (trade and industrial preeminence), politically (global perception/power), and maintaining its national security. Understanding this history of American educational reform is relevant to envisioning the potential that resides within STEM education reform today, regardless of the disciplinary perspective, to meet the challenges this country will face in the coming decades. As we consider STEM education in the context of schooling in America, how can the past 100 years of educational reform help us in knowing what education today must do to be successful in addressing the economic challenges of tomorrow?

According to Berube and Berube (2007), the 20th Century could easily become known as the *Age of Educational Reform*. Their review of American educational history reveals that there have been only three main educational reform movements –

Progressive, Equity, Excellence – over the past 100 years spanning all of the 20th Century with continued impact now extending into the 21st. These movements were accompanied or driven by large societal forces external to the educational realm. An examination of the driving forces behind these three main educational reform movements provides insight into the extent to which they have shaped and continue to direct the current focus in America on STEM education.

Originating in the 1890s and extending midway through the 20th Century, the first main reform initiative was the *Progressive Education Movement* which envisioned schooling as an instrument for achieving wholesale social reform (Ravitch, 2000). Educationally, this movement expressly sought to challenge the long-standing traditional academic curriculum and replace it with a new liberal education curriculum that would more completely educate the whole child. John Dewey is considered the lead proponent of the Progressive movement and championed its main theme of applying social science to the educational process. The belief was that social science could elevate education to a science with its own set of methods and measurable ends. Fundamental to this movement was the philosophy of child-centered education, where both methods and ends could be derived from the innate needs of the child as reflected in the broader societal needs. The end of the Progressive movement came in the late 1950s when the launching of Sputnik focused attention on education as the weak link in maintaining national defense and US technological dominance. The child-centered curricula gave way to one that was designed to be much more teacher-centered, with an emphasis on science, mathematics, and foreign language content.

The early 1960s saw the birth of the civil rights movement, which took over as the dominant societal force and focused attention on the inequities within the American educational system. The result was the onset of the *Equity Reform Movement*. The aim of this second main educational reform initiative was to fulfill the progressive agenda by more completely educating the child and ensuring an equal education for the poor and disadvantaged. The civil rights movement of the 1960s and 1970s resulted in the passage of certain key legislation such as the Elementary and Secondary Education Act (ESEA, 1965), Title I, and Head Start that directly addressed inequities in education and continue today through the reauthorization of No Child Left Behind (NCLB, 2001). These brought about changes in American schooling through innovative programs that demonstrated long-term success in educating the poor. However, as the 1970s drew to a close the goal of educating the poor began to fall from political favor and was replaced with the Back to Basics movement. Attention was now shifting to the need for students to learn more content, moving education toward reestablishing excellence within a set of core subjects.

The *Excellence Reform Movement* represents the third and final main educational reform movement and is responsible for reestablishing content as the primary curricular focus within US public education. A quarter of a century ago the *Excellence* movement got its start when America was shaken from complacency by the realization that in the face of increasing foreign competition it was losing its global economic dominance. It was the landmark document *A Nation at Risk: The Imperative for Educational Reform* prepared by the National Commission on Excellence in Education (NCEE) in 1983 that launched this movement. In its opening sentences the NCEE claimed that "Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world." The report was written as a political document placing blame for the country's fall from dominance squarely on the soft pedagogical practices of the American educational system by claiming "Our society and its educational institutions seem to have lost sight of the basic purposes of schooling, and of the high expectations and disciplined effort needed to attain them." This political document challenged long-standing national educational practices and called for society, its people and schools, to become committed to achieving excellence in all of education. At this point the agenda was set for the *Excellence Reform Movement* and focused all national education efforts on the teaching and learning of content as the corrective measure for solving the problems in schooling created by the first two movements. The content targeted represented a rather narrow band of the overall curriculum placing the primary emphasis on science, technology and mathematics. It was believed that this renewed attention on the teaching of content within these disciplines would lead the nation to achieving the excellence needed to compete globally. In retrospect, the nation had come full circle. The return to an educational system that privileged content within a narrow band of the curriculum over educational process is the very issue challenged by the Progressive movement more than 100 years ago.

Since the beginning of the *Excellence* movement in the early 1980s, curricular reform has remained singularly focused on improving student content knowledge and understanding of science, technology, and mathematics. In 1989 a clear national direction for curricular change arose in the form of *Science for All Americans* (*SfAA*) produced through the efforts of Project 2061 (AAAS). This document, as well as the *Benchmarks for Science Literacy* (*BfSL*) that followed in 1993, provided the rationale and conceptual structure that all curriculum reform efforts should adhere to in their efforts to improve student interest and proficiency in science, mathematics, and technology (SMT). The unmistakable intent behind these AAAS publications was for curricular reformers to envision the teaching of these content areas as an integrative endeavor. This intent is clearly conveyed in their concept of science as being "…the union of science, mathematics, and technology that forms the scientific endeavor…" (AAAS, 1989, p. 25) and "…the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others" (AAAS, 1993, pp. 321-322). In the two decades following these AAAS publications each of the SMT education communities developed reform documents reflective of this intent. In practice, however, the schooling system continued to support separate programs and promote traditional approaches of teaching this content in isolation from one another. To this day the challenge remains for substantively bringing together isolated SMT programs within a structure that supports true collaboration and integration of content and practices.

The Lure of an Acronym

What's in an acronym? At first blush, looking at the overabundance of prior acronyms related to science, technology, engineering, or mathematics throughout the past quarter century, the answer to this question would appear to be straight forward. Historically, acronyms in and of themselves have not proved to be particularly effective in forging programmatic collaborations. In the past decade alone the number of acronyms related to these disciplines used by the National Science Foundation (NSF), arguably the largest facilitator of STEM education reform, is staggering. A small representative sampling (Householder, 2007) would include:

- IMaST (Integrated Math, Science, and Technology)
- ISE (Informal Science Education)
- ISTE (International Society for Technology in Education)
- MESA (Math, Engineering, Science Achievement)
- MSP (Math, Science Partnerships)
- MST (Mathematics, Science, and Technology)
- MSTE (Mathematics, Science, and Technology Education)
- Phys-Ma-Tech (Physics, Mathematics, and Technology),
- SIMaST (Students Integrated Math, Science, and Technology)

- SMET (Science, Mathematics, Engineering, and Technology),
- SMETE (Science, Mathematics, and Technology Education), and most recently
- STEM (Science, Technology, Engineering, and Mathematics)
- TSM (Technology, Science and Mathematics)

One obstacle to acronyms bringing together disparate programs is that interpretations vary considerably across constituents based on their specific needs or perceptions. The STEM acronym is especially problematic for promoting solidarity in educational reform because it allows each discipline to perceive and present itself as the focal point (S + T + E + M), and therefore perpetuate their traditional silo approaches to teaching and learning. In particular, the "T" in STEM continues to be misunderstood by mainstream America. Though the "T" was clearly understood to be about technological literacy when presented in the foundational SMT education reform documents (AAAS, 1989; AAAS, 1993; NRC, 1996; NCTM, 2000; ITEA, 2000) and equally so by major STEM funding organizations such as the NSF, the misperception remains strong. More surprising though, is finding that this issue can be problematic even within these supportive organizations as revealed through recent years of participation as an NSF reviewer. It is all too common for particularly novel approaches for promoting collaborative, integrative practices across math and science through design-based learning where the "T" is misunderstood and the proposal is therefore ultimately not supported during the review process. The "T" continues to be perceived by many panelists as instructional or education technology whose purpose is only to enhance instruction of science or mathematics. This issue was most poignantly demonstrated during a post review debriefing session when it became necessary to clarify for the audience of national experts in their respective STEM fields that the "T" represented a discipline in and of itself whose educational goal was technological literacy for all. Misunderstandings such as this are also easy to find currently being promoted by national organizations. One such example is the National High School Alliance (2008) who, when explaining what STEM education is, defines the "T" as the component:

> "that allows students to apply what they have learned, utilizing computers with specialized and professional applications like CAD and computer animation. These and other applications of technology allow students to explore STEM subjects in greater detail and in a practical manner."

As well, statewide STEM efforts such as those in Texas offer similar examples. The professional development efforts in Texas targeting technology and engineering are extensive and over the past few years have become well established through programs such as Texas STEM (T-STEM) Academies, MST Teacher Preparation Academies, and Engineering Summer Programs. Yet even within these efforts the "T" in STEM continues to refer strictly to instructional technologies, though recent recognition that it refers to technological literacy is expected to result in corrections to the misunderstanding (T-STEM PDI specialist, personal communication, October 15, 2008) The continued perception of the "T" being instructional technology is not surprising given that the primary use of technology in classrooms across America is still computer-based drill and practice, business applications, and information access via the web (Anderson & Ronnkvist, 1999). Furthermore, the STEM education reform movement as a whole is perceived by the general public to mean improvements targeting math and science education as indicated in recently collected state data (AACTE, 2007; ECS, 2008).

In June of 2007 the American Association of Colleges for Teacher Education (AACTE) published a report titled *Preparing STEM Teachers: The Key to Global Competitiveness* that profiled a select portion of teacher preparation programs across the nation meeting the critical need for better STEM teachers. Of the 59

STEM teacher preparation programs profiled within the 28 states included in the report, there were only 11 who together reported a total of 9 programs that specifically addressed the preparation of engineering or technology education teachers. By far, the majority (85%) of the 59 profiled programs were focused on preparing teachers of science and mathematics. As well, in a report by the Education Commission of the States one year later on STEM initiatives at the high school level (ECS, 2008), data gathered from state statutes, rules and regulations, and state education agency web sites showed science and mathematics content areas remain the primary focus. Specifically, data collected indicate that where STEM initiatives are present, they target predominantly math and science content and/or teachers: 38 states use financial incentives to recruit predominantly math and science teachers; only three states require end-of-course exams for technology or engineering; no schools reported technology or engineering teachers within their critical STEM shortages; Utah and Texas are alone in having STEM professional development (PD) for technology education or engineering. Despite nearly a decade of growing attention on the need to improve STEM education in America, the dichotomy continues between the nation's call for change and the ability of America's educational system to implement that change. For all practical purposes with respect to PK-20 STEM education in the US, at present the evidence points to business as usual. The educational practice in PK-20 STEM disciplines continues to maintain a predominantly "silo" mind set, singularly focused on mathematics and science. Yet despite these findings, there is still good reason to remain optimistic regarding the influence of the STEM acronym.

Ascertaining the effect of but one acronym among hundreds on bringing disparate programs together is not easily determined. The better question to ask might be "What cumulative effects can be found from the initiatives behind these acronyms in promoting collaborative approaches to teaching and learning among the

STEM fields?" Answering this question is more feasible and likely revealed through results of sustained efforts supporting the excellence reform movement these past few decades. One very recent and powerful indicator comes in the form of the "Enhancing Science, Technology, Engineering, and Math (STEM) Education Act of 2008" (eSTEM Act, H.R. 6104) that was simultaneously introduced in both the U.S. House and Senate in June of 2008. This "eSTEM Act" bill seeks to ensure America's global competitiveness through significant improvements in STEM education by:

- Raising to committee status the STEM Education Subcommittee of the President's Office of Science and Technology Policy with a mandate to design coherent national STEM strategies
- Create an Office of STEM at the U.S. Department of Education to coordinate STEM education initiatives nationally
- Establish a voluntary Consortium on STEM Education whose mission would be to develop common content standards for K-12 STEM education
- Create the National STEM Education Research Repository as a clearing house to promote replication of creative programs through open access to the latest innovations and best practices in STEM education

The intent of the eSTEM Act to bring coherence to STEM education at the program level is most clearly conveyed in its goal of developing common content standards for K-12 STEM education. Impetus for this goal comes from a number of sources, but most recently in March of 2008 through the publication of *Technology Counts 2008* by Education Week and the concurrent testimony by Bill Gates before the House Science and Technology Committee March 2008. In speaking to the committee Mr. Gates called on the nation to "identify a smaller set of clear, high and common state standards that reflect what young people truly need to know to be successful in the 21st century…" Both the mathematics and science education communities recognize and share in this need to establish more clearly defined critical knowledge sets. Of the six main charges to the mathematics community presented in the March 2008 final report by the National Mathematics Advisory Panel, the first was "The mathematics curriculum in Grades PreK-8 should be streamlined and should emphasize a well-defined set of the most critical topics in the early grades." (p xiii). The *Principals and Standards for School Mathematics* produced by the National Council of Teachers of Mathematics (NCTM, 2000) currently presents these critical topics as "Focal Points" through the *Curriculum Focal Points for Prekindergarten through Grade 8 Mathematics* (NCTM, 2006). The science community is taking similar action. In February, 2007 officials of the National Science Teachers Association (NSTA) recognized this same need for science education and began efforts toward identifying crucial concepts of the subject. Their goal is to establish "anchors" that reflect core ideas to be emphasized at each grade level (Cavanagh, 2007). It is of note that these science anchors will be drawn from both the 1993 Benchmarks for Science Literacy (AAAS) and the current *National Science Education Standards* (NRC, 1996). The efforts at the national level to create common K-12 STEM education content standards and to develop well-defined sets of critical topics in both mathematics and science that all students should learn are very strong indicators of movement toward the integrative concept of teaching STEM as envisioned by those who crafted *SfAA* and the *BfAA*.

An additional indicator of the momentum building toward STEM education program collaborations nationally is the extent to which funding is being provided at national, state, and local levels. The largest contributor of funds supporting STEM education in one form or another is the National Science Foundation (NSF). Their awards database (www.nsf.gov/awardsearch) clearly shows that NSF has had a long record of funding projects that target STEM education, and particularly in supporting secondary school STEM educators in upgrading both content and pedagogical knowledge in their fields since the mid-1950s (Vanderputten, 2004; Sherwood & Hanson, 2008). However, only within the last three decades have they funded projects that more purposefully address the educational connections between science, technology, and mathematics. At the state and local level, the growing momentum is highlighted by the National Governors Association initiative on *Building a Science, Technology, Engineering, and Mathematics Agenda* launched in February 2007 (NGA, 2007a), with significant support from external funding sources such as the Bill and Melinda Gates Foundation. The *Agenda* charged governors in every state to develop and adopt policies that would address three specific recommendations for promoting collaboration among key stakeholders at all levels in STEM education:

- Aligning rigorous and relevant K-12 STEM requirements to the expectations (inputs) of postsecondary education and the workplace
- Developing statewide capacity for improved K-12 STEM teaching and learning to implement that aligned STEM education and work system
- Supporting new models that focus on rigor AND relevance to ensure that every student is STEM literate upon graduation from high school and a greater number of students move onto postsecondary education and training in STEM disciplines.

To support governors in their efforts to adopt these new policies and promote new pathways for achieving STEM literacy at the secondary level, NGA awarded $500,000 grants to six states (Colorado, Hawaii, Minnesota, Ohio, Pennsylvania, and Virginia) to improve STEM education by establishing STEM Education Centers (NGA, 2007b). These are but two examples reflecting the trend and momentum of growing support for STEM education program collaborations in America. Can further evidence be presented to demonstrate that the umbrella acronym STEM is bringing programs together? As the list of select examples drawn from the NSF awards database provided in Table 1 below shows, the answer is a resounding ***yes***.

Table 1
Select Examples: K-12 STEM Initiatives

State	Date	K-12 STEM Initiatives
Arizona	1976 2004 2007	Women in Science and Engineering: experience latest imaging technology CTE program updates to align with state academic standards Bioscience High School: specializes in the sciences and related careers
Virginia	1985	Thomas Jefferson High School for Science and Technology: redesigned the school as an Integrated Biology, English, and Technology program
Illinois	1986 2004	Math and Science Academy: experimental laboratory model implementing new and experimental pedagogical techniques CTE/Vocational Centers – funding for pre-engineering programs (PLTW)
Delaware	1992 2003	Delaware Science Coalition – long term focus on math/science reform Increased HS graduation requirements in math/science
New Jersey	1993	Merck Institute for Science Education – focus on improving K-8 science
California	2000	Hi-Tech High: charter school emphasizing project-based program for science, math, and engineering
Massachusetts	2003	Smith Summer Science and Engineering Program: girls participate in precollege integrated STEM coursework Revised state high school education standards to promote the technology and engineering standards National Center for Technological Literacy created by the Museum of Science in Boston designed K-12 curricula, standards, and professional development for technology and engineering education; by 2010 all HS graduates must pass the Massachusetts Comprehensive Assessment System exam for Science and Technology/Engineering
North Carolina	2004	New Schools Project: focus on life-sciences, engineering, biotechnology, and information technology; goal to have Learn and Earn early-college high school sites in all 100 counties by 2008
Texas	2005	T-STEM initiative: Texas High School Project designed to create 35 specialized STEM academies through a mix of charter, traditional, and early-college high schools (T = instructional technology) UTeach at UT-Austin: professional development of secondary/postsecondary teachers
Maine	2006	CTE integration into state overall academic framework with emphasis on numeracy and literacy
Kentucky	2005	Interdisciplinary CTE courses developed to meet state academic course requirements (i.e. CAD/Construction address geometry standards)
Rhode Island	2005	STEM initiatives for revising new high school science curriculum (Physics First) to include dual-enrollment options
48 States & DC	2006	Nontraditional and Alternative STEM teacher certification programs (primarily focus on M/S)
Indiana	2007	Redesigned STEM high school models (focus is on math)
Minnesota	2007	Developing model programs in digital content and STEM remediation STEM high school requirements, that include dual-enrollment options Science/Math/CTE education teacher induction and mentoring program
Ohio	2007	Ohio STEM Learning Network (OSLN) created to provide $200 million to support PK-16 STEM initiatives statewide. All partners work together to share best practices and innovative ideas for STEM education.

These K-12 level national trends are impacting education personnel decisions at both the postsecondary and state levels. New postsecondary faculty hires are increasingly being made specifically to support new university STEM initiatives, and newly created STEM coordinator positions are being filled to oversee statewide STEM initiatives. University web sites reveal that program collaboration trends in STEM education fields are also evident in the increased number of mergers between technology education and engineering programs across the country such as:

- Utah State University: Engineering and Technology Education Department in the College of Engineering
- University of Southern Maine, Department of Technology in the School of Applied Science, Engineering, and Technology
- Purdue University: Engineering/Technology Teacher Education Program in the College of Technology
- Illinois State University: Department of Technology in the College of Applied Science and Technology
- Central Connecticut State University: Technology and Engineering Education Department in the School of Engineering and Technology

Attempts in the U.S. to systemically integrate the teaching and learning of content across the STEM fields have been made for decades without large scale success. However, the difference in today's reform efforts is an authentic readiness for change at all levels. The steady progress toward globalization finds economies of the world are increasingly interdependent, interwoven, and inextricably linked. The flat world concept (Friedman, 2005) of today recognizes the onset of a global reconfiguration where regional and geographic boundaries are increasingly irrelevant (Berube & Berube, 2007). Competition for flat world economies of tomorrow demands a workforce prepared for new STEM fields, and as has been the case many times before, education is seen as the means by which we prepare that workforce. Educational systems are historically reactive entities, and in the current environment of increasing economic competition and threats to national security, these systems have now reached a point of readiness for responding to and accepting new and innovative approaches to preparing the future workforce. Our educational systems of today were designed for a prior era and are ill equipped for preparing a future STEM workforce (NCEE, 2007). The challenge for the educational systems of today is their lack of capacity to make substantive changes that will lead to improved student learning in STEM fields. However, new systems alone cannot affect the changes needed in the classroom to improve student learning. Research over the past two decades clearly shows that the single most essential factor and strongest predictor of education's capacity to respond is the educator in the classroom (Darling-Hammond, 2000, 2002; Darling-Hammond & Youngs, 2002; U.S. DOE, 2007).

STEM Education and Pedagogies of Practice

Challenging the Norms

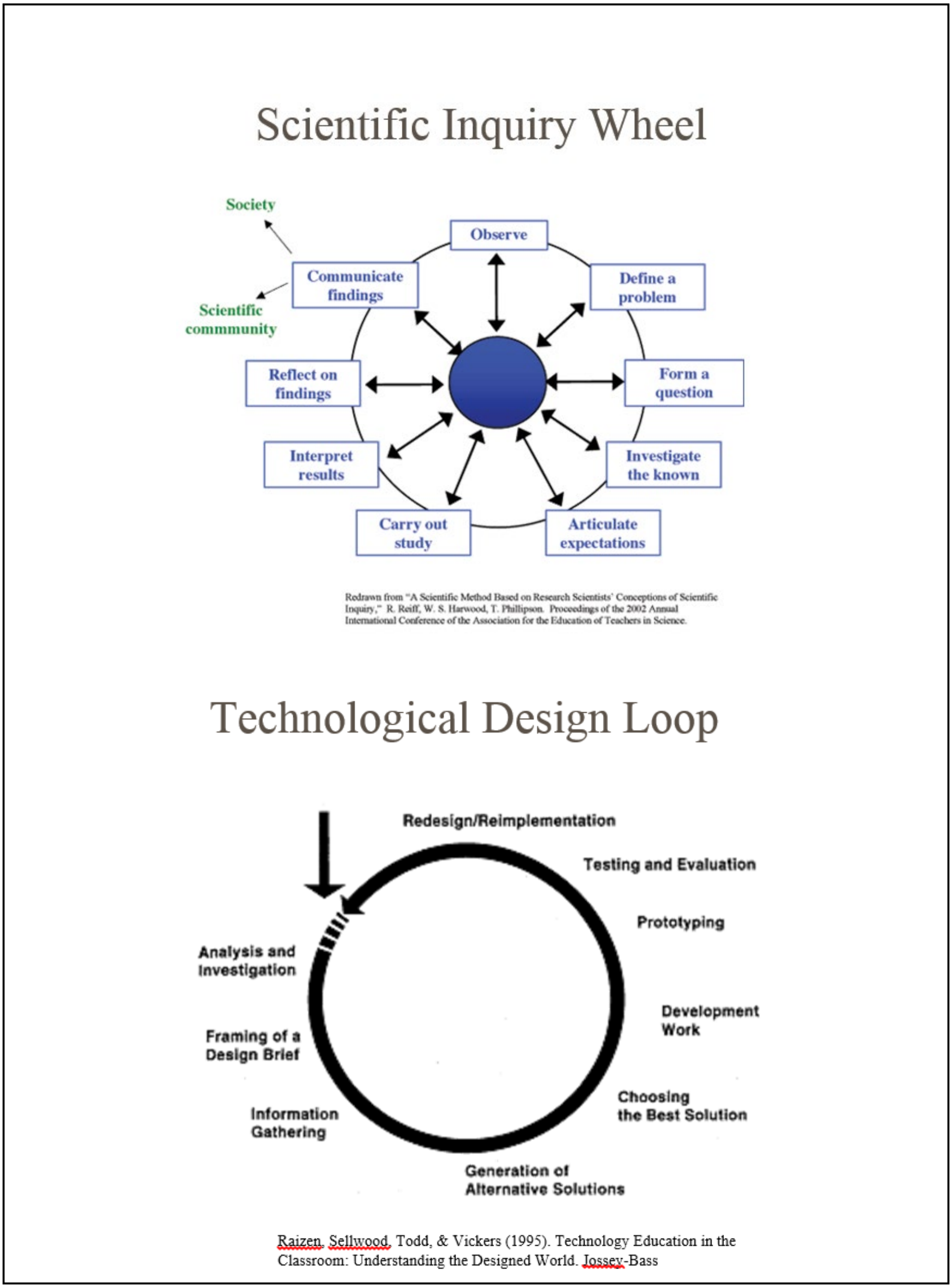
Ultimately students learn what their teachers teach them, and if the instructional approach used is one where content is fragmented and presented in isolation from other content then it will be learned that way (Humphreys, Post, & Ellis, 1981). Positively affecting students' abilities to transform knowledge into personally useful strategies for learning new content and concepts requires that teaching be improved in a way that promotes integrative strategies of student learning. This logic also begs the question "What *is* the integrative type of student learning we wish to bring about?" Cognitive science research supports the notion that *integrative* learning, as promoted through experiential education, creates the best opportunities for students to make connections in a manner that suits how the brain organizes information and constructs knowledge (Bruning, Schraw, Norby, & Ronning, 2004; Shoemaker, 1991). The brain continually searches for meaning within the patterns of information it receives and organizes that new knowledge by associating (scaffolding) it with meaning and understanding developed through prior experiences (Cromwell, 1989). Coupled with continued cognitive research on the importance of student-centered integrative instruction (Bransford, Brown, & Cocking, 2000), this provides a strong argument against the teaching and learning of isolated content and mere facts. Effective teaching presents content in meaningful contexts presented through instruction intentionally designed in a way that students will develop connections through experiences guided by purposeful inquiry.

Such findings are the very premise and rationale for integrative STEM education (Sanders & Wells, 2005), and support the argument that integrative teaching practices, those that are based on the intentional design of instruction guided by intentional inquiry experiences, avoid the fragmentation of isolated facts that typically have little relevance to overall student learning outcomes (Lipson, Valencia, Wixson, & Peters,1993). Recent research finds that students participating in integrative STEM classes are more motivated to learn because the relevance of what is being taught becomes apparent in the connections they see among the disciplines in real-life scenarios (Satchwell & Leopp, 2002). This exemplifies a growing body of research confronting stakeholders of pre-collegiate education, from policy makers to local schools, who are increasingly under pressure to do more toward equipping students to be competitive in the STEM fields (Education Week, 2008). As a result, nationally these stakeholders are now recognizing the need to find common educational ground for better preparing students PK-12 in the STEM fields.

Toward a Pedagogical Commons

The backdrop of increased state mandates to address No Child Left Behind requirements, concern for the lack of relevancy in PK-12 curricula, and the absence of STEM practices that promote student understanding of the interconnectedness of content and concepts across STEM disciplines is providing the impetus for collaboration among the STEM fields for preparing the workforce of tomorrow. A workforce whose knowledge base is more than a superficial understanding of isolated facts is required. The workforce of tomorrow must develop a knowledge base that reflects understandings of the relationships among disciplinary content that is essential for solving complex problems involving interrelated causes (Benjamin, 1989). Experts across the STEM fields increasingly view integrative approaches to teaching and learning as critical for taking the nation's STEM performance to the next level (Education Week, 2008). In the past two years, efforts in both the mathematics and science communities have begun to address this need through better alignment of national education standards across the STEM disciplines, with legislative support such as that provided by the eSTEM Act (2008). These efforts parallel one of the primary goals of the eSTEM Act for developing a set of common national STEM standards. Common standards will bring attention to instructional practices and alignment of pedagogical models across the disciplines. Movement in this direction is already apparent. Comparisons of pedagogical models (Fig. 1) presented by the respective STEM education fields, coupled with explanations of learning goals within their national education standards, clearly indicate points of intersect around student learning and understanding of connections, problem-solving, logic, inquiry, and design.

Figure 1. Comparison of science and technology education signature pedagogical models.



Among these models and instructional practices *integrative approaches* to teaching and learning STEM content and concepts are the pedagogical commonality.

Integrative STEM Education and Improved Learning

Integrative STEM education (I-STEM ED) is the exploration of teaching and learning strategies in the context of design-based instruction, and implemented among any two or more STEM subject areas (Sanders, 2006; Sanders & Wells, 2005). The pedagogical framework that supports this approach to teaching are instructional practices that intentionally couple design-based learning and scientific inquiry with the expressed intent of facilitating knowledge acquisition and transfer of STEM content (Wells, 2008; Sanders, 2008). Three instructional models, multidisciplinary, interdisciplinary, and transdisciplinary (Drake & Burns, 2004), have typically been employed for implementing integrative curricula. Calls for recognition of such integrative genre in technology education have been made before (Petrina, 1998), though transdisciplinary practices by those in the field are actually more the norm. The transdisciplinary approach addresses discipline-specific content at varying levels of complexity through focus on a central design-based problem. In so doing content is brought to bear by students on an as needed basis during the design process, which avoids the practice of presenting fragmented, isolated content in traditional approaches. In this way students recognize the relationships among the disciplinary content in relevant meaningful ways. Integrative STEM (I-STEM) education practice such as this demonstrates the parallelisms between design-based learning and scientific inquiry that create the opportunities for "border crossings" (Klein, 1996; Lewis, 2006). The design-based strategy as employed in technology education serves as the contextual bridge for integrative learning of STEM content. Ultimately integrative STEM education (I-STEM ED) fosters a blended pedagogical approach and establishes the curricular foundations that have been long supported by cognitive research. An example of this is found in a meta-analysis of 30 studies on integrative programs conducted in 2000 by Hartzler. Findings from her research revealed that students in integrative classrooms consistently outperformed those students in traditional classrooms on standardized tests and other measures. Evidence of such outcomes is similarly supported by results from research efforts to study project-based learning instruction by The George Lukas Educational Foundation (Drake, 2003; Furger, 2002).

Factors essential for effectively implementing I-STEM ED are embedded within the design of instruction. The process of instructional design must begin with the intention of teaching content connections and the explicit identification of content/concept learning outcomes for the targeted disciplines. There is no disciplinary claim for integrative approaches, but technology education is unique in that it affords the curricular flexibility and the instructional environments necessary for facilitating design-based learning (DBL). As a result, technology education presents the ideal educational platform for employing DBL designed to intentionally teach STEM content by engaging students in authentic learning that is guided by the method of scientific inquiry. Assessment is another critical factor in the design of integrative STEM education instruction. Every explicit learning outcome must be accompanied by an equally explicit assessment of that outcome. Assessment tools must align with criteria for what constitutes integrative practices on the part of the student. Assessment criteria are derived from established goals for integrative learning, and are incorporated as both formal and informal tools, at both formative and summative evaluation points (Miller, 2005). Instructional design and classroom practices of this caliber will challenge even the most seasoned educator. There are few models currently available for current practitioners to follow, and initial attempts will likely occur by individuals within their own classrooms. Most educators are not adequately prepared with sufficient science, technology, engineering, and mathematics content or pedagogical content knowledge necessary to teach multiple subject areas simultaneously (Warner, 2003; Zubrowski, 2002). Collaboration among STEM teachers therefore affords the most promise for implementing integrative practices.

Research on integrated curricula indicates that teacher collaboration and implementation require significant common planning time to accomplish integration (Shea, 1994). Shoemaker (1991) identified a set of essential components necessary to integrated curricula: recognized core skills and processes, curriculum strands/themes, major themes, guiding questions, unit development, and evaluation; all of which translate into attention specifically focused on the instructional design process, and where intentional design and inquiry are best facilitated by design-based learning methods. Instructional modifications to accommodate the integrative STEM approach could be in the form of two teachers working together to teach the same topic but separately in their own classes. Or it could be a team of teachers who design thematic units or courses redesigned around interdisciplinary units of study. Satchwell and Loepp (2002) found that collaboration among STEM teachers involving a common curriculum, problem-solving model, and assessment procedures was effective in promoting integration of STEM content and concepts, and facilitated students' transfer of knowledge across disciplines. However, regardless of how teachers chose to collaborate, the time necessary for collaboration was significant, and certainly any progression toward large-scale implementation of integrative STEM practices will require systemic changes at both school system and site-based levels.

Fostering New Approaches

Schooling: Infrastructures and New Design Initiatives

Building on decades of research in cognitive science on teaching/learning, today's focus on integrative STEM education clearly signals the need for re-conceiving schooling in America. The collaborative model of integrative STEM education where teachers work together on planning, teaching, and assessment develops common expectations of student learning across subject areas, which positively affects student performance. More than a decade ago Lipson (1993) identified a set of the positive effects resulting from integrative teaching and learning. He found that an integrative approach provides students the opportunity to *apply knowledge and skills*, fosters the *realization of connections* among content dealt with and leading to faster recall, helps students develop *blended disciplinary perspectives*, promotes both *depth and breadth of understanding*, cultivates *positive attitudes* toward learning, and affords students sufficient quality time to more *thoroughly explore* the curriculum.

New integrative teaching practices must be accompanied with new assessment criteria for appropriate evaluation of student performance (learning outcomes) within an integrative STEM education model. Authentic, design-based problems used to guide clearly defined scientific inquiry experiences requires the design and use of assessment tools that give a true accounting of student understanding of concepts from the integrative perspective. When programs commit to integrative STEM education where students are expected to achieve integrative learning goals, approaches to presenting integrative experiences must be intentionally designed to achieve those goals and have tools to assess student integrative achievements (Miller, 2005). Requisite of such assessment are well orchestrated plans designed to use guided inquiry (aka Design-Based Learning – product/artifact oriented) to target specific core concepts in two or more subjects. The use of designed-based learning methods best facilitates student learning and the understanding of disciplinary content/concept connections. This is not a new concept in education. Rather, it is an expansion upon research that originally identified best practices for engaging students and improve the learning process. Despite sufficient evidence supporting improved student learning resulting from integrative STEM education approaches, there remains the question of whether or not there are educators sufficiently prepared to develop and implement it.

It's About Teachers Not Programs

Are teachers being prepared to effectively teach STEM? From a traditional silo approach the answer is yes, but in ways that will achieve the holistic, integrative intent called for in the reform documents of the past quarter of a century (e.g., AAAS, 1989, 1993; ABET, 2000, ITEA, 1996, 2000; NCTM, 1989, 2000; NRC, 1996) the answer would be no. The major obstacles to changing traditional methods are current national/local education policies, schooling structures, and mechanisms for teacher preparation (Toulmin, 2008). Ultimately, the most significant changes needed are in teacher practices. Teacher expertise, as has been consistently and repeatedly supported through research, remains the single most important factor in facilitating student achievement (Darling-Hammond, 2000, 2002; Darling-Hammond & Youngs, 2002; U.S. DOE, 2007). It's about the teacher much more than it is about programs. Given the overwhelming evidence of the centrality of teacher quality to reform in American education (Darling-Hammond, Chung, Frelow, 2002; Darling-Hammond, 2007), why are teacher preparation programs still inadequate in developing teachers with the necessary STEM teaching expertise?

Our past perseveration on increasing teachers' content knowledge has not resulted in improved teaching abilities (Fennema & Franke, 1992). Instead, research finds that those teachers with more subject matter "methods" courses where they acquire the necessary pedagogical content knowledge (PCK) are more successful in promoting student engagement and improving learning (Darling-Hammond, 2007; Malcom, 2008). Furthermore, these methods are not the typical/traditional didactic strategies, but must include the type of hands-on/minds-on experiential learning required in design-based learning approaches. Wenglinsky (2002, 2000), using data from the National Assessment of Educational Progress (NAEP), found that student achievement goes up in both mathematics and science when teachers have specific professional development (pre/in-service) in hands-on teaching methods that target higher-order thinking skills. These findings argue strongly for the redesign of teacher preparation programs and other professional development efforts that provide the extensive PCK necessary for designing, developing, and implementing integrative STEM education instruction. There is also ample research evidence demonstrating the effectiveness of such programs for increasing teacher PCK and thus their teaching effectiveness, but there are few preparation programs providing this kind of professional development (Darling-Hammond, 2007 p 7; Darling-Hammond, Chung, Frelow, 2002; Monk, D. 1994). Needed are teacher preparation programs designed to involve pre/in-service teachers in joint curriculum and planning, modeling and demonstrating teaching strategies, and classroom coaching. This model for developing instructional expertise, and particularly integrative strategies, requires observation of expert teaching as demonstration of how new and/or veteran teachers are to practice, followed closely by opportunities to practice them with the expert's help (Darling-Hammond, 2007 p 8). Currently programs that ascribe to this model are the Professional Development Schools (PDS) where partnerships are established between university teacher preparation programs and PK-12 schools to design, develop, and demonstrate preeminent teaching practices. In the PDS model pre-service/novice teachers learn to teach within the classroom alongside master teachers while they are concurrently completing their university coursework. Similar to the teaching hospital concept, these pre-service teachers gain the classroom experience necessary for the scaffolding of information presented in the university courses. The PK-12/University *collaboratory* (Wells, 1999) that is created through professional development schools establishes teacher preparation environments that are uniquely positioned to create and foster the new approaches to schooling that directly address the need for *Reformed Education* (Wells, 2007, 2008). It is this *collaboratory* (Wells, 1999; Wells, Webb-Dempsey, & Van Zant, 2001) that forges the necessary common ground between university and PK-12 stakeholders leading to a reformation of teaching/learning practices in both settings.

Reformed Education – Incremental and Piecemeal

The true potential of STEM education reform lies in the opportunity to affect change in teacher practice. High quality research on instructional practices has not supported approaches that are either entirely "student-centered" or "teacher-centered." Such research indicates that student learning is best facilitated using a blend of strategies when and where they are most likely to have a positive impact under specified conditions (National Mathematics Advisory Panel, 2008). This is a basic tenant of I-STEM education, and the process by which *an educator* would develop an "integrative" pedagogy requires that they consider carefully their own teaching. Integrative instruction places the *teacher* in a position that requires them to reflect on what they actually do when teaching, and why. In so doing, the teacher must return to basic questions such as "Why have I chosen this learning objective, this strategy, and this particular technique?" What exactly am I expecting students to learn about connections among STEM content? If instruction is not explicitly designed to teach connections, such outcomes are unlikely to be achieved. Improving the design of instruction to be "intentionally integrative" (I-STEM Ed) learning holds the most promise for actually increasing the likelihood of improving student learning. Professional development for teachers, both pre-service and in-service, that establish classroom practices that include intentional design of instruction will result in teaching that is more than a series of activities, and where student learning is not left to chance. What this calls for is not educational reform writ large, but *Reformed Education* approached through well conceived and effective pre-service and in-service professional development programs. Reformed education is about recruiting and adequately preparing teachers with both the content knowledge and the pedagogical content knowledge necessary to implement the specific teaching strategies needed to effectively teach their content (Mehalik, Doppelt, & Schunn, 2005; Zubrowski, 2002).

Eyes to the Future

In the ideal sense that STEM education has been presented within the rhetoric of national reports and calls for action to advance U.S. economic vitality and national security, the current education system is by and large not designed to support it. Specifically, the intent conveyed in the past quarter century of reform literature calls for (STEM) education to be “integrative” in its approaches, but the reality is that of continued S + T + E + M taught alone and in isolation from one another; simply more of the same. To achieve the wholesale ideal would require sustained systemic changes in secondary schooling in the form of substantive restructuring of schooling to address known barriers such as: class scheduling to allow for common planning time, for teacher collaboration, team teaching, co-design of instruction, multi-modal testing (classroom and standardized), sustainable pre- and in-service professional development, and the redesigning of teacher preparation programs (Brown, 1997) that introduce new methods that promoted integrative design of instruction and true collaborations among STEM disciplines all working toward this common goal. Yet achieving these ideals is only likely if there is sufficient evidence to convince not only the policymakers and administrators (Malcom, 2008), but the practitioners themselves who would bare the burden of implementation in the classroom. Furthermore, change of this magnitude, if not done in concert with national/state policymakers and state/local administrations, will not provide the necessary infrastructure for establishing the I-STEM education approach. The potential does indeed exist, though currently there is no real evidence of commitment on the part of the U.S. educational system (Kadlec & Friedman, 2007).

Wholesale systemic changes in infrastructure, schools, and programs are long-term goals, and are not immediately necessary in order for reform to take hold. Incremental change is good for promoting *Reformed Education*, and a return to focusing on **the teacher** for improving the ability to teach well is a key starting point. Teacher quality is central to *Reformed Education*. Strategies for change that focus on improving teaching practices provide the greatest potential for improving learning outcomes in our PK-12 students – our single most important national resource. Technology education at the secondary school level has the teachers, the preparation programs, and an established PreK-12 presence. What we do not have are those preparation programs that develop classroom educators with the teacher knowledge needed for *Reformed Education*. Such educators are the transformative intellectuals needed to bring about this change (Berube & Berube, 2008).

References

ABET Engineering Accreditation Commission. (2004). A*BET criteria for accrediting engineering programs.* Baltimore, MD: ABET, Inc. Author.

American Association for the Advancement of Science (1989). *Science for all Americans.* Washington, DC: Author

American Association of Colleges for Teacher Education. (2007). *Preparing STEM teachers: the key to global competitiveness.* Retrieved August 28, 2008 from http://www.aacte.org/Governmental_Relations/AACTE_STEM_Directory2007.pdf

American Association for the Advancement of Science (1993). *Benchmarks for science literacy: Project 2061.* Washington, DC: Author.

Anderson, R. E., & Ronnkvist, A. (1999). *The Presence of computers in American schools.* Report No. 2. Ivinve, CA: Center for Research on Information Technology and Organizations, University of California, Irvine, and the University of Minnesota. Retrieved September 14, 2008 from http://www.crito.uci.edu/TLC/findings/Internet-Use/startpage.htm

Benjamin, S. (1989, September). An ideascape for education: What futurists recommend. *Educational Leadership, 47*(1), 8-16.

Berube, M. & Berube, C. (2007). *The end of school reform.* Rowman and Littlefield. Landham, MD.

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

Brown, C. & Smith, M. (1997). Supporting the development of mathematical pedagogy. *The Mathematics Teacher*, 90(2), 138-143.

Bruning, R. H., Schraw, J. G., Norby, M.M., & Ronning, R. R. (2004). *Cognitive psychology and instruction.* Columbus, OH: Pearson.

Cavanagh, S. (2007, February 28). NSTA to provide 'anchors' to winnow topics. *Education Week, 26*(25), 5-14. Retrieved March 6, 2007, from Academic Search Complete database.

Cromwell, S. (1989). A new way of thinking: The challenge of the future. *Educational Leadership, 49*(1), 60-64.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Educational Policy Analysis Archives, 8*(1). Retrieved October 7, 2008 from http://epaa.asu.edu/epaa/v8n1

Darling-Hammond, L. (2002). The research and rhetoric on teacher certification: A response to "Teacher certification reconsidered." *Educational Policy Analysis Archives, 10*(36). Retrieved October 7, 2008 from http://epaa.asu.edu/epaa/v10n36

Darling-Hammond, L. Chung, R., Frelow, F. (2002). Variation in teacher preparation: How well do different pathways prepare teachers to teach? *Journal of Teacher Education 53*(4), 286-302.

Darling-Hammond, L. & Youngs, P. (2002, December). Highly qualified teachers: What does scientifically-based research actually tell us? *Educational Researcher*, 31(9), 13-25.

Darling-Hammond, L. (2007). *Improving the Nation's STEM capacity: creating a systemic approach.* Testimony at American Association of Colleges for Teacher Education Congressional Briefing July 21 on Preparing STEM Teachers: The Key to Global Competitiveness. Retrieved September 16, 2008 from http://www.aacte.org/Governmental_Relations/hammond_STEM_testimony.pdf

Drake, S. & Burns, R. (2004). *Meeting standards through integrated curriculum.* Association for Supervision and Curriculum Development. Alexandria, VA.

Education Commission of the States (2008, June). *High school level STEM initiatives.* Retrieved October 10, 2008 from http://mb2.ecs.org/reports/Report.aspx?id=1409

Education Week (2008, March). STEM: The push to improve science, technology, engineering, and mathematics education. *Technology Counts 2008.* Retrieved September 19, 2008 from http://www.edweek.org/ew/toc/2008/03/27/index.html

Fennema, E. & Franke, M. (1992). Teachers' knowledge and its impact. *Handbook of Research on Mathematics Teaching and Learning*, Grouws, D. (Ed), 147-164. National Council of Teachers of Mathematics

Fishman, B., Marx, R., Blumenfeld, P., Krajcik, J. (2004). Creating a framework for research on systematic technology innovations, *Journal of the Learning Sciences*, *13*(1), 43-76.

Friedman, T. L. (2005). *The world is flat: A brief history of the twenty-first century.* New York: Farrar, Straus, and Giroux.

Furger, R. (2002). *Assessment for understanding: Taking a deeper look.* The George Lukas Educational Foundation. Retrieved September 12, 2008 from http://www.edutopia.org/assessment-for-understanding-taking-deeper-look

Gates, B. (2008, March). Congressional Testimony to the House Science and Technology Committee, Washington, DC. Retrieved October 10, 2008 from http://democrats.science.house.gov/Media/File/Commdocs/hearings/2008/Full/12mar/Hearing_Charter.pdf

Hartzler, D. S. (2000). *A meta-analysis of studies conducted on integrated curriculum programs and their effects on student achievement.* Unpublished doctoral dissertation, Indiana University, Bloomington, IN.

Honda, M. & Obama, B. (2008, May). *Enhancing Science, Technology, Engineering, and Mathematics Education (STEM) Act of 2008.* H.R. 6106/S. 3047. Retrieved September 9, 2008 from http://honda.house.gov/legislation/2008/stem.shtml

Householder, D. (2007). *Selected NSF projects of interest to K-12 engineering and technology education.* Retrieved August 27, 2008 from http://www.ncete.org/flash/research/NSF_Projects_in_ETE_Nov_15_07.pdf

Humphreys, A., Post, T., Ellis, A. (1981). *Interdisciplinary methods: A thematic approach.* Santa Monica, CA: Goodyear Publishing Company.

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

Klein, J. T. (1996). *Crossing boundaries: Knowledge, disciplinarities, and interdisciplinarities.* University Press of Virginia, Charlottesville, VA.

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

Lipson, M. Valencia, S. Wixson, K., & Peters, C. (1993). Integration and thematic teaching: Integration to improve teaching and learning. *Language Arts, 70*(4), 252-264.

Mehalik, M. Doppelt, Y, Schunn, C. (2005). *Middle-school science through design-based learning versus scripted Inquiry: Better overall science concept learning and equity gap reduction.* Paper presented at the 2005 American Education Research Association.

Malcom, S. (2008, April). Chat transcript on STEM: The push to improve science, technology, engineering, and mathematics education. Retrieved August 29, 2008 from http://www.edweek.org/chat/transcript_04_02_08.html

Miller, R. (2005). Integrative learning and assessment. *Peer Review, Summer/Fall,* 11-14.

Monk, D. H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review, 13*(2), 125-145.

National Center on Education and the Economy (2007). *Tough choices or tough times,* Executive Summary. Retrieved September 3, 2008 from http://www.skillscommission.org/pdf/exec_sum/ToughChoices_EXECSUM.pdf

National Commission of Excellence in Education (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: Author.

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (2006). *Curriculum focal points for prekindergarten through grade 8 mathematics.* Reston, VA: Author.

National Education Association (NEA) of the United States (1894). Report of the committee of ten on secondary school studies: With the reports of the conferences arranged by the committee. National Education Association: American Book Co.

National High School Alliance. (2008). *What is STEM education?* Accessed September 14, 2008 from http://www.hsalliance.org/stem/FAQ.asp

National Governors Association (2007a). *Building a science, technology,* engineering, *and mathematics agenda.* Washington, DC: Author.

National Governors Association (2007b). *NGA Awards $500,000 grants to six states to improve STEM education.* News Release, Washington, DC: Author.

National Mathematics Advisory Panel (2008). *Foundations for success: The final report of the national mathematics advisory panel.* U.S. Department of Education: Washington, DC.

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

National Science Teachers Association (2004). *Scientific inquiry: NSTA position statement.* Retrieved August 27, 2008, from http://www.nsta.org/pdfs/PositionStatement_ScientificInquiry.pdf

Partnership for 21st Century Skills (2007). *21st Century curriculum and instruction.* http://www.21stcenturyskills.org/documents/21st_century_skills_curriculum_and_instruction.pdf

Petrina, S. (1998). Multidisciplinary Technology Education. *International Journal of Technology and Design Education, 8,* 103-138.

Kadlec, A. & Friedman, W. (2007). *Important, but not for me.* Report from Public Agenda, Washington, DC. Retrieved October 3, 2008 from http://www.publicagenda.org/files/pdf/important_but_not_for_me.pdf

Ravitch, D. (2000). *Left back: A century of failed school reforms.* New York: Simon and Schuster

Sanders, M. (2006, November). *A rationale for new approaches to STEM education and STEM education graduate programs.* Paper presented at the 93rd Annual Mississippi Valley Technology Teacher Education Conference, Nashville, TN.

Sanders, M. (December, 2008). STEM, STEM education, STEMmania. The Technology Teacher, pp. 20-26.

Sanders, M. & Wells, J. (2005). *STEM graduate education/research collaboratory.* Paper presented to the Virginia Tech School of Education faculty, Virginia Tech.

Satchwell, R. E. & Loepp. F. (2002). Designing and implementing an integrated mathematics, science, and technology curriculum for the middle school. *Journal of Industrial Teacher Education, 39*(3), 41-66.

Shea, T. (1994). *An ethnographic study of change management during IMaST implementation.* Unpublished master's thesis. Normal, IL: Illinois State University.

Sherwood, R. & Hanson, D. (2008). A review and analysis of the NSF portfolio in regard to research on science teacher education. E*lectronic Journal of Science Education, 12*(1), 20-38. Retrieved September 28, 2008 from http://ejse.southwestern.edu/volumes/v12n1/articles/art2-sherwood.pdf

Shoemaker, B. (1991). Integrative education: A curriculum for the twenty-first century." *Oregon School Study Council*, *33*(2), 793-797.

Smith, C. & Gillespie, M. (2007). Research on professional development and teacher change: implications for adult basic education. *Review of Adult Learning and Literacy, 7*, National Center for the Study of Adult Learning and Literacy.

Toulmin, C. (2008, April). *Chat transcript* on STEM: The push to improve science, technology, engineering, and mathematics education. Retrieved August 29, 2008 from http://www.edweek.org/chat/transcript_04_02_08.html

U. S. Department of Education (2007). *No Child Left Behind fact sheet*. Teacher-To-Teacher Initiative. Retrieved July 23, 2008 from http://www.ed.gov/teachers/how/tools/initiative/factsheet.pdf

Vanderputten, E. (2004, April). *Knowledge about what works for teachers: Why is it rarely used?* Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.

Warner, S. A. (2003). Teaching design: Taking the first steps. *The Technology Teacher, 62,* 7-10.

Wells, J. G. (1999). *Trek 21: Educating teachers as agents of technological change.* Funded proposal submitted to the U.S. Department of Education, Preparing Tomorrow's Teachers to Use Technology (PT3) program.

Wells, J. G. (2007). Key design factors in durable instructional technology professional development. *Journal of Technology and Teacher Education, 15(1),* 101-118.

Wells, J. G. (2008). *Potentials of Integrative STEM Education in technology education.* Paper presented to the Virginia Tech I-STEM Education Graduate Seminar, Virginia Tech.

Wells, J., Webb-Dempsey, J., and Kuhn-Van Zant, A., (2001). Evolutions of evaluation: Trek 21 & PT3. Proceedings of the *Preparing Tomorrow's Teachers to Use Technology.*

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality.* Princeton, NJ: Educational Testing Service.

Wenglinsky, H. (2002). How schools matter: The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archives 10*(12). http://epaa.asu.edu/epaa/v10n12 (accessed October 9, 2008).

Zubrowski, B. (2002). Integrating science into design technology projects: Using a standard model in the design process. *Journal of Technology Education, 13*(2), 48-67.

Expert and Novice Technological Literacy

Presented at the 96th Mississippi Valley Technology Teacher Education Conference, 2009, Nashville, TN

Chapter 11

David Stricker
University of Wisconsin-Stout

Introduction

Cognitive science research has been thin regarding how well students learn concepts covered in technology education. Technical education, on the other hand, has enjoyed a body of research that has focused on strategies that various experts and novices employ to solve problems. Although technology and technical education are considered separate because of their missions, the discoveries made in studying how technicians and other experts in their respective fields use their knowledge and make decisions should not be lost on technology educators. Indeed, if the aim of technology education is to offer an opportunity for students to become technologically literate or rather understand "in increasingly sophisticated ways that evolve over time, what technology is, how it is created, and how it shapes society, and in turn is shaped by society" (ITEA, 2000, p.9), understanding the findings garnered from cognitive science research regarding the nature of expertise and its effect on problem solving and decision making can serve to inform technology education practice.

The purpose of this article is to apply the findings from cognitive science research regarding expert and novice problem solving in order to reveal the potential technology educators have with regard to making an impact on their students' futures. Specifically, technology education's unique potential to deliver expert level technological literacy will be considered along with the impacts this would have on students as future citizens. The following review is intended to provide a conceptual basis for the eventual analysis of expert and novice decisions regarding technology and its societal impact. Specifically, the pending decision regarding the expansion and subsequent additional storage of waste at a nuclear power plant located in Prairie Island, Minnesota will be used to showcase opinions and decisions that exhibit characteristics aligned with expert and novice thinking about technology related issues.

Novice and Expert Thinking

Complex systems are seemingly universal in many aspects of the world today. Understanding these complex systems is difficult because it requires abstract thinking and often challenges current beliefs regarding phenomena (Hmelo-Silver, C. E. & Pfeffer, 2004). Research in novice and expert performance exist not only in arenas that would readily excite technology educators like physics (Chi, Feltovich, Glaser, 1981; Larkin, McDermot, Simon & Simon, 1980; Larkin & Reif, 1979; Pretz, Naples & Sternberg, 2003) and electronics (Egan & Schwartz, 1979; Johnson, 1987; Lesgold, Lajoie, Bunzo & Eggan, 1992), but also in the realms of history (Winburg, 1991), and medicine (Elstein, Shulman & Sprafka, 1978; Grosswald, 2007). A few of the salient processes that begin to surface in the way experts and novices address information about problems are presented here.

Experts tend to approach and sort problems based on underlying structure. They have a cognitive map of sorts, built on experience and knowledge, which allows them to envision a system thoroughly. This enables them, based on symptoms purposefully observed, to not only choose an efficient strategy, but to easily entertain other strategies if new information surfaces. (Chi, et al., 1981; Sweller, 1988; Johnson, Flesher, Ferej &

Jehng, 1992). Novices, on the other hand, tend to leap head long into a problem using much more superficial surveying strategies such as visual inspection to identify problem areas. By using these weak strategies, only superficial faults can be detected which can often result in missing a problem completely. Additionally, novices are resistant to explore other strategies when faced with evidence that their current plan is inefficient.

Experts are able to select appropriate aspects of a problem based on prior knowledge. This allows them to be more efficient in forming a solution because they only need to concentrate on a specific area. Essentially, they are able to use their knowledge as a filter to get to the heart of a problem quickly. Novices faced with a similar multifaceted problem have a tendency to be guided more by their senses. This, combined with their lack of knowledge, handicap a novice during the problem solving process because they are less able to identify important clues that could reduce the complexity and, subsequently, time involved in solving the problem (Johnson, 1987; Thomas, Johnson, Cooke, DiCola, Jehng & Kvistad, 1988).

Not only do experts obviously possess extensive knowledge and skills, they also are able to employ these attributes through intelligent planning. For example, Johnson (1994) in referring to his work of observing expert and novice service technicians reported that there is:

> .. little difference between expert and novice troubleshooters in their ability to acquire and interpret information, to perform procedural tests, or to generate and evaluate hypotheses… the primary difference between expert and novice troubleshooters is their ability to identify critical areas of a problem, which result in 'smarter' decisions being made regarding the type of information to look for and the logical locations of faults (p. 3).

Technological Literacy

Although some grey areas exist regarding how technological literacy is structured and clearly implemented (Lewis and Gagel, 1992), there are common themes that occur in the literature. Specifically, Hayden (1989) speaks of students having the knowledge and abilities to select and apply appropriate technologies in a given context. Steffens (1986) refers to technologically literate students as knowing about and comprehending technology, as well as possessing the right attitudes and evaluation skills toward the application of new technologies. Croft (1991) also spoke of cognitive abilities such as making wise decisions about the uses of technology and having the capacity to describe the basic technology systems that make up society. Pearson & Young (2002) in their explanation of a technologically literate person, speak of the awareness that all technologies entail risk and their use involves trade-offs and a balance of costs and benefits. Although tools and skills are mentioned periodically in some of the pieces noted above, it is obvious that there is a greater emphasis on students' ability to understand technology at a conceptual level.

This separation of concepts and skills has a rich history in technology education. In fact, one of the clearest and most seminal representations of this delineation can be found in the debate between David Snedden and John Dewey in 1915 (1977). Snedden, a champion of vocational/technical education, contended that the "common man be educated for a life of practical efficiency through an entirely different program of courses than the elite…training in the trades and business was a legitimate function of public education" (Drost, 1977, p. 24). Dewey, wary of the societal changes underway resulting from Industrial Revolution (Dewey, 1900), felt that manual training should be taught within the conceptual goals of general education (Dewey, 1901). Said differently, Dewey's overall approach and support for industrial/vocational education of the time was based on the general education premise that it not be geared for a specific technology or occupation, but for intellectual and moral growth of all students (Tozer & Nelson, 1989, Dewey, 1977, Dewey, 1916).

Today, as technology education remains focused on delivering technological literacy, Dewey's ideas still resonate. Following this goal, laboratory activities, often the most noted and recognizable feature of technology education, are not meant to develop tool skills and specific technical knowledge. Rather, this is the charge of schools and instructors of specific technical education as seen in vocational schools and career centers. In other words, the goal of technology education is to develop key concepts about technology and not to cover large volumes of specific information that may become obsolete quickly.

However, even though much of the research reviewed above regarding expert and novice problem solving occurs in technical settings where participants are vocationally trained, the results can and should be used to inform and reinforce the importance of imparting technological literacy through technology education.

Expert and Novice Technological Literacy

Decisions and the way they are made by experts and novices in the review of literature above indicate general patterns of cognitive processes technicians with differing levels of knowledge and experience progress through in order to solve a particular problem. More importantly, the accuracy and effectiveness of the decisions made can be traced to the amount of knowledge and experience they have in relation to a particular system or technology. The way in which experts and novices arrive at making informed or ill-informed decisions should be of particular interest to technology educators. If the charge is to enable each student to become technologically literate, the ability to make informed decisions regarding the use of technology is an integral part of this goal. It would stand to reason from the evidence demonstrated in the cognitive science research that in order for students to make accurate and effective decisions about technology in their daily lives, they not only need to have a working knowledge of existing technologies and their functions, but be able to spend time wrestling with the advantages and limitations of putting them to use. As a result, through informed planning, students would be able to formulate strategies built on this knowledge and experience rather than relying on superficial information they may be initially presented with in order to make efficient and reasoned judgments.

Opportunities to examine evidence of expert and novice cognitive behavior with regard to situations demanding technological literacy are not hard to come by. For example, consider that a fear of flight still exists even though, when compared with driving, commercial aircraft can move us ten times as fast and get us to our destination much more safely (Lewis, 1990). Lewis also points out the fact that we live our lives surrounded by the miracles of modern chemistry, however, even though adding fluoride to our water has the ability to nearly end tooth decay, a general fear of chemicals prevents much of the nation from benefiting from this technology.

Indeed, most current political, legal, and ethical issues have a technical component and a technologically literate person in America is likely to make their voices known via voting, contacting an editor of a paper, a member of Congress, or by using other mechanisms afforded to them in a democratic society (NAE, 2002). However, the declaration that "the simple act of asking and trying to answer questions about technology can lead to a better understanding not only of technical, but also of the social, economic, and political aspects of the issues at hand" (NAE, 2002, p.37) rests on the premise, based on the cognitive research reviewed above, that a person would have the knowledge and experience of an expert that would guide them to ask the right questions that would lead to an efficient and accurate answer. As will be demonstrated in the following example, this is not always the case. Indeed, some clear observations can be made that should buoy the notion that all students should be technologically literate.

A Vignette

Nuclear power begins when uranium atoms are split in a controlled reaction that, in turn, produces a large amount of heat that is used to boil water until it turns into steam. This steam is used to spin turbines that are connected to electrical generators. In Minnesota, two electrical plants produce electrical power this way, one being located in Prairie Island, literally an island in the Mississippi River about 40 miles southeast of the Twin Cities and about 5 miles north of Red Wing, Minnesota.

The Prairie Island nuclear plant, owned by Xcel Energy, utilizes nuclear energy produced using a pressurized water reactor. This type of reactor heats water that remains contained in a closed loop. The heat from this loop, not the water used to move it, is then transferred to another closed loop of water that flows to a steam generator. A third water line pumps water from the Mississippi River to cool the resulting steam. This design contains the water running through reactor area in a closed loop that never comes into contact with the water used to power the steam generator, containing radioactivity to the reactor area (Minnesota Department of Commerce, 2002). Prairie Island utilizes two reactors; the first began operating in December 1973 and the other in December 1974 (Xcel Energy, n.d.). Each reactor at Prairie Island holds 121 fuel assemblies that contain Uranium. Spent fuel is highly radioactive because it contains byproducts produced while the reactor was operating. These byproducts will remain radioactive and will take a tremendous amount of time to decay and become stable again. For example, one byproduct, Plutonium-239, is estimated to remain hazardous for a quarter million years (Minnesota Department of Commerce, 2002).

When first removed from the reactor, the spent fuel is stored in a pool inside the plant. Once it has cooled, the fuel is transferred to dry storage containers on site (Xcel Energy, n.d.). Xcel Energy and the Minnesota Department of Health monitor the air quality near the plant, as well as the water in the Mississippi. In addition, the Health Department also tests well water and milk at a local farm. Very small amounts of radiation, not different from the background radiation we are all exposed to, are typically found. The containers that hold the waste (called "casks") are made of steel and filled with helium. A continuous monitoring system measures the pressure of the helium inside the containers to ensure there is no leaking (Hemphill, 2009a).

Recently, Xcel Energy expressed interest in boosting Prairie Island's generating capacity by increasing the heat generated by the two nuclear reactors, and capturing the added heat with improved equipment. In addition, Xcel is seeking permission to store additional spent nuclear fuel on-site. These actions would allow continued plant operations through 2034 (Hemphill, 2009b).

At a public meeting held on the evening of April 21st, 2009, about 35 neighbors of the Prairie Island nuclear plant gathered to discuss plans regarding the proposed production expansion and additional on-site nuclear waste storage. As can be predicted, many viewpoints were voiced. Using two reports written by Minnesota Public Radio reporter Stephanie Hemphill (Hemphill 2009a and 2009b), direct quotes as well as summaries from and about the positions taken at the meetings can be used to illustrate the expert and novice cognition summarized above in the context of technological literacy. For example, Hemphill interviewed a man who lives nearby and, at one time, delivered supplies to the plant when it was being built. She reported that the man worries about his family's safety and commented:

> It is probably a safe place right now, but when you buy a new car, and you drive it 20 years, it's done after 20 years, right… even though they may have upgraded internal equipment, the outside equipment which protects us from whatever they got, has to deteriorate somewhat (Hemphill, 2009a, p.3).

Considering the brief factual description of the plant, its functions and outputs presented in this article alone, it is clear the opinion expressed here is based more on the person's senses rather a knowledge of the systems at work in the plant. Also, his strategy for assembling his viewpoint is based on comparing a car to a nuclear power plant in relation to their longevity of use is inadequate. These mechanisms are indicative of a person possessing only a novice level of technological literacy in relation to nuclear power and the particular way it is produced at the facility he is being asked to comment on.

Next, during the public meeting described above, some of the attendees referred to President Obama's declaration that a once planned permanent repository for nuclear waste at Yucca Mountain in Nevada will not be a reality. The notion of the spent fuel currently being housed at Prairie Island becoming permanent was not acceptable to one of the meeting attendees:

> What's in those casks is very dangerous; we're talking about stuff that has to be kept completely out of the environment and out of reach of animals and people for thousands and thousands of years. I mean it's like having a party on Saturday night and then having people clean up after your party for 35 years. It's crazy (Hemphill, 2009b, p.1).

Although the person's idea that what is in the casks is indeed dangerous and does have to be securely contained, his comment betrays a lack of knowledge regarding measures currently undertaken to store and secure waste at the plant. Indeed, the casks, in addition to being continually monitored, are protected by a 20 foot high earthen berm and surrounded by fencing topped with barb wire. Also, the strategy he has chosen to voice his concern regarding the length of time the waste will be radioactive is not only inadequate, but the situation is not analogous in regards to time or qualities of materials being addressed. Much like the person being interviewed in the previous scenario, strategies this man chose to frame the problem at hand were ill-informed and based on superficial information and correlations. Interestingly, he garnered some applause from the group for these comments.

Lastly, nuclear power is gaining favor among some because the plants don't produce greenhouse gases that can alter the climate. The actual generation of power by nuclear technology produces no greenhouse gases at all (Lewis, 1990). In an effort to study possible impacts of the proposed expansion project at Prairie Island and to examine possible alternatives, an Environmental Impact Statement was prepared by the Minnesota's Office of Energy Security. The contents of this paper were discussed at the meeting. A former mayor of a city near Prairie Island said the environmental report shouldn't describe nuclear power as carbon-free. In an interview after the meeting, she said nuclear energy should only be compared with other sources of power by counting greenhouse gas emissions throughout the full life-cycle of the generating system. She went on to say:

> There most certainly would be carbon emissions associated with the mining of the raw material and the transportation of that material to the plant, and then the management and handling of the waste from the time it's taken from the reactors until the time it is safe, which as we know would be many thousands of years (Hemphill, 2009b, p.2).

Despite the alluring fact that the act of generating energy by nuclear means is clean in and of itself, the former mayor displayed clear examples of expert problem solving by recognizing the underlying structure that surrounds the entire process of generating energy using nuclear technology. This cognitive map obviously was built on experience and knowledge that allowed her to envision the entire system involving the mining of material, transportation, and management needs thoroughly; all clear indicators of a technologically literate citizen.

Summary

By merely examining the comments of the well informed and calculating as opposed to those who just "know enough to be dangerous", the responsibility of technology educators to deliver technological literacy is not only clear, but has tremendous weight. Conversations about technology education's ability to provide basic knowledge and skills, enhance the opportunity for students to develop career awareness, and develop self-evaluation of attitudes toward constructive work and how this work can be used (ITEA, 1995) seem terribly inadequate in light of the breadth, complexity, and impact technology has on the lives of students today.

It is an obvious and unfortunate observation that cognitive science research needs to be conducted in technology education. As mentioned, technical education has responded in their research efforts to understand the increased level of skill required to maintain complex equipment. Technology education, even before mainstream conversations regarding engineering, could not avoid witnessing industry's switch from concrete (hands-on) tasks to abstract (minds-on) tasks which require mental skills such as symbolic and abstract thinking (Grubb, 1984). The urgency is no longer how to offer an opportunity for students to become technologically literate. Rather, technological literacy should be viewed as a tool used by an expert; a scalpel to cut through a menagerie of distractions and half-truths in order to make an informed, authentic, and novel decision that they not only can trace back to sound reasoning, but demonstrate their place in an enlightened citizenry.

References

Chi, M., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, *5*, 121–152.

Croft, V. (1991). Technological literacy: Refined for the profession applications for the classroom. Unpublished paper presented at the 1991 annual conference of the International Technology Education Association.

Dewey, J. (1900). *School and society.* Temecula, CA: Library reprints, Inc.

Dewey, J. (1901). The place of manual training in the elementary course of study. *Manual Training Magazine*, *2*(4), 193-199.

Dewey, J. (1916). *Democracy and education*. New York: Free Press.

Dewey, J. & Snedden, J. (1977). Two communications. *Curriculum Inquiry*, *7*(1), 33-39.

Drost, W. (1977). Social efficiency reexamined: the Dewey-Snedden controversy. *Curriculum Inquiry*, *7*(1), 19-32.

Elstein, A. S., Shulman, L. S., & Sprafka, S. (1978). *Medical problem solving: The analysis of clinical reasoning*. Cambridge: Harvard University Press.

Egan, D.E., Schwartz, B.J. (1979) Chunking in recall of symbolic drawings. *Memory and Cognition, 7,* 149-58.

Grubb, W.N. (1984). The bandwagon once more: Vocational preparation for high-tech occupations. *Harvard Business Review*, *54*(4), 429-451.

Hayden, M. What is technological literacy? *Bulletin of Science, Technology and Society, 119*, 220-233, STS Press.

Hmelo-Silver, C. E. & Pfeffer, M. G. (2004). Comparing expert and novice understanding of a complex system from the perspective of structures, behaviors, and functions. *Cognitive Science*, *28,* 127-138.

Grosswald, S.J. (2007) Problem-solving strategies of experienced and novice physicians. *Journal of Continuing Education in the Health Professions, 12*(4), 205-213.

Hemphill, S. (2009a). Plans for Prairie Island nuclear plant face opposition. In *MPR News Q.* Retrieved September 15, 2009 from http://minnesota.publicradio.org/display/web/2009/05/22/prairie_island_nuclear_plant/

Hemphill, S. (2009b). Neighbors share concerns about Prairie Island nuclear plant. In *MPR News Q*. Retrieved September 15, 2009 from http://minnesota.publicradio.org/display/web/2009/04/22/red_wing_nuclear/

International Technology Education Association. *(1995). This we believe. Retrieved September 15, 2009 from http://www.iteaconnect.org/AboutITEA/ThisWeBelieve.pdf*

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

Johnson, S.D. (1987). *Knowledge and skill differences between expert and novice service technicians on technical trouble shooting tasks* (Report No. 20). St. Paul: University of Minnesota, Training and Development Research Center. (ERIC Document Reproduction Service No. ED 284 054)

Johnson, S. D., Flesher, J. W., Ferej, A., & Jehng, J. C. (1992). *Application of cognitive theory to the design, development and implementation of a computer-based troubleshooting tutor.* Berkeley: University of California at Berkeley, National Center for Research in Vocational Education.

Larkin, J. H., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Cognitive Science, 12*, 101–138.

Larkin, J. H., & Reif, F. (1979). Understanding and teaching problem solving in physics. *European Journal of Science Education*, *1*(2), 191-203.

Lesgold, A., Lajoie, S. P., Bunzo, M., & Eggan, G. (1992). SHERLOCK: A coached practice environment for an electronics troubleshooting job. In J. H. Larkin & R. W. Chabay (Eds.), *Computer assisted instruction and intelligent tutoring systems: Shared goals and complementary approaches,* 201–238. Hillsdale, NJ: Erlbaum.

Lewis, H.W. (1990). Technological Risk, W.W. Norton & Company, New York, NY.

Lewis, T., & Gagel, C. (1992). Technological literacy: A critical analysis. *Journal of Curriculum Studies*, *24*(2).

Minnesota Department of Commerce. (2002). Resources on Minnesota Issues Nuclear Waste Storage in Minnesota. In *Minnesota Legislative Reference Library*. Retrieved September 15, 2009 http://www.leg.state.mn.us/LRL/Issues/prairieIsland.asp

NAE (National Academy of Engineering). (2002). Technically speaking: Why all Americans need to know more about technology. Washington D.C.: National Academic Press.

Pearson, G. & Young, A. (2002). Technically speaking: Why all Americans need to know more about technology. Washington D.C.: National Academy of Sciences.

Pretz, J. E., Naples, A. J., & Sternberg, R. J. (2003). Recognizing, defining, and representing problems. In J. E. Davidson & R. J. Sternberg (Eds.), *The Psychology of Problem Solving,* 3-30. Cambridge, UK: Cambridge University Press.

Sjoberg, L. (2003). Risk perception, emotion and policy: the case of nuclear technology. *European Review, 11*, 109-128 doi:10.1017/S1062798703000127

Steffens, H. (1986). Issues in the preparation of teachers for teaching robotics in schools. In J.

Heywood & P. Matthews (Eds.), *Technology, Society and the School Curriculum*. Manchester, England: Roundthorn Publishing.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*, 257–285.

Thomas, R.G., Johnson, S.D., Cooke, B., DiCola, C., Jehng, J. & Kvistad, L. (1988). Cognitive science research as a basis for instructional design: Implications for vocational education (Unpublished technical report). Berkeley, CA: National Center for Research in Vocational Education.

Tozer, S. and Nelson, R. E. (1989) Vocational teacher education: emerging patterns for general studies, academic majors and professional education, in: Beyond the Debate: perspectives on the preparation of vocational education teachers. University Council for Vocational Education, Macomb: Western Illinois University.

Wineburg, S. S. (1991). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of Educational Psychology*, *83*, 73–87.

Xcel Energy, (n.d.). Prairie Island Nuclear Generating Plant. In *Prairie Island*. Retrieved September 15, 2009 from http://www.xcelenergy.com/Company/About_Energy_and_Rates/Power%20Generation/MinnesotaPlants/Pages/PrairieIslandNuclearGeneratingPlant.aspx

Tracing Technology Education's Lineage, With an Eye toward the Future

Presented at the 96th Mississippi Valley Technology Teacher Education Conference, 2009, Nashville, TN

Chapter 12

Marie Hoepfl
Appalachian State University

> *Technology is the application of knowledge, tools, and skills to solve practical problems and extend human capabilities. Technology is best described as process, but it is more commonly known by its products and their effects on society. It is enhanced by the discoveries of science and shaped by the designs of engineering. It is conceived by inventors and planners, raised to fruition by the work of entrepreneurs, and implemented and used by society. Sometimes, though, it enters the social system imperceptibly and brings about many changes, often in unforeseen ways.*
>
> Excerpted from: *Project 2061 Panel Report: Technology* (Johnson, 1989, p. 1)

The questions that were provided to help frame the content of this paper were: What is the DNA (the enduring concepts) of technology education? Does the profession need to embrace a single curriculum or a common core of courses to rally around? Are there core concepts? Core content? Core instructional strategies? Is there a signature pedagogy for technology education? Should there be? To answer these questions, the author undertook a selective review of historical documents from the past century, synthesized key ideas, and considered them in light of current developments in technology education. The thinking of past scholars in the field continues to have relevance today, and reflection on the past serves as a useful reminder of the enduring power of their ideas.

Parallels between Biological and Technological Evolution

At the risk of taking the metaphor too far, it may be helpful to review some of the basic principles and structures of biological heredity as a means of considering the curricular heritage of technology education. DNA and RNA are genetic molecules (polymers) made of building blocks called nucleotides. Nucleotides have three distinct components: a nucleobase, a sugar, and a phosphate. There are four types of nucleobases, and these constitute the "alphabet" in which the genetic information is encoded. In a DNA nucleotide the nucleobase is composed of some combination of the molecules A, G, C, or T (adenine, guanine, cytosine, or thymine); in RNA the molecule U (uracil) replaces the T. Nucleobases are compounds rich in nitrogen, and they bind to one another according to simple rules of pairing: A pairs with U (or T), and G pairs with C. These base pairs form the rungs of the familiar twisted ladder of DNA. Each strand of DNA or RNA has a backbone comprised of the phosphate and sugar molecules.

Ricardo and Szostak (2009) cited three definitions for what it means to have biological life: (1) "a defining property of living systems is that they self-assemble against nature's tendency toward disorder, or entropy" (Schrodinger); (2) "life is 'a self-sustaining chemical system capable of Darwinian evolution'" (Joyce); and (3) "life is a network of feedback mechanisms" (Korzeniewski) (Ricardo & Szostak, 2009, p. 56).

The possibilities for unique pairings within DNA molecules results in a rich diversity of life forms on Earth. Fundamentally, however, the components of these life forms can be distilled down to a small number of elements. Is the same true of the content of technology education? If so, what are those components? Taken as a whole, do these components comprise a self-sustaining disciplinary approach that has demonstrated evidence of evolutionary change whereby the best-adapted characteristics persist?

The Lineage of Technology Education: Persistent Ideas

In an effort to trace the persistent ideas within industrial arts/technology education (the two terms may be used interchangeably throughout this paper), the author undertook a selective review of primary curriculum theory documents of the 20th century. This review was not comprehensive; readers interested in such a historical treatment of the literature of the field are encouraged to see the recent work of Herschbach (2009). The thesis of this paper is that there are, indeed, persistent curricular elements evident throughout the lineage of technology education and that from an evolutionary perspective these represent the essential components that must remain a part of any curricular structure in technology education (see Table 1). They are presented here and in the next main section in a roughly chronological order.

Essential Content

The importance of the work of John Dewey, Gordon Bonser, and Lois Mossman in establishing a theoretical and philosophical basis for technologically-oriented (practical) studies at the elementary level is well documented. For example, Dewey advocated for the marriage of knowing and doing within a curriculum that focused on the social issues of the day—on the realities and concerns students had to contend with in their day-to-day lives. He wrote:

> There is no such thing as genuine knowledge and fruitful understanding except as the offspring of *doing*.…Men have to *do* something to the things when they wish to find out something; they have to alter conditions. This is the lesson of the laboratory method, and the lesson all education has to learn. The

> laboratory is a discovery of the conditions under which *labor* may become intellectually fruitful and not merely externally productive. If, in too many cases at present, it results only in the acquisition of an additional mode of technical skill, that is because it remains too largely but an isolated resource…surrounded by other studies where traditional methods isolate intellect from activity. (Dewey, 1916, pp. 321-322)

In a similar vein, Bonser (1921) wrote about what he termed a "common error" in elementary school curricula: "their omission of much that is of very great significance for the conduct of life." These omissions included "much that is of directly usable value about foods, clothing, sanitation, and personal care of the body," as well as information about "production, manufacture, exchange, and use of the various material commodities of everyday life" (p. 20). For Bonser, school subjects should grow "out of life activities in which their use [is] apparent" (p. 138), including nature studies, English, arithmetic, history, and what he called "industrial arts" (p. 141). The practical arts on which the latter would focus would include agriculture, fishing and hunting, mining, manufacture, transportation, and trade. He called for intelligent use of products, and for an examination of the social relationships between producers and users, including attention to aesthetic design.

The extraordinarily important work done by William E. Warner and his colleagues in their *Curriculum to Reflect Technology* (1947) adopted a longitudinal study of socioeconomic indicators such as the U.S. Census to identify subject matter classifications to guide the study of technology. These included power, transportation, manufacture, construction, communication, and management. The approach was very systematic, organized, and detailed—an effort further elaborated by the later work of Delmar Olson, a Warner protégé (Olson, 1963). This exhaustive approach, however, raised a concern that has bedeviled many curriculum theory and standards efforts since: "It was impossible to cover everything of importance, but no practical way of limiting instruction was presented" (Herschbach, 2009, p. 68). Stated differently, this "overload of too many alternatives" has "contributed to the expansion of the theory-practice gap" that has long existed between curriculum *theories* for technology education and the actual instruction delivered by in-service teachers in K-12 schools (Colleli, 1989, p. 6).

Paul DeVore, whose influence was evident in a number of important curriculum documents of the 1960s through the 1990s, including the 1981 *Jackson's Mill Industrial Arts Curriculum Theory*, was a long-term proponent of applying a taxonometric structure to the content of technology, in part due to his efforts to situate technology as a discipline worthy of inclusion in the general education of all students. In his view the technical and the socio-cultural elements of technology were given equal due, and within each strand of the taxonomy it was possible to delineate content to increasingly finer levels (e.g., DeVore, 1966). Most importantly, he sought an approach to curriculum development that was "logical, consistent, and attainable" (1966, p. 19). In practice, the technical elements of the taxonometric structure tended to overshadow the socio-cultural elements, and they remain very much in evidence in classrooms across the United States today.

Lux and Ray (1970) posed the study of technology within the overall realm of human knowledge, which includes descriptive knowledge (science), prescriptive knowledge (arts and humanities), formal knowledge (mathematics and logic), and praxiological knowledge (the professions). Lux and Ray noted that praxiology "draws upon the formal, descriptive, and prescriptive domains as *necessary* but *insufficient* background" for professional practice, and acknowledged that "praxiology has been given less recognition in the formal school" than have the other domains of knowledge—at least outside of professional programs (1970, p. 303).

It might be argued that the most important step in the transition from industrial arts to technology education occurred with the publication of the *Jackson's Mill Industrial Arts Curriculum Theory* (Snyder & Hales, 1981). This document provided a sort of culminating synthesis of prior work, building on the analyses of the components of human technological activity put forward by Warner and colleagues, Olson, DeVore, and others, while at the same time building a compelling case for this study in light of our changing understanding of the human technological footprint on the environment.

The societal component.

At a conference focusing on the societal challenges posed by technological advancement and, by extension, the educational dilemmas these present, Juergen Schmandt (1970) identified six problems that formed an "agenda for action" for society. These included:

1. The need to restructure [society's] mechanisms to control and orient the power of technology,
2. The need for political decisions against the development of particularly dangerous technologies,
3. The task of alleviating technology-induced dislocations and of educating people to live with change,
4. The creation of mechanisms capable of reducing negative side effects of technology and of taking such action before the crisis is upon us,
5. The development of new knowledge and institutions for guiding complex social systems which for their very existence and survival are dependent on the interaction of a variety of highly sophisticated technologies, and
6. The search for social incentives and institutional mechanisms which would apply the problem-solving power of technology to the solution of unmet social needs (Schmandt, 1970, pp. 10-11).

Schmandt thus delineated the elements for what might be termed the *imperative* for technology education. These and other societal challenges—in particular the environmental challenges posed by population growth and technological advancement—emerge repeatedly in various forums where the study of technology is advocated.

An underlying goal of all of the major curriculum theory efforts for technology education over the last 100 years was to establish the importance of the study of technology and its centrality to every student's life. Petrina, acknowledging that we still face the challenge of "justifying" the study of technology, says that merely pointing to the ubiquity of technology (and the fact that we rely on it so completely) is not enough. Instead, the imperative for technology studies lies in the *significance* of technology: it is "central to action, cognition, and emotion;" it is necessary for meeting our basic needs of food, water, and shelter; it represents a fundamental part of our culture; and, increasingly, it involves high-stake decisions about risks and impacts (Petrina, 2007, p. 188).

The skills component.

Justifications for technology education over the years have also generally included its contribution to student career development (e.g., International Technology Education Association [ITEA], 1996), whether via exploratory activities or more forthright development of workplace skills. Even if one shies away from adopting a workforce development stance toward technology education (and many do), it remains important to identify the essential components of technological *praxis*, a goal that is probably not possible to achieve through analysis of historical documents.

The definition of technology quoted on page one of this chapter contains the statement: "Technology is best described as process" (Johnson, 1989, p. 1). Although the individuals who were part of the *Project 2061* Technology Panel may not have been specifically thinking about the development of *technical* skills, they did comment that "observation, measurement, and analysis are universal tools of technology….[and] should be used throughout elementary and secondary education in both technical and social contexts" (Johnson, 1989, p. 7).

Attempting to distill the essential *skills* that are, or should be, part of technology education is at least as challenging as attempts to identify essential *content* components—one can quickly become mired in comprehensive listings of task skills. Nonetheless, two efforts at addressing this challenge are worth mention here. The first is the work of Harold Halfin, whose dissertation research at West Virginia University resulted in a list of seventeen "processes of the technologist" that retains its usefulness today (Halfin, 1973). The second was an initiative undertaken by the U.S. Department of Labor in 1991, called *What Work Requires of Schools* (a.k.a. "The SCANS Report") (Secretary's Commission on Achieving Necessary Skills, 1991). Each of these documents has surfaced repeatedly through the years since it was introduced, demonstrating its enduring applicability.

It must be said that in spite of the consistent viewpoints from many educators about the content and pedagogy of technology education, agreement about the need for the study of technology has been nowhere near universal, as illustrated in a 1981 essay by Bjorkquist and Swanson:

> Technology is bigger than any one field of study and it is presumptuous to think that industrial education can lead or reflect technology beyond some very limited view. The limiting factor that we must wrestle with is *industry* [emphasis added] and probably a narrow slice of industrial technology at that. (1981, p. 14)

Table 1. *Summary of Content Areas for Technology Education*

Source	Content Descriptors
Dewey, Bonser, Mossman (1920s)	*Knowing* and *doing* were to be married into curricular experiences that reflected the social issues of the day. The "industrial" or practical arts would be included in the education of all students and would include study of agriculture, fishing and hunting, mining, manufacture, transportation, and trade. Bonser and colleagues called for intelligent use of products and for examination of the social relationships between producers and users, including attention to aesthetic design.
Warner et al. (1947): *A Curriculum to Reflect Technology*	"Content in the new Industrial Arts curriculum is derived via a socio-economic analysis of the technology and not by job or trade analysis as of old…. Now the subject matter classifications are conceived of as including: *Power, Transportation, Manufacturing, Construction, Communication*, and *Management*" (p. 41).
Olson (1963): *Industrial Arts and Technology*	In addition to detailed subject matter classifications based on an analysis of industry, Olson presented descriptions of what he considered to be the "functions" of the industrial arts curriculum. The choice of titles to frame these functions illustrated the broad reach and purpose of the proposed curriculum: The Technical Function: The Science of Industrial Arts; The Occupational Function: Vocational Orientation; The Consumer Function: An Enlightened Utilization; The Recreation Function: Re-Creation in Discretionary Time; The Cultural Function: Understanding the Material Culture; and The Social Function: Man, the Master of the Machine.

DeVore (1966): Taxonometric approach	A focus on "man's universal technological endeavors" would include study of "construction, communication, production, research and development, transportation, craft industries and an hierarchical division of labor" (1966, p. 7), with the essential technical elements comprising production, communication, and transportation (p. 13). Furthermore, these must be considered in light of their social/cultural relationships.
Brown (1970): *Model of a Theoretical Base for Industrial Arts Education*	"The subject matter for industrial arts is the concepts and principles involved in procuring, transforming, utilizing materials and/or energy and the disposing of refuse pertaining thereto" (p. 20).
Maley (1973): *The Maryland Plan*	"The evolution, utilization, and significance of TECHNOLOGY in the areas of transportation; communication; tools; machinery; power generation; and, energy storage and conversion. The aspects of INDUSTRY which pertain to organization, management, materials, finance, occupations, processes, products, and problems. The societal problems and benefits resulting from technology and industrial enterprise" (as summarized by Smith, 1970).
Snyder and Hales (1981): *Jackson's Mill Industrial Arts Curriculum Theory*	Expanded the taxonometric structure around four "human technical adaptive systems:" communication, construction, manufacturing, and transportation. The technical components of these systems "consist of…tools, resources, techniques, and systems," while the "socio-cultural components consist of individual and institutional responses for utilizing and responding to the technical means" (p. 20).

American Association for the Advancement of Science (1989): *Project 2061: Science for All Americans*	This effort to articulate science content for the 21st Century did two important things: first, it clearly distinguished between the STEM fields of science, technology, engineering, and mathematics (although this was before use of the acronym came into vogue); and second, it included a chapter specifically devoted to technology, called "The Designed World," taking the position that knowledge about technology is necessary for scientific literacy (p. 39). The areas of technological design identified included agriculture, materials, manufacturing, energy sources, energy use, communication, information processing, and health technology. Notably, *Project 2061* also identified nine core concepts central to an understanding of technology. The Technology Panel of *Project 2061* also emphasized the importance of introducing the "tools of technology," including "the library, laboratory, shop, equipment, computers, and the use of mathematics" (Johnson, 1989, p. 5). According to Johnson, "Nearly every consultant advocated the need for more [experiential learning]. A key question is how to expand the technique to serve a much broader pedagogical role" (p. 5).
Savage and Sterry (1990): *A Conceptual Framework for Technology Education*	This document reaffirmed the content structure proposed in *Jackson's Mill*, with the addition of "bio-related technology" and a detailed problem-solving methodology promoted as the "Technological Method Model."
ITEA (2000): *Standards for Technological Literacy*	Although the content descriptors of communication, construction, manufacturing, and transportation were still in evidence, the list was expanded to include agricultural and medical technologies, along with four standards addressing the socio-cultural elements of technology, and three focused solely on the process of "engineering design." In addition, the authors identified six "core concepts of technology: systems, resources, requirements, optimization and trade-off, processes, and controls" (pp. 32-33).

The importance of the *Standards for Technological Literacy*, published in 2000, lay primarily in its engagement with an interdisciplinary team of contributors that included mathematicians and math educators, scientists and science educators, engineers, and technology educators. Politically, it signaled that the field of technology education was ready to take a more prominent role in the education of all children. Indeed, since 2000 those in the profession have seen the ascendancy of the acronym "STEM," a term whose widespread use among educators at all levels (K-16 and beyond) hints at a growing acceptance of what were once called the "practical arts" of technology and engineering alongside the traditional fields of science and mathematics. An additional useful feature of the *Standards for Technological Literacy* was the inclusion of conceptual statements to illustrate each standard—a distinct improvement on earlier curriculum theory documents that tended to identify static content descriptors rather than conceptual understandings (ITEA, 2000).

Persistent Approaches and Contexts

Vocational relatives in the family tree.

Brown (1977) stated: "Industrial arts never has been part of the manual training tradition" and has "an entirely separate lineage and operates on a distinctly different theoretical base [than vocational education]" (p. 3). Nevertheless, he acknowledged the appeal of the manual training tradition:

> Within that system there is no equivocation on what is to be taught nor on the reasons for teaching it. The methods of teaching are equally clear. The manual training teacher knows quite well what he is doing and why. He knows exactly how to go about doing it. He operates from a theoretical base that is explicit, direct and easy to understand. Manual training inferentially has an important message for industrial arts. It is that a theoretical base that is as clear and

> direct as the one from which manual training operates must be established for industrial arts. *Nothing less will suffice* [emphasis added] (pp. 4-5).

Colleli's *Primer* for technology education (1989) included a graphic timeline that illustrated very compactly what he termed "the theory-practice gap" between curriculum documents and actual classroom teaching practices in technology education (p. 6). For the reasons outlined by Brown (1977), in part, and also probably due to the fact that many technology teachers consider themselves *technologists* first and *teachers* second, it has been easy for technology teaching practice to focus almost exclusively on the technical-vocational functions at the expense of the social-cultural-developmental functions of technology studies. Technology education's placement, in many states, under the funding umbrella of the Perkins Act provided any additional impetus that may have been needed to insure a vocational perspective in practice. According to Pearson and Young (2002), 40% of technology education programs at that time were "still identified most closely with vocational education" (p. 54).

Technological literacy.

Technological literacy has served as a persistent goal of technology education. Definitions of what this means can vary depending on the source. According to the ITEA (now ITEEA), "technological literacy is the ability to use, manage, and understand technology" (1996, p. 6). This literacy served as the fundamental rationale for the study of technology that was outlined in *Technically Speaking: Why All Americans Need to Know More About Technology* (Pearson & Young, 2002), a document whose strategic importance to technology education should not be underestimated. Regardless of which curriculum theory document one selects from technology education's history, the importance of knowing about technology so that one can be a more effective contributor to, and participant in, society has been stressed.

A major contribution made by the *Jackson's Mill* document was the degree to which it made the case for technological understanding on the basis of the Earth's ecological constraints and natural limits, presaging later arguments for technological literacy such as *Technically Speaking* (Pearson & Young, 2002). Technological understandings should be applied in the process of "planning for futures that are appropriate for sustaining a human and humane life," requiring both awareness, and responsible use, of finite natural resources (Snyder & Hales, 1981, p. 22). Nevertheless, in spite of its compelling arguments and demonstrated influence on the enacted curriculum in schools across the country, *Jackson's Mill* imposed the same tyranny as other standardized curriculum models: too much material to cover, with too little time in the curriculum to cover it. This resulted in maintaining, in many cases, a strictly technical-vocational type of approach.

Still, technological literacy continues to provide an essential compass point that directs the study of technology, along with providing an overarching goal for that study. One of the more helpful conceptualizations of technological literacy—because it suggested a clear developmental trajectory—was the model presented by Todd (1991), as adapted by Stephen Petrina (2007) and shown in Table 2.

Developmental transitions in the study of technology.

There is a rich body of literature that established a rationale for the study of technology at the elementary level (in the spirit of Dewey, Bonser, and Mossman), as well as the structure and focus of such a study. These included *Industrial Arts for the Elementary School* (Thrower & Weber, 1974); *Teaching Children about Technology* (Scobey, 1968); and *Elementary School Technology Education* (Kirkwood & Foster, 1997). All, in their various ways, emphasized the general education function of the study of technology to connect students more closely with the technological world around them, as well as the developmental benefits of hands-on learning. In spite of this advocacy, technology education is not widely found at the elementary level. We see today some very promising efforts to engage elementary students and teachers in technologically-oriented activity (such as the work being done at City College of New York by Gary Benenson and Jim Neujahr, and the ongoing efforts at the Museum of Science in Boston under the direction of Christine Cunningham and others). What may set these efforts apart from earlier efforts, and lead to greater success in promoting more widespread adoption, is their explicit alignment with science and engineering.

Table 2. *A Taxonomy of Technological Literacy (Todd, 1991, p. 24; Petrina, 2007, p. 192)*

Levels	Types of Knowledge	Competence
Technological perception	Knowing what	Attention
Technological expression	Knowing what, that	Expression
Technological capability	Knowing what, that, and how	Application
Technological ingenuity	Knowing what, that, how, when, and why	Invention
Technological sensibility	Knowing what, that, how, when, why, and why not	Judgment

Dominant instructional approaches.

In an article published in 1994, Patrick Foster used selected quotes from current and historical documents to illustrate his thesis that “technology education” was simply a “logical renaming” of industrial arts—that the change was neither revolutionary nor, in the end, truly evolutionary. One might argue with his thesis, but I wish here only to borrow from his discussion of the dominant instructional approaches associated with technology education. These include *integration* of technology with other subject areas, examining the *social/cultural impacts* of technology, and engaging students in *problem solving*. Using selected quotes, Foster showed clearly that these strategies were being discussed and promoted just as widely in the early 1900s as they were at the end of the 20th century (Foster, 1994). Today, we have perhaps traded a focus on problem-solving for an emphasis on engineering design, although one might be hard pressed to differentiate from the two approaches in a typical classroom setting. The one contextual approach that was certainly evident throughout the 20th century (and that was identified by Foster in 1994) but that is little discussed today as a basis for the curriculum is a focus on "industry" or "industrial activities."

Any number of documents has called for using an instructional approach that develops "problem-solving skills" in students (or, alternatively, that claim that technology education teaches students how to become effective problem solvers). This approach was presented as a dominant methodology for technology education in the *Conceptual Framework for Technology Education* (Savage & Sterry, 1990), under the heading "the Technological Method Model" (p. 13). It might be said that "design" represents the most popular current incarnation of problem solving in technology, since both draw upon similar skills and strategies. However, *claiming* that technology education advances problem-solving and design skills is different from actually *doing* so; Petrina (2007) called technological problem-solving "one of the most used and abused approaches to technology studies" (p. 123). The question that is often not adequately addressed when these methodologies are employed is: "How does doing lead to knowing?" (Petrina, 2007, p. 124).

In a Delphi study conducted by Hacker, de Vries, and Rossouw (2009), which set as its goal a preliminary identification of the essential content and contexts of engineering technology education, the researchers summarized panelist responses by identifying three primary characteristics of the contexts in which technology should be studied. They should (a) encompass the human-made world, (b) be truly relevant to students' lives, and (c) exemplify enduring human concerns (p. 21). Additionally, the group sought some indication of what panelists believed to be the focal categories for engineering technology education studies. Categories ranged from "energy in society" and "biotechnology" to "sustainable technology," "transportation" and "medical technologies" (p. 44), although the team admitted that there was a higher level of disagreement among panelists with regard to contexts than there was to content. The team also expressed surprise at the extent to which the traditional categories of manufacturing, transportation, construction, and communication were identified as important (p. 44).

The DNA of Technology, Revisited

Our biological heritage, our genetic code, is built upon the foundation of four molecules that join to form the nucleotides that bond with sugar and phosphorus to create our DNA. These molecular building blocks join in specific, predictable ways, but the ensuing organism manifests a rich tapestry of traits.

What are the building blocks of technology education? This author proposes that there are four: resources, manipulations, methodologies, and categories (Figure 1). These represent the fundamental components of any program for the study of technology. Each can be identified throughout the historical lineage of the field. Although their external characteristics have evolved, manifesting in one generation an emphasis on industry, in another an emphasis on engineering, their essential traits are stable and robust. Furthermore, they should only be considered within the "backbone" of the environmental and social contexts in which they occur.

Resources encompasses, most importantly, the material and energy inputs required by all technological systems. *Manipulations* means that there must be a hands-on element; that knowledge of "how to do" is demonstrated through the manipulation of materials or tools. *Methodologies* can refer to any procedural task associated with technology, whether it be designing, measuring, troubleshooting, or operating. Finally, *categories* refers to those areas of human technological activity that provide the focus of study. These could include agriculture, energy generation, construction, transportation, or more—with two important caveats: (1) preference should be given to categories that most directly reflect aspects of the students' lives, and (2) no attempt should be made to achieve an exhaustive coverage of all categories.

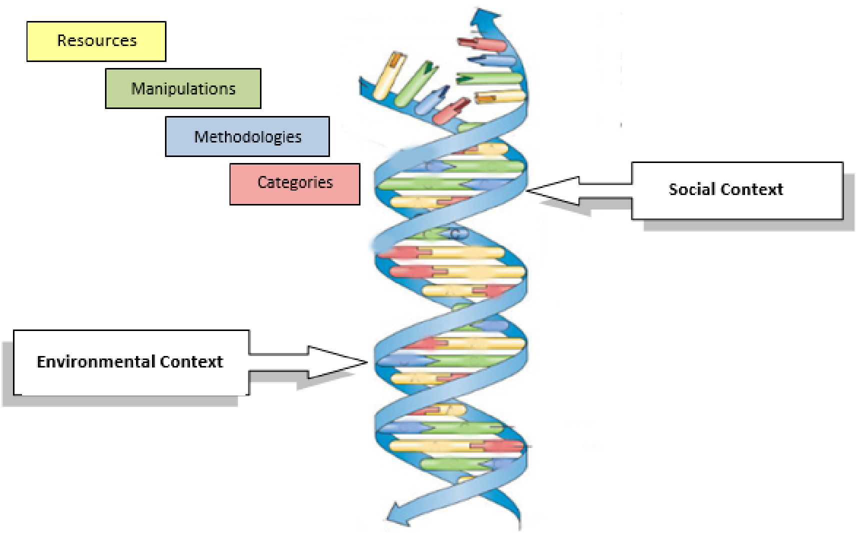


Figure 1. Visual representation of the "DNA" of technology education.

Barriers to the Evolution of Technology Education

A case has been made here that the concepts and contexts of technology education are, in fact, well established and have been for some time. What, then, are the barriers preventing technology education from achieving its evolutionary potential to serve as a dominant component of the educational enterprise in K-12 education and beyond? This dilemma has been explored exhaustively (see, for example, Herschbach, 1989; Wicklein, 1993; Zuga, 1997; Boser, Palmer, & Daugherty, 1998; Hoepfl, 2002; Erekson & Shumway, 2006; and others). I would like to revisit some of the more obvious contributing factors as well as posit some ideas that may have received less attention over the years.

1. The scope of technology education has been too broad. Even a cursory review of any of the curriculum theory or standards documents reviewed here will quickly show that the sheer amount of information included could not be addressed sufficiently with even a lifetime devoted to its study. This has resulted in enormous inconsistency in what has been taught from one school to the next, and in the ways that technology education has been taught. A contributing problem is that there have not been enough teachers sufficiently prepared to teach the content of technology education, particularly as so broadly envisioned. All of these factors remain true today and are particularly troubling in times of shrinking educational resources.

2. Strategic partnerships between technology education and other fields of study are lacking. Although promising efforts have been made to align technology education with other fields, most notably science and engineering, these remain at best "fringe" efforts and have not permeated mainstream practice. At the same time, technology education has continued to sever its relationship with career-technical (vocational) education, a relationship that need not undermine the general education goals of the discipline of technology, and should be revisited.

3. The emphasis on the importance of praxis (the "doing" of technology) has been diminished. By in some cases abandoning core content and contexts (e.g., materials, manipulations) we have abandoned a strategic strength of technology education. At the same time, we have failed to adequately address elements of another core area (methodologies; e.g., problem-solving, design, valuing). We see this in the increased use of cookie-cutter curricula such as instructional modules, the increased reliance on computer modeling at the expense of real experimentation, and the dismantling of technology laboratories and shops.

4. There has been a failure to acknowledge (or reconcile) the dichotomy between the dominant "world views" of technological thought. There is a fundamental divergence between the approach that calls for critical analysis of technology and its relationship to society and culture, on the one hand, and the approach taken by technological optimists (see, for example, Huesemann, 2003), who seek continual expansion of our technological capabilities as the primary goal of technological literacy. Both of these goals can be found as subtext to nearly every one of the curriculum efforts reviewed here.

The challenges of this paradoxical relationship were acknowledged nearly thirty years ago at a conference convened by Paul DeVore in Morgantown, WV. There, Juergen Schmandt, who was then the Associate Director of the Program on Technology and Society at Harvard University, described our tendency to avoid the difficult political decisions of the technological age and instead to wait for new technological solutions to take care of whatever problem society faces. He noted: "The very success of technology is the solid base on which this optimistic faith is built. It is an attitude which understandably is often characteristic of scientists and engineers" (p. 11). Challenging the notion that complex social problems can be solved by straightforward technological solutions, he said: "It is difficult to say what is more dangerous: uncritical glorification or ignorant neglect of science and technology on the part of political decision-makers" (p. 12). The general lack of scientific and technological literacy among members of a society, combined with technocratic optimism, results in "a dangerous gap" between the power of our technology and the capacity of our social mechanisms to control this power (p. 14).

Just a few days ago, the latest issue of *National Geographic* appeared in this author's mailbox. On page 18 (Berlin, 2009) was a short piece about the "Bloodhound SuperSonic Car" under development in England. The car is expected to achieve a top speed of 1,050 miles per hour via jet and rocket propulsion, besting the current land speed record by nearly 300 miles per hour. Of the $15 million Bloodhound—funded by corporations, the British government, and universities—it was said it "isn't just for joyrides. It's also a lure for students. 'If we want a low-carbon world… we need to grow more engineers.' Britain's government agrees. It's allotting a million dollars for schools to study the sound-barrier buster's advanced systems" (Berlin, 2009, p. 18). How can anyone who takes the critical analysis element of technological literacy seriously reconcile such analysis with a society that spends $15 million dollars on a high-powered machine to "lure" students into wanting to create a "low-carbon world?" This example handily illustrates the often dichotomous nature of views about technology.

5. Women have been chronically underrepresented in the field of technology. There was a notable lack of participation by women on most (if not all) of the seminal technology education curriculum theory efforts of the 20th century. There is no need to place blame and it may not be possible to identify the primary causes of this lopsided representation of society, but the fact remains that an important source of advocacy for the technological literacy cause has been largely left out of the conversation (see, for example, Zuga, 1999; McCarthy, 2009).

The Way Forward: Continuing to Evolve a Framework for Technological Literacy

On the first page of this narrative, this author listed the questions that were provided as a framework for the paper. In this concluding section, the responses given to the questions posed are as follows. (1) What is the DNA (the enduring concepts) of technology education? A: Resources, manipulations, methodologies, and categories, aligned within a structural matrix formed by social and environmental contexts. (2) Does our profession need to embrace a single curriculum or a common core of courses to rally around? A: Yes, sort of. (3) Are there core concepts? A: Yes. (4) Core content? A: Yes. (5) Core instructional strategies? A: Yes, there could be. (6) Is there a signature pedagogy for technology education? A: Yes, there could be. (7) Should there be? A: Yes.

To conclude this analysis, several recommendations are offered based on this review of technology education's lineage.

1. We should engage in the development of a new set of standards to identify/affirm the core concepts and contexts of technological literacy. Such an effort must result in a more distilled collection of enduring concepts and identification of a set of "universal skills" in order to avoid what has proven to be the persistent tyranny of too much to teach. A belief underpinning earlier curriculum efforts, including *The Maryland Plan*, was that content should be general enough to reduce "the chances of concentrating on information which may become obsolete in the student's life-time" (Smith, 1970, p. 20). This belief was echoed by Lux and Ray (1970), who wrote that "a secondary school program geared to occupational practices which may be obsolete within a few years is grossly inefficient" (p. 307). In spite of these claims, writers of the extant curriculum documents could not avoid natural tendencies to be systematic and comprehensive in identifying curriculum content.

Addressing the debate in the mid-1970s about whether the discipline of industrial arts should be renamed, Donald Lauda pondered the merits of modifying the word *technology* with the adjective *industrial*: "On the one hand the use of a modifier (e.g., industrial) implies the inability to cope with the totality called technology. On the other hand, one is left with the impression that all technical knowledge and the socio-cultural consequences can be compressed into a curriculum package" (Lauda, 1976, p. 8). No matter what adjective we might employ (with "engineering" being the latest contender) curriculum developers must resist the tendency to be overly-ambitious.

The groundbreaking *Project 2061* effort, which was one of the first to formally pose technology as a critical component of science and technological understanding as a part of scientific literacy, charged the members of its Technology Panel with the task of delineating explicitly the features of the "technology component." Panel members were given some clear parameters, however. The content had to include only those topics that were of technological and human significance. It needed to include only a "small core of essential knowledge and skills." And the team was told to "ignore the limitations of present-day education" curricula and structures (Johnson, 1989, p. viii). Anticipating what instruction in science could or should look like in the year 2061, the AAAS panel's suggestions were "meant to go beyond adding bits of technology to the present school curriculum," but instead were meant to serve as "the basis for a major revision of U.S. education, reflecting throughout the learning process the pervasiveness of technology in our lives" (Johnson, 1989, p. xi). The panel noted that a curriculum designed to teach about technology would possibly need to make "increased use of team teaching" (p. 3).

2. We should continue to pursue strategic partnerships, not for their political benefits but for their functional benefits. Lowen (1970) provided a graphical description (see Figure 2) of the constraints of the present-day curriculum structure that is useful in illustrating what a revised model might look like, à la *Project 2061*. The situation he described in 1970 remains familiar today: "The curricula in the traditional disciplines fall strictly around the periphery of th[e] plot…. [but] we must operate in the center…if we really want to create an interdisciplinary program" capable of addressing society's needs (p. 42). We have long noted the interdisciplinary nature of the study of technology and its capacity to serve as an effective curriculum integrator. New efforts are needed to achieve "real life" integration models like ones used at the collegiate level, such as Stanford University's "d.school" (http://dschool.stanford.edu/).

Another important aspect of the need for strategic partnerships is accepting the reality of what it will take to achieve technological literacy. We need much more than isolated partnerships with engineering educators. We need to embrace the role that will have to be played by historians, scientists, elementary school teachers, and so on if all Americans (not to mention the rest of humanity) are to know more about technology. According to Pearson and Young (2002), there are fewer than 40,000 technology education teachers in the United States, compared with 1.7 million teachers who are responsible for teaching science across the K-12 spectrum (p. 20). There simply are not enough technology educators available, and the stated goal (technological literacy) is too broad. Let's look for new ways for science educators (among others) and technology educators to work together, combining the unique strengths of the training of each in the development of curriculum models.

3. We should focus our attention on technological categories/ contexts that address fundamental human and environmental needs of the present day. The STS approach, which achieved its greatest popularity in the 1980s and 1990s, can offer some guidance. The STS approach calls for content selection based on current problems and issues in society, and its potential "to serve the goals of developing student decision making and problem solving process skills" (Gilberti, n.d., p. 45). Harking back to the words of Dewey, Bonser, and Mossman, let's seek out those categories that best relate to the day-to-day lives of our students and the needs of the society in which they live. Agricultural, communication, transportation, and sanitation needs of a region would all make good starting points.

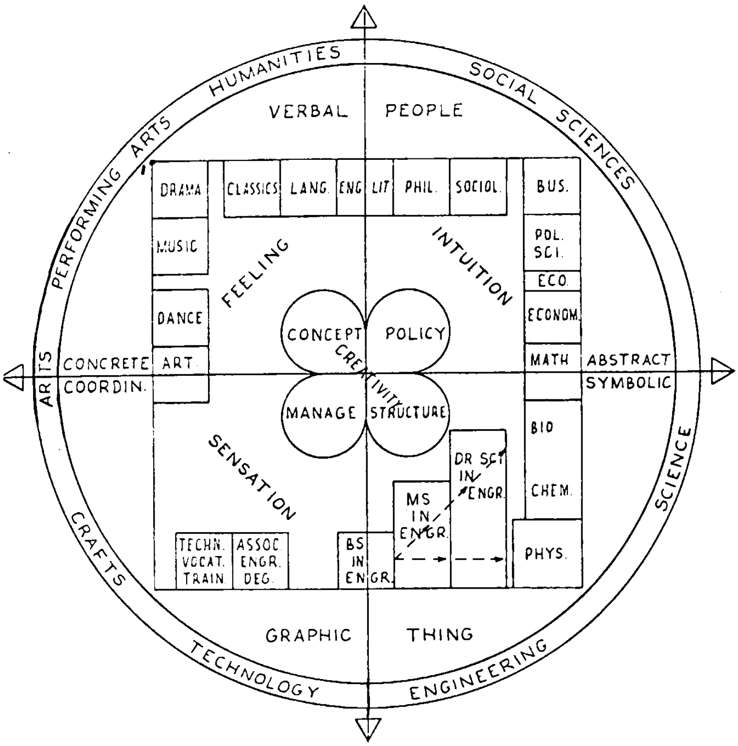


Figure 2. A graphical depiction of the structure of formal education (Lowen, 1970, p. 42).

4. We should not lose sight of the core element of manipulations and praxiology; let's seek to identify the "universal tools" that will serve our students well no matter the specific topic or context, and teach them well. Crawford, in his recent account of his personal journey from work as an electrician's apprentice at age 16 through a Ph.D. program in political philosophy and eventual decision to work as a motorcycle mechanic, made a case for the unique value of working with one's hands:

> …a realistic solution must include ad hoc constraints known only through practice, that is, through embodied manipulations. Those constraints cannot be arrived at deductively, starting from mathematical

> entities. These experiments…help us to understand why certain aspects of mechanical work cannot be reduced to rule following. (Crawford, 2009, p. 24)

Crawford quoted the ancient philosopher Anaxagoras and Martin Heidegger, both of whom spoke of the intelligence and knowledge humans gain through the use of their hands as they touch, use, and take care of things:

> If these thinkers are right, then the problem of technology is almost the opposite of how it is usually posed: the problem is not "instrumental rationality," it is rather that we have come to live in a world that precisely does *not* elicit our instrumentality, the embodied kind that is original to us. We have too few occasions to *do* anything. (p. 69)

Experience with hands-on manipulations of materials is seen as a critical component of technological literacy: "Someone who is knowledgeable about the history of technology and about basic technological principles but who has no hands-on capabilities with even the most common technologies cannot be as technologically literate as someone who has those capabilities" (Pearson & Young, 2002, p. 22). The reverse is also true: a high degree of technical proficiency alone does not ensure technological literacy, nor can it be presumed that engineers or other technical specialists understand the social, cultural, and environmental implications of their work. What remains to be explicitly defined is *what* types of doing are most beneficial, and in what contexts, in the development of technological literacy.

In their Delphi study to identify the "essential concepts of engineering design," Wicklein, Smith, and Kim (2009, p. 65) posed specific questions that focused on the essential skills or understandings needed for effective engineering design. These included mathematical understandings such as arithmetic, geometry, and creating spreadsheets; scientific knowledge such as Newton's laws of force and motion; and general skills such as ability to work in teams, ethics, and basic communication skills.

Notably absent from this exploration of *engineering* capability was any mention of hands-on activities. Recent attempts to more closely link engineering and technology as nearly synonymous enterprises may be shortchanging one or both of these areas of activity by overlooking critical components.

5. We should shake technology education loose from the craft orientation that has characterized some of the earlier curricular efforts and teaching practices. The goal of technological literacy cannot be reconciled with an approach governed by its "avocational" contributions, nor with the arts orientation found in many earlier industrial arts programs that included such activities as leather tooling and making pottery. As pleasant, engaging, and even remunerative as such activities might be, they do not represent the type of activity needed for critical understandings and capabilities relative to technology.

6. We should think more broadly about technological development over the life span. Related to recommendation two, conceptualizing technological development as it exists from birth through adulthood can help us better understand the foundations of technological literacy and its manifestations at all levels of growth. Thus, we would not remain content with the current structure of schools where technology education, if it exists at all, is confined to grades 6-8 or 6-12. We should find new ways to participate in the K-5 classroom, which might include conducting research on such things as mechanistic reasoning (with a tip o' the hat to Rich Lehrer at Vanderbilt University) or participation in curriculum development efforts to elaborate the "designed world" standard found in *Project 2061.* We should work with our career-technical education colleagues across the aisle to identify and help develop expanded and high-quality educational programs for students who want to delve more deeply into a particular technical field, whether it is automotive mechanics or carpentry. At the same time, we should not lose sight of the many possibilities that exist for technological development at the postsecondary level and beyond—even if they don't necessarily include the word "technology."

References

American Association for the Advancement of Science. (1989). *Science for all Americans: A Project 2061 report on literacy goals in science, mathematics, and technology.* Washington, DC: Author.

Berlin, J. (2009, October). Fastest car. *National Geographic, 216*(4), 18.

Bjorkquist, D.; & Swanson, R.A. (1981). Technology education: A good beat, but, hard to dance to! *Technology Education Symposium II.* Menomonie, WI: University of Wisconsin Stout.

Bonser, F.G. (1921). *The elementary school curriculum.* New York: The Macmillan Company.

Boser, R.A, Palmer, J.D., & Daugherty, M.K. (1998). Students' attitudes towards technology in selected technology education programs. *Journal of Technology Education, 10*(1), 4-19.

Brown, K. (1977). *Model of a theoretical base for industrial arts education.* Washington, D.C.: American Industrial Arts Association.

Colleli, L. (1989). *Technology education: A primer.* Reston, VA: International Technology Education Association.

Crawford, M.B. (2009). *Shop class as soulcraft: An inquiry into the value of work.* New York: The Penguin Press.

DeVore, P.W. (1966). *Structure and content foundations for curriculum development.* Washington, D.C.: American Industrial Arts Association.

Erekson, T., & Shumway, S. (2006). Integrating the study of technology into the curriculum: A consulting teacher model. *Journal of Technology Education, 18*(1), 27-38.

Foster, P. (1994). Technology education: AKA industrial arts. *Journal of Technology Education, 5*(2), 15-30.

Gilberti, A.F. (n.d.). The Science/Technology/Society approach. In A.F. Gilberti (Ed.), *Integrating Technology, People, and the Environment* (pp. 43-49). Reston, VA: International Technology Education Association.

Hacker, M.; de Vries, M.; & Rossouw, A. (2009). *CCETE Project: Concepts and contexts in engineering technology education, results of the international study.* Hempstead, NY: Hofstra University.

Halfin, H.H. (1973). *Technology: A process approach*. Unpublished doctoral dissertation, West Virginia University, Morgantown.

Herschbach, D. R. (1989). Conceptualizing curriculum change. *The Journal of Epsilon Pi Tau, 15* (1), 19-28.

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

Hoepfl, M.C. (2002). The gap between theory and practice. *Journal of Industrial Teacher Education 39*(4). Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v39n4/editor.html

Huesemann, M.H. (2003). The limits of technological solutions to sustainable development. *Clean Technologies and Environmental Policy, 5*(1), 21-34.

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

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

Johnson, J.R. (1989). *A Project 2061 panel report: Technology.* Washington, D.C.: American Association for the Advancement of Science.

Kirkwood, J.J., & Foster, P.N. (Eds.). (1997). *Elementary school technology education.* 46th Yearbook of the Council on Technology Teacher Education. Peoria, IL: Glencoe McGraw-Hill.

Lauda, D.P. (1976). *Technology as content: Can teacher education cope?* Charleston, IL: Eastern Illinois University.

Lowen, W. (1970). Technology, education and society. In P.W. DeVore & W.J. Smith (Eds.), *Education in a Technological Society* (pp. 35-45). Morgantown, WV: West Virginia University Office of Research and Development.

Lux, D.G., & Ray, W.E. (1970). Toward a knowledge base for practical arts and vocational education. *Theory Into Practice, 9*(5), 301-308.

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

McCarthy, R. (2009). Beyond smash and crash: Gender-friendly tech ed. *The Technology Teacher, 69*(2), 16-21.

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

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

Petrina, S. (2007). *Advanced teaching methods for the technology classroom.* Hershey, PA: Information Science Publishing.

Ricardo, A., & Szostak, J.W. (2009). Life on Earth. *Scientific American, 301*(3), 54-61.

Sanders, M. (2001). New paradigm or old wine? The status of technology education practice in the United States. *Journal of Technology Education, 12*(2), 35-55.

Savage, E., & Sterry, L. (1990). *A conceptual framework for technology education.* Reston, VA: International Technology Education Association.

Schmandt, J. (1970). Technology and social purpose. In P.W. DeVore & W.J. Smith (Eds.), *Education in a Technological Society* (pp. 1-16). Morgantown, WV: West Virginia University Office of Research and Development.

Scobey, M.M. (1968). *Teaching children about technology.* Bloomington, IL: McKnight & McKnight Publishing Company.

Secretary's Commission on Achieving Necessary Skills (SCANS). (1991). *What work requires of schools: A SCANS report for America 2000.* Washington, DC: U.S. Department of Labor.

Smalley, L. (Ed.). (1989). Focus on problem solving. *Technology Education Activity Forum, 2*(1).

Smith, W.H.. (1970). *The Maryland Plan: Industrial arts program for the junior high school.* College Park, MD: University of Maryland Department of Industrial Education.

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

Thrower, R.G., & Weber, R.D. (Eds.). (1974). *Industrial arts for the elementary school.* 23rd Yearbook of the American Council on Industrial Arts Teacher Education. Bloomington, IL: McKnight Publishing Company.

Todd, R.D. (1991). The natures and challenges of technological literacy. In M. Dyrenfurth & M. Kozak (Eds.), *Technological Literacy.* 40th Yearbook of the Council for Technology Teacher Education (pp. 10-27). Peoria, IL: Glencoe.

Warner, W.E., Gary, J.E., Gerbracht, C.J., Gilbert, H.G., Lisack, J.P., Kleintjes, P.L., & Phillips, K. (1947, April). *A curriculum to reflect technology.* Presented at the American Industrial Arts Association conference, Columbus, OH. Reprinted 1965 by Epsilon Pi Tau, Bowling Green, OH.

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

Wicklein, R., Smith, P.C., and Kim, S.J. (2009). Essential concepts of engineering design curriculum in secondary technology education. *Journal of Technology Education, 20*(2), 65-80.

Zuga, K. (1997). An analysis of technology education in the United States based upon an historical overview and review of contemporary curriculum research. *International Journal of Technology and Design Education, 7*, 203–217.

Zuga, K. (1999). Addressing women's ways of knowing to improve the technology education environment for all students. *Journal of Technology Education*, *10*(2), 57-71.

Technology Education Perspectives of STEM Education

Presented at the 97th Mississippi Valley Technology Teacher Education Conference, 2010, Chicago, IL

Chapter 13

Chris Merrill
Illinois State University

In 2010, the author was asked to develop and deliver a research-based paper and presentation to Mississippi Valley Technology Teacher Education members at the 97th Annual Conference, held in Rosemont, Illinois based on a series of pre-determined questions that provided focus to the perspectives held by technology education professionals regarding science, technology, engineering, and mathematics (STEM) education. The purposes of the paper and presentation were to provide research-based findings, approaches, and perspectives of STEM education as they relate to technology education. At the time of this paper and presentation, technology education as a discipline was moving toward increased discussions and approaches to best formalize STEM at the K-12 and post-secondary levels, especially in regard to technology teacher education. Based on a report by the National Governors Association (2007), in the new global economy, states need a workforce with the knowledge and skills to compete – a new workforce of problem solvers, innovators, and inventors who are self-reliant and able to think logically. A key to developing these skills is strengthening STEM education at the K–12 level.

STEM Education at the K-12 Level

Efforts are underway by STEM-focused individuals and professional organizations to increase the STEM-based student talent pool in the United States, especially in engineering and engineering-related fields, by implementing curricular options and outreach programs at the K-12 levels. Academic and professional bodies such as the American Society for Engineering Education (ASEE) have provided guidelines for K-12 engineering that focus on hands-on, interdisciplinary, and standard-based education that emphasizes the social relevance of the engineering discipline (Douglas, Iversen, & Kalyandurg, 2004). In 2002, the National Academy of Engineering (NAE) published *Technically Speaking: Why All Americans Need to Know More about Technology* emphasizing the need for all people to obtain technological literacy to function in the modern world. The International Technology and Engineering Educators Association (ITEEA) released the *Standards for Technological Literacy: Content for the Study of Technology* (ITEEA, 2000), which attempts to increase students' technological literacy at all levels of the K-12 curriculum through the use of engineering design.

Brophy, Klein, Portsmore, and Rogers (2008) in their work on advancing engineering in the classroom, identified and described some of the more popular programs that are presently active at the K-12 levels. Below, a few of the programs are highlighted.

- **Engineering is Elementary (EIE):** This is one of the largest elementary engineering curriculum development projects. It focuses on integrating engineering with reading literacy and existing science topics in the elementary grades. The project is primarily funded by the National Science Foundation (NSF) with matching funds from industry. It was originally developed at the Boston Museum of Science to meet new engineering standards like those defined by Massachusetts. EiE is aligned with national and many state standards and integrated with science, language arts, mathematics, and social studies. Pre-service teacher education programs are beginning to use these materials in their courses. EiE also provides in-service professional development for educators who want to implement the curriculum.

- **LEGO Engineering**: The most prominent project of Tufts Center for Engineering Educational Outreach for the past 12 years. The center initially selected the LEGO material to implement the majority of its engineering efforts at the K-12 levels as well as at the college level because of their ease of use, as well as their power to enable students in hands-on engineering design. The LEGO toolkit provides students the opportunity to design solutions to various problems, while still allowing them to make changes with their design. Students can create working products of significant complexity, while still remaining open-ended. The LEGO engineering inspired books and activities help to give educators at the elementary, middle, and high school /college levels basic activities to bring engineering into the classroom and teaching engineering content. There are a number of ways that teachers and students become involved with LEGO engineering: (a) through after-school programs, (b) engineering conferences, and (c) week-long summer workshop for local teachers.
- **Project Lead the Way:** Project Lead the Way is currently one of the more popular initiatives at the middle and high school levels. PLTW is a non-profit organization that works with public schools, the private sector, and higher education to increase the quantity and quality of engineers and engineering technologists, by providing students with engaging pre-engineering activities. PLTW offers a multi-year, problem-based/project-based curriculum that has been adopted by over 1400 schools (7 percent of all U.S. high schools) in all 50 States and the District of Columbia

(Tran & Nathan, 2010). The middle school curriculum (Gateway to Technology) introduces students in grades six through to eighth to the broad field of technology through units such as *design and modeling, the magic of electrons, the science of technology, and automation and robotics*. The standard-based pre-engineering curriculum (Pathway to Engineering), is designed for the high school level. This curriculum challenges students to solve real-world engineering problems by applying their knowledge and skills in mathematics, science, and technology. The four year engineering-related sequence consists of eight hands-on courses; three are foundation courses *(introduction to engineering design, principles of engineering and digital electronics)* four are specialized courses *(aerospace engineering, biotechnical engineering, civil engineering and architecture, and computer-integrated manufacturing)* and one one is a capstone course *(engineering design and development)* (PLTW, 2001). Once a teacher has been selected by the school to teach PLTW courses, he or she must complete assessment readiness and training that has a focus in mathematics and core training. Teachers then attend a two-week professional development summer training institute at their state's affiliated training center for each course that they will teach; these courses are taught by master teachers and affiliated university professors.

- **The Infinity Project:** The Infinity Project was developed in 1999 by the Institute for Engineering Education at the Southern Methodist University, in conjunction with Texas Instruments, U.S. Department of Education, and National Science Foundation. The Infinity Project focuses on technological literacy and engineering at the middle and high school levels through curriculum on advanced topics in digital signal processors (DSPs), including the Internet, cell phones, digital video and movie special effects, and electronic music. Teachers in the Infinity Project must be certified in mathematics, science, or technology, be comfortable working with computer programs, and be motivated to participate. Teacher participants attend a 35-hour professional development institute taught by master teachers.

- **The Vanderbilt Instruction in Biomedical Engineering for Secondary Education (VIBES).** VIBES started in 1999. The project was funded through the National Science Foundation's Vanderbilt-Northwestern-Texas-Harvard/MIT engineering Research Center (VaBTH ERC). VIBES consists of learning modules to teach high school level engineering, physics, or portions of an anatomy or physiology course. Teachers participating in VIBES must be teaching a relevant course and have approval from their home school to participate in VIBES workshop. Workshop training is an average of two days per unit and costs $250 per unit, plus housing and/or food expenses. Teachers can remain in contact with VIBES developers via phone and email in case they have questions or concerns about the material as they teach.

Table 1. *Other STEM Programs at the K-12 Levels*

Program	Grades	Type of Program
Adventure Engineering	6-12	Adventure Engineering was created in 1998 with financial assistance from the National Science Foundation. Adventure Engineering was integrated into numerous Denver area public schools beginning in 2003. Today, Adventure Engineering units are used in classrooms all over the U.S. The mission is to help improve elementary, middle and high school student attitudes towards and competency in science, math, and engineering by developing and offering fun, effective team-oriented project-based curricula. It is their hope that Adventure Engineering curricula inspires and builds confidence in students who would not otherwise pursue science and engineering futures.

Table 1. *Other STEM Programs at the K-12 Levels (continued)*

Program	Grades	Type of Program
ASEE	K-12	Here you will find a variety of tools to boost your students' math and science skills, enliven the classroom with engineering projects, expand your own professional horizons and stay informed.
Center for Technology Education	K-16	The HOFSTRA Network of Secondary Teachers is designed to support secondary school teachers in their first few years in the classroom. The association holds conferences where new and experienced teacher practitioners and HOFSTRA professors come together to share teaching methods and materials, develop curriculum, and discuss issues in the field.
Center for Mathematics, Science, Technology, and Pre-engineering	3-5	Preparing K-12 teachers to develop and implement integrated math, science and technology activities, which utilize an inquiry and design-based (I&DB) problem-solving approach. Preparing and publishing technologically based integrated curriculum for K-12 school adoption. Preparing special education teachers to use computer technology to provide access to the curriculum and improve the education of children with disabilities.
DTEACh	K-6	Today's educators are striving to make science, technology, engineering, and math (STEM) education fun and exciting by offering students innovative, hands-on learning opportunities. DTEACh supports these teachers with curriculum development and in-service teacher training. With a focus on 21st-century skills, the DTEACh method helps educators teach core content in new, exciting, and challenging ways.
Engineering by Design	K-12	The International Technology and Engineering Educators Association's STEM Center for Teaching and Learning™ have developed the only standards-based national model for Grades K-12 that delivers technological literacy. The model, Engineering by Design™ is built on Standards for Technological Literacy (ITEEA); Principles and Standards for School Mathematics (NCTM); and Project 2061, Benchmarks for Science Literacy (AAAS)

Table 1. *Other STEM Programs at the K-12 Levels (continued)*

Program	Grades	Type of Program
INSPIRE- research and teacher professional development	P-5	INSPIRE is dedicated to addressing the downward trends in engineering interest, preparedness, and representation; to transforming P-12 education to include engineering; to preparing a globally competitive engineering workforce; and ultimately to creating a society of engineering-literate citizens
National Center for Engineering and Technology Education	K-12	The National Center for Engineering and Technology Education is a collaborative network of scholars with backgrounds in technology education, engineering, and related fields. Our mission is to build capacity in technology education and to improve the understanding of the learning and teaching of high school students and teachers as they apply engineering design processes to technological problems
MWM- Material World Modules	6-12	The NSF-funded Materials World Modules (MWM) Program has produced a series of interdisciplinary modules based on topics in materials science, including Composites, Ceramics, Concrete, Biosensors, Biodegradable Materials, Smart Sensors, Polymers, Food Packaging, and Sports Materials. The modules are designed for use in middle and high school science, technology, and engineering, and math classes and have been used by over 35,000 students in schools nationwide. MWM is based on principles of inquiry and design and emphasizes active, hands-on learning.
NASA- For Educators	K-12	NASA's Science Education Program creates products using NASA's results in Earth-Sun system science, solar system research, universe exploration, and the development of new technologies to support learning. The program sponsors educational activities at all levels of formal and informal education to provide opportunities for learners to investigate their world and their universe using unique NASA resources.

Table 1. *Other STEM Programs at the K-12 Levels (continued)*

Program	Grades	Type of Program
Primary Engineer	P-11	Is a not-for-profit organization established in 2005 with the aim of encouraging more young people to consider careers in STEM-related professions. Its work is supported by Tomorrow's Engineers and industry. Primary Engineer STEM by STEALTH courses: This series of courses is delivered to secondary teachers who then incorporate it into their primary liaison program. Courses focus on practical skills and the application of practical mathematics and science to 'design and make' design technology activities. The courses are appropriate for primary teachers wishing to attend directly The Primary Secondary and advanced Leaders award in STEM. This project aims to give students between the ages of 5-19 the opportunity to be leaders for STEM subjects in the school and meet and interview professional from a range of STEM backgrounds. The Award is tracked to the BTEC STEM Leadership Qualification.
CeMaST	K-12	The primary goal of CeMaST is to pursue and support projects and activities that seek to improve the teaching and learning of science, technology, and mathematics.

Structure of STEM Programs at the Elementary and Middle School Levels

As at the high school level, most of the STEM initiatives at the middle school and the elementary level are combinations of in-school and outreach programs. Table 1 lists some of the in-school and out-of-school outreach programs that target both the high school and middle school levels. STEM programs, however, have different emphases at the middle and elementary level school levels. Take, for example, the California Department of Education's STEM goals for elementary and middle schools reflect the general focus at each level. In California at the elementary level, the general focus of STEM programs is to provide the introductory and foundational STEM courses that lead to success in challenging and applied courses in secondary grades by (a) introducing awareness of STEM fields and occupations; (b) stimulating student interest in “wanting to” rather than “having to” take further STEM-related courses; and (c) providing standards-based and structured project-based learning that interconnects STEM subjects. At the middle school level in California, the goal is to (a) introduce a program of study consisting of rigorous and challenging courses; (b) increase student awareness of STEM fields and occupations, especially for underrepresented populations; (c) increase student awareness of the academic requirements of STEM fields and occupations; and (d) begin student exploration of STEM-related careers (California Department of Education, 2010).

The State Educational Technology Directors Association (SETDA) 2008 report on science, technology, engineering, and mathematics speaks to the current state of STEM education. The report stated that:

> The initial force behind STEM education initiatives was to develop future engineers and scientists through the implementation of specialty or magnet high schools focusing on science, technology, engineering, and mathematics. There are over 100 schools specializing in mathematics, science, and technology serving 37,000 students nationwide. While this approach works for students enrolled in these high schools, the majority of kids in most school districts in the country do not have STEM school options. Instead, in most school districts, science, technology, engineering, and mathematics are included as part of the entire curriculum – not as a specific focus. Many of these STEM subject areas are not integrated into the curriculum or taught on an everyday basis. For example, 29% of K-5 teachers report teaching science two or fewer days per week. (SETDA, 2008, pp. 3)

The report identified several initiatives that are taking place at district levels in middle and elementary schools. One such program is the Middle and Elementary School Mathematics and Science Programs located in Prince William County, Virginia. Three middle schools and two elementary schools in Prince William County offer Mathematics and Science Programs. The programs are designed to challenge and motivate students in science and math through hands-on discovery and exploration while developing critical thinking skills. These specialty schools stress rigorous academic instruction, strong performance expectations, and high behavioral standards. They use research-based, innovative instructional strategies within the framework of a traditional education. Another example can be found in the STEM Elementary Schools located in Utica, Michigan. Initially targeting grades 3-6, teachers and curriculum leaders have been working the last several years to develop STEM modules using the curriculum development templates of CurrTech Integrations. The modules are prepared within the framework of guiding philosophies such as 5E teaching/learning cycle, Understanding by Design (UbD), problem-based learning, performance-based assessments, inquiry, and formative assessments. The modules culminate in a final engineering-based problem in which students have to apply science, technology, and mathematics to an engineering process. Finally, the report highlighted the Scales Technology Academy Program, located in the Temple Elementary School District in Arizona. The program provides one-to-one laptops for all students from kindergarten through fifth grade and focuses on a high-technology curriculum. Scales Technology Academy provides a balance between core knowledge and 21st Century skills and infuses technology in all aspects of the curriculum. Students are taught to be independent learners, critical thinkers, and problem-solvers, and teachers use interactive whiteboards, document cameras, and audio enhancements among other technology tools. A unique feature of the school is the entire campus is wireless, promoting anytime, anywhere learning for all students. In September 2010 the National Inventors Hall of Fame School Center for STEM learning dedicated its new building and home of one of the nation's first STEM middle school. The school is an outcome of planning by five partners from the public and private sectors in 2004 for an Akron middle school that focuses on STEM. Although the school emphasizes STEM disciplines, it also incorporates all the required Ohio Content Standards, such as English language arts and physical education. The school also is noteworthy for its emphasis on project-based learning. Teachers are "coaches" who guide students in solving problems that can range from how to reduce noise levels in a room to restoring wetlands that had been drained for farming (The University of Akron, 2010).

The Department of Defense (DOD) carried out a survey of the science, technology, engineering, and mathematics programs the DOD is involved in. Table 2 highlights just some of the information on STEM activities that target the middle school and elementary school levels (DOD, 2010).

Table 2. *DOD STEM Initiatives*

Program/ Project Title	Program Description
Great Minds in STEM	Great Minds in STEM is the new name of the Hispanic Engineer National Achievement Awards Conference (HENAAC). Great Minds' campaign "STEMUP" is a community-wide education and outreach program that seeks to create awareness, and inspire, motivate, and develop skills. It focuses on Hispanic students and their families in the 18 schools of the Boyles Heights Community in East Los Angeles. Great Minds works with ROTC, the Y Center, Boy's Clubs, local universities and colleges (including Cal. State Los Angeles), and the private sector to encourage interest in higher education in STEM fields and disciplines. The program also provides vehicles such as scholarships to foster this pathway. Administered by the Army Corps of Engineers, and funded at $7.4M over five years.

Table 2. *DOD STEM Initiatives (continued)*

Program/ Project Title	Program Description
STARBASE Program	STARBASE emphasizes experiential applications, student interaction, and problem-solving experiments. Students and teachers visit military bases for 20 to 25 hours of instruction in 13 topics. They learn and apply knowledge in team inquiry, then add reasoning processes to build understanding of applied science, math and technology. Facilities, simulators, and trainers are made available. Collaboration between military bases, school districts, and communities ensures the integration of instruction with state and local science and math objectives. In 2008, there were 60 locations in 34 states, Washington, D.C. and Puerto Rico. There were also various outreach programs to American Indians in Missouri, Oklahoma and South Dakota. Program participants are primarily 5th graders from populations historically under-represented in STEM. These students may be disabled, socio-economically disadvantaged or come from inner cities, rural locations, or other areas with typically low academic performance.
Junior Solar Sprint - (JSS)	A national competition in which students explore concepts and technology to address global climate change, reduce air and water pollution, and reduce foreign fuel dependence. Focuses on the design, construction and racing of solar electric cars. Conducted by the Northeast Sustainable Energy Association and partially supported by AEOP.
eCybermission	Web-based competition promotes self-discovery and real-life applications of STEM. Teams propose a solution to a real-world problem in their communities and compete for regional and national awards. Encourages the pursuit of advanced education and careers, and increases the number of technologically literate citizens and future Army employees. Administered by RDECOM.
Discovery Academy	An interdisciplinary (science, math, language arts and social studies) 60-hour Web platform for teachers nationwide to incorporate into summer camps, the classrooms, or after-school programs.

STEM Programs, Literacy and Career Preparation

Most engineering outreach programs that were reviewed for this paper state in their mission statement that their aim is to increase technological literacy and encourage students to choose careers in STEM fields. Technological literacy's core concepts and content are based on the *Standards for Technological Literacy: Content for the study of Technology* (ITEEA, 2000). It is the view of some that if pre-engineering is placed in the technology education curriculum, teachers can prepare students that are both technologically literate and who possess engineering skills (Schroll, 2002; Grimsley, 2002; Wicklein, 2003). In fact, engineering and engineering design are both key components of the standards, and nowhere do the standards indicate that engineering and technological literacy are mutually exclusive. In addition, engineering societies were supporters and contributors to the development of these standards (Thomas, 2003).

The ACT (2006) report offers some insight as to what is happening at the high school level in regard to STEM interest. ACT research suggests that at the very time our nation most needs promising students to enter STEM majors and careers, students' interest in these fields is on the decline. Over the past ten years, the percentage of ACT-tested students who said they were interested in majoring in engineering has dropped steadily from 7.6 percent to 4.9 percent. Over the past five years, the percentage of ACT-tested students who said they were interested in majoring in computer and information science has dropped from 4.5 percent to 2.9 percent. ACT data indicate that high school students must take not only the right *number* of courses in high school but also the right *kinds* of courses—rigorous courses that will prepare them for the demands of college and the workplace. The ACT College Readiness Benchmark for Mathematics is 22 and for Science 24. Students who meet or surpass the Benchmark in a particular subject area have a high chance—75 percent or greater—of earning a course grade of C or higher and a 50 percent chance of earning a B or higher in a typical first-year college course in that area. Students who take more than three years of mathematics (Algebra I & II, Geometry, and additional higher-level courses) are significantly more likely to meet the College Readiness Benchmark in Mathematics (22) than those who take only three years or less of mathematics. Similarly, students who take an upper-level sequence of science courses that includes physics are substantially more likely to reach the College Readiness Benchmark in Science (24) than students who took only biology and chemistry or less.

At the policy the level, the National Action Plan report of 2007 point to some policy decisions that seek to align STEM education with career preparation. In the plan, it was noted that NSF should continue to play a critical role in developing human capital in STEM fields. The science and engineering workforce includes pre-college STEM teachers as well as those working in research, industry, and higher education. Developing a strong STEM teaching force would significantly strengthen STEM education across the nation and bolster the science and engineering workforce. NSF can play a significant role in strengthening the STEM teaching force because it has a unique relationship with and ability to, effect large-scale change in the higher education system and therefore should consider support for the following types of programs to strengthen pre-college STEM teaching:

- Develop and fund effective programs for STEM teacher preparation. This could include expansion of the Robert Noyce Scholarship program, which targets college students aspiring to teach STEM at the high school level.
- Use its strong connections with higher education to encourage and provide tools to university faculty and administrators who are committed to providing effective STEM teacher preparation programs.
- Develop programs that encourage student interest in STEM fields at all grade levels. One possibility would be to develop programs that provide STEM experiences for high school students similar to those offered by the

Research Experiences for Undergraduates (REU) program.

- Use its research base in learning and educational practice to develop and disseminate effective in-service teacher professional development model programs or modules that can be implemented on the large scale.
- Continue to support and grow programs that build bridges between P-12 and higher education, such as its highly successful model Math and Science Partnership (MSP) Program. The NSF's MSP program has demonstrated success in improving both student mathematics and science performance in K-12 schools and the willingness of higher education STEM faculty to work with K-12 teachers. The Board is on record with its strong support for this program at NSF. Consideration should be given to expanding the program to include technology and engineering partnerships as well as math and science.
- Support STEM professionals who wish to pursue research on teaching and learning in their respective STEM fields, perhaps in collaboration with education researchers with complementary and supporting interests and skills.
- Expand financial support for programs that have an established record of improving the performance and persistence of minority students pursuing STEM careers, including STEM teaching, such as the Louis Stokes Alliance for Minority Participation (LSAMP).
- Partner with secondary schools, institutions of higher education, business and industry, and government agencies to strengthen the technical workforce.
- Ensure that STEM teachers and students are aware of and familiar with the full range of opportunities provided by cyber-enabled teaching, discovery, and learning. (National Science Board, 2007, pp. 14- 16)

According to the Governor's report "Building a Science, Technology, Engineering, and Math Agenda" by the National Governors Association (2007), several strategies are necessary to build the STEM field. These include aligning state K–12 STEM standards and assessments with postsecondary and workforce expectations by:

- Aligning state STEM standards and assessments to international benchmarks through state-level participation in the Program for International Student Assessment (PISA) and/or The Trends in International Math and Science;
- Aligning K–12 STEM expectations with readiness for all postsecondary pathways to the knowledge-based economy; and
- Aligning STEM expectations between elementary, middle, and high school levels to help create a coherent K–12 STEM system (pp. 10-12).

Another strategy recommended in the report relates to career and technical education (CTE) as an option for all students with the same postsecondary pathways readiness expectations as for non-CTE students, particularly in its training for high-wage, high-skill occupations in STEM fields. Additionally, in the report, it was stated that "aligning instruction to career cluster knowledge and skills creates a fundamentally different type of instruction where academic and technical instruction is blended and transitions among learner levels are seamless" (p. 20). Within the CTE community, there is a two-fold goal to support this strategy to inject rigor and relevance into both existing and emerging programs. Career clusters, for example, is a grouping of occupations and broad industries based on commonalities. The 16 career clusters provide an organizing tool for schools, small learning communities, academies, and magnet schools. **Arizona** conducted a comprehensive review of its CTE curriculum during which specific program standards were written and programs were updated to include reinforcement of state academic standards. As a result, in 2004, CTE graduates who took two or more CTE courses outperformed the general high school student population taking all three of Arizona's high-stakes academic tests (AIMS). The state's next step will be to look at CTE curriculum and identify the STEM standards embedded within current CTE courses and to add STEM standards where gaps exist. The State of Maine is integrating CTE into the state's overall academic framework. As a result, Maine's CTE Centers are increasingly emphasizing numeracy and literacy. The state has also launched a P–16 demonstration project that locates two high schools, the CTE Center, a community college, and a university on the same site. Meanwhile, the State of Kentucky has developed a series of interdisciplinary CTE courses that meet academic course requirements. For example, two courses, computer-aided drafting and construction are structured so that they cover all 23 state standards for geometry (National Governors Association, 2007, p. 20).

Teacher Preparation and Certification

The number of universities offering STEM degree programs are slowly increasing. Below are highlights from just a few of the programs in the U.S. that are STEM-based and/or focused.

- One of the first degree programs to focus solely on the teaching of STEM disciplines is Virginia Tech. The STEM education graduate program started in spring 2006. These new graduate degree options develop 21st century K-16 STEM educators, leaders, scholars, and researchers prepared to investigate, teach, and disseminate new integrative approaches to STEM teaching and learning. According to the information found on the Virginia Tech School of Education website (2010), their focus on the investigation and application of new integrative approaches to STEM education uniquely sets them apart from other STEM programs.

- Another STEM degree program is the STEM Education and Leadership program offered at Illinois State University. The Master of Science Degree focuses on integrated STEM education and leadership. Graduate students are enrolled in online, face-to-face, and hybrid coursework focusing on STEM pedagogical content knowledge, STEM integrated curriculum, STEM learning theories/cognitive science, and STEM leadership for the public schools. Complementing the STEM-based coursework, teachers also take coursework in educational research and statistics with a focus on action research, curriculum development, emerging technologies, and assessment.
- The University of California Riverside (UCR) Graduate School of Education offers an integrated single subject teaching program for science–mathematics. UCR's Integrated Science - Mathematics Program is an intense track for students who desire to incorporate education courses while working on STEM Bachelor Degree requirements; allows candidates to earn a STEM degree and meet the requirements to enter into UCR's teaching credential program. Public school field experiences are combined with coursework and paid fellowships are available (University of California Riverside, 2010).
- Old Dominion University has undergraduate and graduate degrees related to STEM education and has renamed their department to the Department of STEM Education and Professional Studies.

Who is teaching what in STEM?

The National Governors Association report (2008) highlighted serious concern of retaining STEM teachers. According to information found in the report, the shortage of STEM teachers in the U.S. is directly linked to the low quality of STEM education. The shortage of mathematics and science teachers is projected to reach 283,000 by 2015 and the shortage of technology educators is even more severe. In view of the high attrition of STEM teachers either by way of resignation or retirement, states must take steps to address this systemic problem not only thorough financial incentives and other recruitment strategies, but also through high-quality preparation, support, and professional development of STEM teachers. This is more urgent in view of the fact that teachers with STEM content knowledge and/or experience are drawn to higher salaries and careers in the private sector. Further stated in the report, "forty percent of U.S. middle-school physical science teachers teach subjects out of their field, 30 percent of middle-school biology teachers teach out of their field, and 20 percent of middle school mathematics teachers teach out of their field. The percentages of U.S. high school teachers who teach out of their field range between 8 percent and 15 percent" (p. 9).

Professional Development of STEM Teachers

Custer and Daugherty (2009) summarized several characteristics that emerged from the literature on the professional development of STEM teachers that represents good professional development. These characteristics are:

- They are reform-oriented (grounded in inquiry, reflection, problem-solving, and experimentation).
- They engage students, teachers, parents, school officials, and even the wider community in collective and collaborative participation.
- They involve the participants in active, in-depth learning activities.
- They are based on a well-defined image of effective classroom learning and teaching.
- They focus on improving both content and teaching techniques.
- They include mechanisms for continuous improvement and evaluation.

- They are embedded in the larger school culture and context. , p. 22)

In a case-study of five different professional development programs that target STEM teachers, they indicated that the professional development delivery of all five of the projects featured substantial amounts of time dedicated to hands-on activities, most of which were conducted in a small group format to engage teachers in design-related activities. The projects ranged from relatively small focused initiatives to extensive multifaceted implementation projects. The case studies were conducted at professional development sessions/programs in Engineering the Future (EtF), Project Lead the Way, Mathematics across the Middle School MST Curriculum Project (MSTP), The Infinity Project, and INSPIRES. Custer and Daugherty (2010) found that there was strong alignment with what constitutes good professional development programs and what was actually taking place in the five case studies. These strong areas of alignment included the emphasis on active engagement, problem-solving, experimentation, as well as clear ideas of what constitutes effective learning and teaching.

Finally, on the matter of professional development, Custer and Daugherty (2009) added that a number of engineering-oriented professional development programs are designed to include teachers from a variety of academic disciplines; generally mathematics, science, and technology education. Because of differences in pre-service teacher education, teachers' backgrounds and capabilities often vary across and within the three major disciplines. In addition, it is often difficult to transfer this level of collaboration at the professional development level back into schools when these teachers return because of scheduling, curricular, and assessment constraints. They advise that professional development must be flexible enough to meet the needs of teachers, particularly teachers who have varying levels of science, technology, engineering, and mathematics abilities and at the same time it must be comprehensive enough to ensure that all teachers have the skills to transfer their learning into classroom practice.

References

Akron, T. U. (2010). *The University of Akron*. Retrieved from http://www.uakron.edu/im/online newsroom/news_details.dot?newsId=1371046

American College Test. (2006). *Developing the STEM education pipeline*. Iowa City, IA: ACT.

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

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 Classrooms. *Journal of Engineering Education, 97* (3), 369-387.

Custer, R. L., & Daugherty, J. L. (2009). Professional development for teachers of engineering: Research and related activities. *The Bridge: Linking engineering and society, 39* (3), 18-24.

Daugherty, J., & Custer, R. L. (2010). Secondary level engineering professional development: content, pedagogy, and challenges. *International Journal of Technology and Design Education.* DOI:10.1007/s10798-010-9136-2.

Department of Defense. (2010). *Survey of science technology engineering and mathematics (STEM)*. Retrieved from http://www.acq.osd.mil/ddre/stem/docs/STEM_Program_Survey.pdf.

Douglas, J., Iversen, E., & Kalyandurg, C. (2004). *Engineering in the K-12 Classroom: An analysis of current practices & guidelines for the future.* Washington, DC: The American Society for Engineering Education.

California Department of Education. (2010). *Science, technology, engineering, and mathematics.* Retrieved from: http://www.cde.ca.gov/pd/ca/sc/stemintrod.asp

Grimsley, R. (2002). *Engineering and Technology Education*. Paper presented at the annual meeting of the Mississippi Valley Technology Education Conference. St. Louis, MO.

National Academy of Engineering. (2002). *Technically speaking: Why all Americans need to know more about technology.* National Academies Press: Washington, DC.

National Governors Association. (2007). *Building a science, technology, engineering, and math agenda*. Retrieved from http://www.nga.org/Files/pdf/0702INNOVATIONStem.pdf

National Science Board. (2007). *National action plan for addressing the critical of the U.S. science, technology, engineering and mathematics educational system*. Retrieved from http://www.nsf.gov/nsb/documents/2007/stem_action.pdf

Schroll, M. (2002). *Pre-Engineering at the high school level: A teacher's perspective.* Paper presented at the annual meeting of the Mississippi Valley Technology Teacher Education Conference. St. Louis, MO.

SETDA. (2008). *Science, technology, engineering, and math.* Retrieved from http://www.setda.org/c/document_library/get_file?folderId=270&name=DLFE-257.pdf

Singley, M., & Anderson, J. (1989). *Transfer of cognitive skills.* Cambridge, MA: Harvard University Press.

Thomas, M. G. (2003). *Engineering and technology education.* Paper presented at the annual meeting of the Mississippi Valley technology teacher Education Conference. Nashville, TN.

Tran, N., & Nathan, M. (2010). Pre-college engineering studies: An Investigation of the relationship between pre-college engineering studies and student achievement in science and mathematics. *Journal of Engineering Education, 97*(3), 143-157.

Wicklein, R. C. (2003). *Five good reasons for engineering as a focus for technology education.* Paper presented at the annual meeting of the Mississippi Valley technology teacher Education Conference. Nashville, TN.

Teaching Technology: Are We on the Right Path?

Presented at the 98th Mississippi Valley Technology Teacher Education Conference, 2011, St. Louis, MO

Chapter 14

Jenny L. Daugherty
Louisiana State University

The publication of the National Research Council's (2011) *Framework for Next Generation Science Education Standards* is creating waves across the various STEM disciplines with its inclusion of engineering. Within technology education circles, a flurry of emails was sent wondering what this might mean for the field. Why would one document have such an impact on a discipline with roots reaching back into the late 1800s? Could science embracing engineering be a threat to the very existence of technology education or could it be an incredible opportunity that technology education is poised to take advantage of?

In order to better understand the potential threat or opportunity offered by science and engineering, it is important to situate technology education within its historical context and examine the current climate surrounding STEM education (science, technology, engineering, and mathematics). As with all of the STEM disciplines, technology education has a unique history that has contributed to its current manifestations. Key national reform efforts (i.e., the No Child Left Behind Act of 2001, U.S. Department of Education, 2002), the growing emphasis on STEM education (i.e., *Rising Above the Gathering Storm*, NRC, 2006), and the calls for linking engineering and technology education (*Preparing for the Perfect Storm*, 2006) have shaped the current identity of technology education and positioned it within the larger educational landscape. The identity and position of technology education is important when considering the following questions:

1. Are science and engineering "disruptive technologies" and perhaps dangerous partners for technology education?
2. Who are the partners in teaching technology?
3. Should we "stake out" the "T" in STEM and focus our efforts there?

When addressing these questions it is important to reflect on the history of the field and to recognize that its evolution can shed light on its future; whether it can emerge as a core component of STEM education or, conversely, it will further fracture and be marginalized. Although much of this discussion is focused on the discipline of K-12 technology education, the important issue encompassed in this discussion is one of student learning. If technological literacy is important for all students and is the primary learning outcome of technology education, how can this best be achieved? How does a close partnership with engineering, science, or other disciplines better prepare students to be technologically literate? Does technology education have to exist as a discipline for students to become technologically literate or can other disciplines (science, mathematics, visual arts, history, etc.) sufficiently address the content so that technology education programs are superfluous and unnecessary?

The Evolution of K-12 Technology

The roots of K-12 technology education are often placed in the industrial arts education movement of the late 1800s with transformative stages leading toward an incorporation of engineering content. A move from focusing on tools and materials to a grounding in industry is encompassed in the major stages of technology education. For example, Bosner and Mossman authored *Industrial Arts for Elementary Schools* in 1923, which contained the foundation for industrial arts (Kirkwood, Foster, & Bartow, 1994). By the 1950s, industrial arts or vocational education was an established aspect of the curriculum. During the 1960s three seminal documents were published that led to the development of three fractions within industrial arts that lasted through the 1980s and legacies of which continue (Wright, 1992). DeVore published *Technology: An Intellectual Discipline* (1964). Then in 1966 Towers, Lux, and Ray published *A Rationale and Structure for Industrial Arts Subject Matter*, outlining the Industrial Arts Curriculum Project. Industry was the content base advocated for in the IACP, which was divided into construction and manufacturing. The third document called the *Maryland Plan* (1973), written by Maley, outlined a junior high school industrial arts program.

For the greater part of the 20th century, and to some degree to the present, schools offered a variety of classes under the umbrella of industrial education. By the 1980s these programs began to suffer a decline due to incoherence in the field, a loss in credibility, and changing demands of high school graduation requirements (Hansen & Reynolds, 2003). In an attempt to reach a consensus on the direction of the field and respond to its decline, 21 industrial arts professional educators gathered in 1981. This resulted in the *Jackson's Mill Industrial Arts Curriculum Theory*, which provided a central focus of industrial arts (Wright, 1992). Lauda (2002) pointed out that much of Jackson's Mill Project is based on Maley's work in that it incorporated both a focus on technology with a focus on industry, specifically manufacturing, construction, transportation, and communication.

The Jackson's Mill Project has been referred to as the "starting point of the modern era of technology education" (Wicklein, 2006, p. 25). A sequence of events occurred at the leadership level that moved the field further toward technology education. For example, the *Standards for Industrial Arts Programs* (*SAIP*) were developed during this time period and were later revised by the American Industrial Arts Association in 1985 resulting in the *Standards for Technology Education Programs*. During this same time period, the American Industrial Arts Association, which was founded in 1939 by William E. Warner, changed its name to the International Technology Education Association in 1985. In the late 1980s, Savage and Sterry convened 25 leaders that created *A Conceptual Framework for Technology Education*, which endorsed the domains of knowledge of the Jackson's Mill Theory and added a dimension of problem solving (Savage, 2002).

Thus by the late 1990s, and into the present, the field largely transitioned into technology education, although there are classrooms that still adhere to a manual/industrial arts approach. During this time, the *Technology for All Americans Project* (ITEA, 1996) was funded by the National Science Foundation and the National Aeronautics and Space Administration. The first of three phases focused on articulating a rationale for technology education that emphasized technological literacy as an important learning outcome. The phases resulted in: (a) *Technology for All Americans: A Rationale and Structure for the Study of Technology* (1994-1996), (b) *Standards for Technological Literacy: Content for the Study of Technology* (*STL*), and (c) Companion Standards. With the *STL*, the ITEA outlined what students should know and be able to do to become technologically literate.

The expanded mission and philosophy of technology education, however, have not been universally adopted (Sanders, 2001) and, according to Spencer and Rogers (2006), have led to widespread confusion both within the discipline and amongst the public. Perhaps in response, the ITEA and teacher preparation institutions engaged in "extensive activity related to the promotion of awareness, adoption, and implementation of the *STL* since its publication in 2000" (Russell, 2005, p. 37). This effort seemed to pay off with the *STL* "being used by a majority (over 91%) of states as a model for developing state technology education standards" (Dugger, 2007, p. 20). However, as Dugger pointed out, the "bottom line is that technology education is still an elective in most states" (p. 20). Any substantive change to embrace a philosophy of technology education by schools is voluntary and inconsistent.

In 2007, technology education in the United States was largely an elective course in grades K-12 with varied classroom practices (Dugger, 2007). In 2001, Sanders found that technology programs varied in their titles, with the three most prominent being: (a) technology education, (b) industrial technology, and (c) industrial arts. Although the *STL* have attempted to provide a coherent direction for technology education classes, state frameworks and classroom practices are varied (Dugger, 2007). Technology education has suffered from low enrollment and an average reputation (Hansen & Reynolds, 2003). As Wicklein (2006) argued, "with all of the efforts, documentation, and developmental work supporting the national need for a technologically literate citizenry, it seems that there has been little practical and comprehensive advancement of technology in most public schools" (p. 25).

The most current evolutionary stage of technology education is the inclusion of engineering under a groundswell of support (Daugherty, M., 2005; Erekson & Custer, 2008; Lewis, 2005; Wicklein, 2006). With 25 states offering engineering related standards (Strobel, Carr, Martinez-Lopez, & Bravo, 2011), K-12 engineering is becoming a part of the national curriculum. Technology education has been on the forefront of many of these efforts with different initiatives, such as curriculum projects (i.e., *Engineering by Design* and *Project Lead the Way*) and National Science Foundation funded projects, such as the National Center for Engineering and Technology Education. And recently the professional association and its flagship journal changed names to include engineering (i.e., the International Technology & Engineering Education Association and the *Technology and Engineering Teacher*). Efforts also have been dedicated to articulating the conceptual base of K-12 engineering (Custer, Daugherty, & Meyer, 2010; Rossouw, Hacker, & de Vries, 2010) and identifying a theoretical framework for the re-engineering of technology education (Kelley & Kellam, 2009). However, as of yet, little research evidence exists as to how the inclusion of engineering has impacted technology education, its status in schools, and impact on student's achievement of technological literacy.

Are science and engineering "disruptive technologies" and perhaps dangerous partners for technology education?

In order to address this question, it is important to consider two perspectives: (a) internally from the vantage point of within technology education, and (b) contextually from the vantage point of others within the K-12 context. An internalist perspective focuses on the subject matter (in this case the field of technology education) rather than the larger social context and a contextualist perspective situates the field within its larger context (Pannabecker, 1995).

Internal Perspective

From industrial arts to technology education to now technology and engineering education, the evolution of technology education in some ways reflects a dramatic shift in philosophy; a philosophy that at one time sought to serve the needs of particular students in workforce preparation (industrial arts) to a philosophy of general education that seeks to serve all students (technology education). Based upon a 2001 study of technology education programs, Sanders concluded that "substantive changes *have* taken place in technology education practice, particularly with respect to program names, the purposes of the field, students served, and instructional methods employed" (p. 51). However, the field appears to have not progressed in a uniform manner with pockets of practice reflecting each of the different phases still existing.

In addition, the discipline has not been in agreement with the move toward engineering and has yet to agree on what engineering means within technology education. Williams (2000), for example, argued that because technology is "such a broad area that a focus on any one process will not provide students with a broad concept of the nature of technology" (p. 57). Instead, Williams advocated for teaching a range of processes in addition to design, including problem solving, a systems approach, invention, and manufacturing. Mawson (2003) called design a "dominant discursive regime within technology education" (p. 119) and advocated instead for a focus on "innovative, risk-taking, reflective" (p. 125) problem solving.

A point of contention surrounding the incorporation of engineering is how it is implemented within technology education and the knowledge base required for teaching and learning it. Lewis (2005) characterized two approaches specific to teaching engineering design: (a) conceptual and (b) analytic. Conceptual design is the point where engineering science, practical knowledge, production knowledge and methods, and commercial aspects are brought together. Lewis argued that this type of design is "within the normal purview of technology education" (p. 48). Analytic design, however, relies upon mathematics and scientific principles to make decisions and "poses a challenge" (p. 48) for technology education. Pre-service technology education programs typically do not require students to take extensive mathematics and science courses, which some argue is crucial to engineering. For example, the results of one study indicated that only 17% of technology education teachers had completed mathematics requirements at a level required to teach *Project Lead the Way* courses (McAlister, 2005).

This issue relates directly to another point of contention, the "inauthentic" approach of teaching engineering design. The NAE report on K-12 engineering education (2010) indicated that there is a disconnect between how engineering is taught in K-12 classrooms and how it is approached in the college classroom and practiced as a discipline. As Chandler, Fontenot, and Tate (2011) pointed out, "the sequence of course work in mathematics, physics, and the sciences proved an insurmountable barrier to approximating a typical university model for engineering education of first requiring a foundation in these subjects and then teaching students applications for this content knowledge in the engineering sciences" (p. 43). The perception is that K-12 engineering is often defined by "whatever the person that writes the book or curriculum, develops the website, or provides the training or equipment says it is" (p. 44). Labeling something engineering does not mean it is regarded by others as such.

Others argue that much of the curriculum, approaches the teaching of design using a prescriptive, step-by-step model that is not well grounded in mathematics or science. Wicklein and Thompson (2008) stated that this approach has common features including: (a) the identification of a problem, (b) the development of a proposal, (c) the creation of a model or product, and (d) the evaluation of the model or product. Engineers, however, design in an iterative, non-predetermined manner that is grounded in scientific and mathematical understandings. For example, engineers typically "*predict the behavior* of the design and the *success of a solution* before it is implemented" (Wicklein & Thompson, p. 57) using mathematical modelling. In addition, design is context-specific, in that it is "shaped by the tools and resources available and adapts to the specific, and changing, situation" (McCormick, Murphy, & Hennessy, 1994, p. 6), further complicating its implementation into the K-12 classroom with the demands of assessment, cost and time constraints, and teacher preparedness.

One might argue that the inclusion of engineering has confused the identity of technology education further weakening its position in K-12 education, particularly as science has begun to embrace engineering as a part of its curriculum. If technology education and science both include engineering as vital aspects of their content, albeit perhaps in different manifestations (conceptual vs. analytic) with different goals (technological literacy vs. science literacy), how does technology education demonstrate its value added to the student as an elective part of the curriculum? Is technology education's approach to engineering as an avenue to technological literacy valued by students, teachers, administrators, parents, policymakers, and the public? What evidence exists that engineering within technology education leads to technological literacy or increases knowledge in mathematics or science?

Contextual Perspective

Given the current status of technology education, it is important to examine the larger educational context in order to address the question of whether engineering and science are dangerous partners for technology education. Several educational reform periods have occurred during the twentieth century and into the twenty-first, with perhaps the most notable spurred by the Soviet Union's launching of Sputnik in 1957. This incident "captured national attention and stimulated public pressure to upgrade U.S. science and mathematics education, with particular emphasis on increasing the pool of U.S. scientists and engineers capable of surpassing the Soviet achievement" (Weiss, Knapp, Hollweg, & Burrill, 2002, p. 18).

Another landmark event was the publication of *A Nation At Risk* (1983), which called for higher student expectations. States and professional associations responded by developing new curriculum frameworks, standards, and assessments. By the 1990s the National Council Teachers of Mathematics (NCTM, 1991) and the American Association for the Advancement of Science (AAAS, 1993) had developed math and science standards respectively, in a wave of standards-based reform. As Cajas (2002) noted, standards documents can be interpreted as, "political decisions that attempt to represent the values and desires of society in specific areas" (p. 177). The societal values appear to be placed within mathematics and science (as well as with reading and writing) so as to improve the pipeline from K-12 to higher education.

Since 2004, a new wave of commissioned reports from businesses, associations, and educational entities has called for reform, spurring an emphasis on STEM. For example, the National Center on Education and the Economy's *Tough Choices or Tough Times* (2007) report argued that the "core problem is that our education and training systems were built for another era" (p. 8) and require a total overhaul. Grubb and Oakes (2007) identified four main themes in these reports including a call for: (a) higher standards and rigor, (b) relevance, (c) equity, and (d) making the high school a lively and intrinsically interesting place for students. Two arguments underpin most of these calls for reform: (a) a competitive decline awaits the nation and (b) graduates lack the necessary workforce, civic, and community competencies placing the nation in risk of relinquishing its competitive edge in the marketplace.

Much of the focus on standards-based reform has centered on literacy-related issues and competitiveness in the STEM-related disciplines, with particular emphasis on mathematics and science achievement. This emphasis on STEM has largely ignored the T&E. As De Miranda, Troxell, Siller, and Iversen (2008) stated, "engineering has largely remained a shadowy presence in discussions about the K-12 STEM education, a spectral "E" quietly inserted among its more concrete complements, yielding, if nothing else, an acronym that lends itself nicely to speech and writing" (p. 135). The same holds true for technology. In a review of recent reports, ranging from the Business-Higher Education Forum to the Committee for Economic Development, Bybee and Starkweather (2006) found that very few of the reports addressed technology education.

Given this context it is important to see how the various STEM communities view technology education. One way to accomplish this is to compare each discipline's standards documents and related reports. In Table 1, the definition of the subject, the literacy approach, and examples of how the other domains include each other is outlined. The technology education standards (ITEEA, 2000/2002/2007), K-12 engineering education report (NAE/NRC, 2009), information on the 2014 framework for the NAEP assessment on technology and engineering, and the science standards documents (AAAS, 1990; 1993) and framework document (NRC, 2011) were reviewed. In addition, a definition of engineering literacy offered by Chae, Purzer, and Cardella (2010) derived from a review of the *STL*, *National Science Education Standard*s and *Principles and Standards for School Mathematics* and reports published by the AAAS, NRC, and NAE is included.

Table 1. *Technology, Engineering, and Science Definitions, Literacy, and Inclusion of the Other*

	Technology	Engineering	Science
Definitions	The act of making or crafting, refers to the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants (STL, 2000/2007)	The process of designing the human-made world (NAE/NRC, 2009)	The application of human intelligence to figuring out how the world works (AAAS, 1993)
Literacy	Ability to use, manage, understand, and assess technology (ITEEA, 2000/2007)	Ability to discuss, critique, and make decisions about national, local, and personal issues that involve engineering solutions; understand and explain how basic societal needs (e.g., water, food, and energy) are processed, produced, and transported; solve basic problems faced in everyday life by employing concepts and models of science, technology, and mathematics (Chae, Purzer, & Cardella, 2010)	Understandings and habits of mind that enable citizens to grasp what those enterprises (science, technology, and mathematics) are up to, to make some sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of events and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments, and uncertainties (AAAS, 1993)
	The capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals (NAEP, 2010, p. B3)		
Inclusion of Other	"Science and technology are like Siamese twins. While they have separate identifies, they must remain inextricably connected in order to survive. Science provides the knowledge about the natural world that underlies most technological products today. In return, technology provides science with the tools needed to explore the world" (ITEEA, 2000/2007, p. 44)	"Engineering can be thought of as putting science to work" (NAE/NRC, 2009, p. 43) "Scientific knowledge informs engineering design, and many scientific advances would not be possible without technological tools developed by engineers" (NAE/NRC, 2009, p. 43)	"We use the term "engineering" in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems. Likewise, we broadly use the term "technology" to include all types of human-made systems and processes" (NRC, 2011, 1-4). "It is the union of science, mathematics, and technology that forms the scientific endeavor and that makes it so successful" (AAAS, 1993)

Based upon these documents, technology and engineering are defined very similarly as the process of making the human-made world. Science, on the other hand, is defined as understanding how the natural world operates. In terms of their approach to literacy, the focus within technology education is specifically on the ability to use and understand technology. The science literacy definition, however, is more inclusive with a focus on enabling learners to understand science, technology, and mathematics so that they can "make some sense of how the natural and designed worlds work" (AAAS, 1993).

All of the documents include specific references to the other disciplines. For example, in the 1990 report from the AAAS, the integration of science and mathematics with technology education was described as "vital" (p. 3) and with *Project 2061* (1993), the AAAS recommended that students learn key technological concepts such as design, control, and systems. Until recently this call has largely not been heeded within science education. However, the new framework document (NRC, 2011) will most likely change this with an emphasis on engineering practices. From the perspective of technology, science and technology are inextricably linked in a reciprocal relationship. And the NAE/NRC report on K-12 engineering education (2009) indicated an interlinked relationship between science, technology, and engineering with science informing engineering design and with scientific advances not being made possible without technological tools and engineering. This report and another by ITEA/ITEEA (2009) articulated a rationale for including all of the disciplines in a holistic STEM approach.

The explicit references, made in these standards documents and reports indicate a need for each domain, and for each of the disciplines to maintain a stronghold in the K-12 curriculum. However, upon a closer examination of the documents it appears that technology is being viewed in a narrow, deterministic, artifact-driven manner that merges the role of technology with engineering. For example, the NRC's (2011) report offering a new framework for science education includes a focus on engineering practices and states that technologies "result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants" (p. 1-4). Technology as a result of engineering and the application of scientific knowledge is a limited view of the discipline (although broader than the very narrow view of the general public, see results for the ITEA/Gallup Poll, 2004) and one that does not embrace a technological literacy approach as outlined in the *STL*.

This view of technology might be appropriate as it is integrated into other disciplines; however, if students are to become technologically literate a broader education in technology is perhaps necessary. This indicates the need for technology education as a discipline within K-12 education or a strong, clearly defined focus within other disciplines, so that students can gain a more robust understanding of technology. Although this is not currently part of the value structure of our educational system (i.e., largely not a required course or assessed on standardized tests), efforts might be better placed in demonstrating the discipline's value to student learning. Perhaps developments such as the new NAEP assessment on technology and engineering (NAGB, 2010) will help advance this, but value must also demonstrated by the focused efforts of researchers in technology education.

In addition, the concern that if engineering becomes "housed" within science, (which is part of the core curriculum in schools) it will become the domain of that discipline, will be of less concern if technology education is perceived as valuable beyond an engineering focus. Engineering's presence within science could have damaging effects on technology education if engineering is the core of technology education's identity. Perhaps this concern is unwarranted due to the fact that technology education has a longer history of integrating engineering (NCETE, PTLW, EbD, ITEEA, etc.) and can help facilitate an integrated STEM approach, advocated by the NAE/NCR committee on K-12 engineering education (2010). However, the emphasis on engineering within technology education needs to be well documented in the literature. For example, as Chandler, Fontenot, and Tate (2011) indicated, PLTW and the Infinity Project have "little substantive research that demonstrates how, or if, these curricula help students to develop the 'habits of mind' that the NAE identifies as an engineering skill set with potential to contribute to a technically proficient citizenry for the 21st century (p. 5), or if these curricula are effective cross disciplinary vehicles for teaching standards based concepts in science, math, technology, and other academic subjects, as the NAE also suggests" (p. 44).

The hope is that engineering will not "narrow the choices" (Salinger, 2005, p. 3) for technology education, but broaden them. The inclusion of engineering is often described as facilitating the goals of technology education; not supplanting the entire discipline (Erekson & Custer, 2008). In addition to the belief engineering design enables technological literacy, Wicklein (2006) argued that engineering might elevate the status of technology education. Thus, much of the focus (research, curriculum development, professional associations, etc.) within technology education has been on engineering, perhaps to the exclusion of other content or approaches that are outlined in the *STL* and other technology education frameworks (i.e., Dakers, 2006). If technology education is more than engineering design and is to be considered value added within the broader educational structure, perhaps the discipline needs to focus on the knowledge embedded in technology, the importance of technological literacy, and how that contributes to STEM education (particularly mathematics and science outcomes).

Who are the partners in teaching technology?

If technological literacy is to be achieved by all students it might make sense that it is both achieved within the technology education classroom and integrated within other disciplines. The obvious partners for teaching technology are science and mathematics (Daugherty, Merrill, & Reese, 2010). And other disciplines, such as those within the liberal arts, might be locations within which to advance technology education as well. However, this question gets at a larger issue of interdisciplinary education in the current educational structure, where disciplinary distinctions and the value structure of our educational system matters. Given that technology is not a part of the core curriculum assessed on standardized tests, it may not be positioned as a full partner in STEM education. As Dugger (2009) pointed out, technology education "does not have the same status as mathematics and science in the U.S. schools today" (p. 10). And STEM itself is not understood by some administrators or teachers, nor does there seem to be a clear vision for STEM (Brown, Brown, Reardon, & Merrill, 2011). The committee on K-12 engineering education (NAE/NRC, 2010) pointed to these and other hurdles to STEM education.

Despite the call for integrated STEM, a more important question might be, are disciplinary distinctions important for student learning? In some ways, disciplines provide students with a classification schema within which to organize new knowledge. These classifications can be structural, theoretical, or merely bureaucratic but have been constructed over time and contain meaning for those within and outside them. Parker (2002) offered that a discipline is a "complex structure: to be engaged in a discipline is to share, and be shaped by, the subject, to be part of a scholarly community, to engage with fellow students-to become 'disciplined'" (p. 374). Disciplines are also social constructions that change over time. As McArthur (2010) argued, disciplines are "complex, permeable and contested spaces" (p. 301) that are important to maintain so that rigorous and complex knowledge is generated, shared, and protected. In addition, disciplines are often defined at their edges; in how they are distinct from another closely related discipline.

In terms of interdisciplinary approaches, MacArthur argued that this is "nonsensical without an equal commitment to the legitimacy and importance of disciplinarity" (p. 303). Without the foundation of a discipline, an interdisiciplinary approach is not as strong, lacking the rigor offered within a discipline. Disciplines offer more than the sum of the education offered by a series of classes but "engagement in a transformational process" (Parker, 2002, p. 375), a process that happens by engaging the discipline. Based on this, disciplinary distinctions can be seen as being important for an integrated STEM approach. As Parker argued, in terms of intedisciplinarity, "the challenge is to the discipline to go beyond the easy formulation: subject knowledge and subject skills; to say what central processes gives the discipline its value and distinctiveness?" (p. 380). This question is important to consider if technology is to be viewed as an equal partner/discipline within the STEM equation.

With a distinct disciplinary identity (separate from science and engineering), technology education might be in a better position to facilitate technological literacy and STEM integration. However, there are significant hurdles to a truly integrative approach to STEM that enables a conceptually rich understanding of each of the disciplines; including technology and engineering. As Chandler, Fontenot, and Tate (2011) pointed out, "STEM reform requires a paradigm shift toward integration of disciplinary knowledge and skills against inertia and cultural boundaries existent in our educational system" (p. 42). They aptly identify practical issues that serve as barriers, as well as the "epistemic differences, cultural proclivities, and territorialism" (p. 42) within the different disciplines. An issue particular to technology education is its disciplinary identity.

Should we "stake out" the "T" in STEM and focus our efforts there?

In order to address this question it is important to determine whether technology offers a knowledge base and can be considered a separate discipline? A lively discussion emerged around this issue in the early 1990s (Dugger, 1992; Herschbach, 1995; Petrina, 1993; Savage & Sterry, 1990a, 1990b; Wright, 1992a, 1992b, 1993) that provided a background to the development of the *STL*. Disagreement centered largely on whether technology contains a distinct knowledge base that can be identified and used to ground a discipline. This determination has implications for curriculum and the larger reputation of the field to others. Concern was expressed, however, for how the epistemological base of a technology discipline is defined through "unrepresentative, closed-door, 'white paper' work of 'leaders' (Petrina, 1993) leading to a lack of diversity, discourse, and debate.

A conception of technology was articulated in many of these articles that included a focus on the processes, tools, industries, and artifacts associated with technology. DeVore (2009/1987), for example, argued that technology is focused on the "behavior of tools, machines and technical systems" (p. 1) with learning outcomes such as predictability, replication, reliability, optimization and efficiency of systems. He argued that this knowledge base has evolved into a discipline "which is neither dependent upon nor subservient to science" (p. 1). In addition, a technology knowledge base was identified by some authors. For example, Hershchbach (1995) argued that technological knowledge is characterized by reasoned application, the purpose of which is to efficiently control or manipulate the physical world. Meaning is found in technology through its application within a specific problem context. He argued that technology is "not only content to be learned but the vehicle through which the intellectual processes embedded in technological activity can themselves be learned" (Hershcbach, 1995, p. 39).

DeVore (2009/1987) argued that the nature of technological knowledge is unique from other types of knowledge in that it is the ability to understand "the way things function and to be able to analyze the relationships and synthesize new relationships, to create new inventions, and innovations of designs" (p. 10). Vinceti (1984) identified three categories of technological knowledge: (a) descriptive, (b) prescriptive and (c) tacit. And Hershchbach (1995) further summarized these three categories of technological knowledge. Descriptive knowledge includes the factual information, such as material properties, that provides the framework within which the individual works. Prescriptive knowledge emerges from "successive efforts to achieve greater effectiveness, such as improved procedures or operation, and is altered and added to as greater experience is gained" (Vinceti, p. 33-34). Tacit knowledge is less identifiable then prescriptive and descriptive knowledge but results from practice and experience.

In addition to technology as being inclusive of both artifacts and knowledge, the social implications are often important when considering technological understandings, particularly as they pertain to developing technological literacy. For example, Feenberg (2006) described the philosophical views of technology ranging from neutral to value-laden and agency which ranged from autonomous to human control. The sense of agency from a technological perspective refers to what drives the application and development of the technology and how humans experience, react, or determine its impact.

The belief that technology contains an important knowledge base (whether or not it is at the level of a discipline) is an important one as it relates to the future role of technology education in the curriculum and whether its efforts should be focused on staking out the "T." There is evidence in the science, engineering, and technology standards and documents that technological literacy is indeed an important and worthy educational goal. For example, the NAE and NRC convened a committee in 2006 to establish a common understanding of technological literacy, to relay its importance and to offer recommendations of how best to achieve this literacy. The recognition that technological literacy is important to establish to then determine whether or not this type of learning can best be achieved within a focused technology education environment or integrated into other disciplines.

Conclusion

So is technology education on the "right" path toward developing technological literacy for all students given that it is still an elective for most students, there are different iterations from industrial arts programs to PLTW programs for students, engineering content within technology education lacks definition, and there is little research evidence indicating what students are learning by participating in technology education? After reviewing the history of the field and the larger educational context, it appears that there are three optional paths for technology education's future.

Engineering & Technology Education

This path seems to be the most favored path forward for the field. Technology educators can advocate for a role in K-12 schools that holds to its historical roots and embraces a technological literacy approach through engineering design. Preservice programs can continue to produce teachers that are rooted in the Jackson's Mill approach, have an awareness of engineering design methods, and are prepared for curricula, such as PLTW, but are not exposed to extensive mathematics, science, or engineering coursework. Efforts can be undertaken to demonstrate the value added by using this approach. The current trajectory of this path, however, appears to not be leading to growth or permanency. As Dugger (2009) indicated (based on a study conducted by Moye, 2009), the number of teacher preparation colleges and average number of graduates being produced each year continues to decline in numbers.

Technology Education

This path differs some from the path outlined above in that efforts are focused on researching and building a strong disciplinary identity of technology education and pulling back from such a heavy emphasis on engineering. Large scale efforts are undertaken to document the learning outcomes of technology education specific to technological literacy, as well as science and mathematics (i.e., standardized test scores). The field pulls back from an engineering focus, where it does not maintain an equal or dominating identity within technology education but is incorporated into a larger approach to technology education. Preservice programs prepare teachers to teach the breadth of technology knowledge and incorporate more of a mathematical and scientific focus to the practice of technology, inclusive of design. This path might not lead to permanency either but if value can be demonstrated in terms of what is currently measured (math and science), perhaps this path can lead to growth and a recognized identity and contribution to the STEM discussion.

Integrative STEM Education

This path is less concerned with maintaining a specific technology education presence in the schools but on enabling technology and engineering content to be integrated into all K-12 classrooms (science, math, etc.). Technology education can contribute to new science standards and curriculum efforts to enable the important learning outcomes associated with technological literacy. Preservice programs might evolve into collaborative efforts with science or math programs to prepare STEM or Science & Technology teachers. This path might reach all students, at least with a limited exposure to technology education, but might also be the death knell of technology education programs solely focused on technology education.

Whether or not the discipline of technology education continues to exist as a subject or is absorbed by other disciplines (namely science) is of secondary concern if students are becoming technologically literate. If engineering is an avenue toward technological literacy (Wicklein, 2006; Erekson & Custer, 2008) and science is equipped to include engineering into its domain, perhaps that is the best approach in terms of exposure to all students. Science is required and thus all students will be exposed to engineering and will feasibly be able to develop a sense of technological literacy. However, if technological literacy is developed through a broader exposure to technology knowledge beyond engineering perhaps a disciplinary identity of technology must be maintained in the K-12 curriculum to ensure the goal of technological literacy. An alignment with science and engineering is dangerous if technological learning is only achieved in a limited scope that does not represent the breadth of knowledge necessary to become literate (if that is indeed the goal).

Technology education must articulate the value added dimension to the STEM equation that is more encompassing than engagement in engineering design activities. The value added proposition should be in terms that speak to both its internal and external contingencies; a clear indication of achieving technological literacy and positively impacting student mathematics and science standardized test scores. It seems appropriate that a dimension of this should include a focus on engineering, STEM integration, and other interdisciplinary approaches, but we should not lose sight of our disciplinary identity, the development of technological knowledge and literacy, and its impact on student learning.

References

American Association for the Advancement of Science (1990). *Science for All Americans*. Available online at http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy*. Available online at http://www.project2061.org/publications/bsl/online/index.php

Brown, R. Brown, J., Reardon, K., & Merrill, C. (2011). Understanding STEM: Current perceptions. *Technology and Engineering Teacher*, *70*(5), 5-9.

Bybee, R. W., & Starkweather, K. N. (2006). The twenty-first century workforce: A contemporary challenge for technology education. *The Technology Teacher*, *65*(8), 27-32.

Cajas, F. (2002). The role of research in improving learning technological concepts and skills: The context of technological literacy. *International Journal of Technology and Design Education*, *12*(3), 175-188.

Chae, Y., Purzer, S., & Cardella, M. (2010). Core concepts for engineering literacy: The interrelationships among STEM disciplines. Paper presented at the American Society for Engineering Education, Vancouver, CA.

Chandler, J. Fontenot, A. D., & Tate, D. (2011). Problems associated with a lack of cohesive policy in K-12 pre-college engineering. *Journal of Pre-College Engineering Education Research*, *1*(1), 40-48.

Coppola, R. K., & Malyn-Smiyh, J. (Eds.). (2006). *Preparing for the perfect storm: A report on the forum taking action together – Developing a national action plan to address the "T&E" of STEM*. PTC-MIT Consortium.

Custer, R. L., Daugherty, J. L., Meyer, J. P. (2010). Formulating a concept base for secondary level engineering: A review and synthesis. *Journal of Technology Education*, *22*(1), 4-21.

Dakers, J.R. (2006). Towards a philosophy for technology education. In J.R. Dakers (Ed.), *Defining technological literacy: Towards an epistemological framework* (pp. 145-158). New York: Palgrave.

Daugherty, J. L., Reese, G. C, & Merrill, C. M. (2010). Trajectories of mathematics and technology education pointing to engineering design. *Journal of Technology Studies*, *36*(1), 46-52.

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

De Miranda, M. A., Troxell, W., Siller, T. J., & Iversen, E. (2008). Preparing technology teachers to infuse engineering into technology education: Pre-service, professional development, and outreach. In R. L. Custer, & T. L. Erekson. *Engineering and technology education*. 57th Yearbook, Council on Technology Teacher Education. Woodland Hills, CA: Glencoe, pp. 133-157.

DeVore, P. (1964). *Technology: An intellectual discipline*. Bulletin No. 5. Washington, DC: American Industrial Arts Association.

DeVore, P. W. (2009/1987). Technology and science. In the CTTE Yearbook Planning Committee. *Essential topics for technology educators*. 58th Yearbook, Council on Technology Teacher Education. Woodland Hills, CA: Glencoe, pp. 2-20.

Dugger, Jr., W. (1988). Technology the discipline. *The Technology Teacher*, *48*(1), 3-6.

Dugger Jr., W. E. (2002). Roots of technology education: Standards project. *Journal of Technology Studies*, *28*(2), 96-98.

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

Dugger, Jr., W. E. (2009). A 2009 report on technology education in the United States. A paper delivered at the International Conference on Technology Education in the Asia Pacific Region, Taipei, Taiwan.

Engineering by Design. (1995). *Engineering by Design: A standards-based model*. Retrieved from http://www.iteaconnect.org/EbD/ebd.htm

Erekson, T. L., & Custer, R. L. (2008). Conceptual foundations: Engineering and technology education. In R. L. Custer, & T. L. Erekson. *Engineering and technology education*. 57th Yearbook, Council on Technology Teacher Education. Woodland Hills, CA: Glencoe, pp. 1-12.

Feenberg, A. (2006). What is Philosophy of Technology. In J. R. Dakers (Ed.), *Defining Technological Literacy: Towards an Epistemological Framework* New York: Palgrave Macmillan.

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

Grubb, W. N., & Oakes, J. (Eds.). (2007). *"Restoring value" to the high school diploma: The rhetoric and practice of higher standards*. Education Policy Research Unit. Retrieved March, 20, 2008 from, http://epsl.asu.edu/epru/documents/EPSL-0710-242-EPRU.pdf

Hansen, L. S., & Reynolds, C. J. (2003). The future of industrial technology education at the K-12 level. *Journal of Industrial Teacher Education*, *40*(4), 36-46.

Herschbach, D. R. (1995). Technology as knowledge: Implications for instruction. *Journal of Technology Education*, *7*(1), 31-42.

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

International Technology Education Association (2000/2002/2007). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

International Technology Education Association (ITEA/ITEEA). (2009). *The overlooked STEM imperatives: Technology and engineering.* Reston, VA: Author.

Kelley, T. & Kellam, N. (2009). A theoretical framework to guide the re-engineering of technology education. *Journal of Technology Education*, *20*(2), 37-49.

Kirkwood, J. J., Foster, P. N., & Bartow, S. M. (1994). Historical leaders in technology education philosophy. *Journal of Industrial Teacher Education*, *32*(1), Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v32n1/Kirkwood.html

Lauda, D. P. (2002). Conceptualizations of Jackson's Mills. *The Journal of Technology Studies*, *28*(2), 93-95.

Lewis, T. (2005). Coming to terms with engineering design as content. *Journal of Technology Education*, *16*(2), 37-54.

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

Mawson, B. (2003). Beyond 'the design process': An alternative pedagogy for technology education. *International Journal of Design Education*, *13*(2), 117-128.

McAlister, B. (2005). *Are technology education teachers prepared to tech engineering design and analytical methods?* Paper presented at the International Technology Education Association Conference, Kansas City, MO.

McArthur, J. (2010). Time to look anew: Critical pedagogy and disciplines within higher education. Studies in Higher Education, 35(3), 301-315.

McCormick, R., Murphy, P., & Hennessy, S. (1994). Problem-solving processes in technology education: A pilot study. *International Journal of Technology and Design Education*, *4*(1), 5-34.

Moye, J. J. (2009). *Technology education teacher supply and demand in the United States*. Unpublished doctoral dissertation, Old Dominion University, Norfolk, VA.

National Academy of Engineering & National Research Council. (2006). *Tech tally: Approaches to assessing technological literacy*. Washington: National Academy Press.

National Academy of Engineering & National Research Council. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington: National Academy Press.

National Assessment of Educational Progress (NAEP) Technology and Engineering Literacy Framework and Test Item Specifications. Retrieved from http://www.edgateway.net/cs/naepsci/print/docs/470

National Center on Education and the Economy. (2007). *Tough choices or tough times: The report of the new commission on the skills of the American workforce*. Jossey-Bass.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: U.S. Department of Education.

National Council Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA.

National Research Council (2011). *Framework for next generation science education standards*. Washington: National Academy Press.

National Research Council Committee on Science, Engineering, and Public Policy. (2006). *Rising above the gather storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

Pannabecker, J. R. (1995). For a history of technology education: Contexts, systems, and narratives. *Journal of Technology Education*, *7*(1), 43-56.

Parker, J. (2002). A new disciplinarity: Communities of knowledge, learning and practice. *Teaching in Higher Education*, 7(4), 373-386.

Petrina, S. (1993). Diversity, not uniformity united, not standardized: A reaction to Wright's 'Challenge to all Technology Educators.' *Journal of Technology Education*, 4(2). Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v4n2/petrina.jte-v4n2.html

Project Lead the Way. (1999-2006). About us—PLTW goals. Retrieved March 1, 2008, from http://www.pltw.org/goals.shtml

Rose, L. C., Gallup, A. M., Dugger, W. E., & Starkweather, K. N. (2004). The second installment of the ITEA/Gallup poll and what it reveals as to how Americans think about technology. *The Technology Teacher*, *64*(1).

Russell, J. F. (2005). Evidence related to awareness, adoption, and implementation of the Standards for Technological Literacy: Content for the study of technology. *Journal of Technology Studies, 31*(1), 30-38.

Rossouw, A., Hacker, M., & de Vries, M. J. (2010). Concepts and contexts in engineering and technology education: An international and interdisciplinary Delphi study. *International Journal of Technology and Design Education*, Retrieved from http://www.springerlink.com/content/4u32551r6h44kx42/fulltext.pdf

Salinger, G. L. (2005). The engineering of technology education. *Journal of Technology Studies*. *31*(1), 2-6.

Sanders, M. (2001). New paradigm or old wine? The status of technology education practice in the United States. *Journal of Technology Education*, *12*(2), 35-55.

Savage, E. N. (2002). A conceptual framework for technology education: A historical perspective. *The Journal of Technology Studies*, *28*(2), 98-100.

Savage, E., & Sterry, L. (1990a). A conceptual framework for technology education, part 1. *The Technology Teacher*, *50*(1), 6-11.

Savage, E., & Sterry, L. (1990b). A conceptual framework for technology education, part 2. *The Technology Teacher*, *50*(2), 7-11.

Spencer, B. R., & Rogers, G. E. (2006). The nomenclature dilemma facing technology education. *Journal of Industrial Teacher Education*, *43*(1), 91-99.

Strobel, J., Carr, R., Martinez-Lopez, N., & Bravo, J. D. (2011). National survey of states' P-12 engineering standards. Paper presented at the American Society for Engineering Education, Vancouver, CA.

Towers, E., Lux, D., & Ray, W. (1996). *A rationale and structure for industrial arts subject matter*, ERIC Document Reproduction Service no. ED 013 955.

U.S. Department of Education. (2002). The elementary and secondary education act (the No Child Left Behind Act of 2001). Retrieved March 15, 2008, from http://www.ed.gov/nclb/overview/importance/edlite-index.html

Vincenti, W. G. (1984). *Technological knowledge without science: The innovation of flush riviting in American airplanes*.

Weiss, I. R., Knapp, M. S., Hollweg, K. S., & Burrill, G. (Eds.). (2002). *Investigating the influence of standards: A framework for research in mathematics, science, and technology education*. Committee on Understanding the Influence of Standards in K-12 Science, Mathematics, and Technology Education. Washington, DC: National Academy Press.

Wicklein, R. C. (2006). Five good reasons for engineering design as the focus for technology education. *The Technology Teacher*, *65*(7), 25-29.

Wicklein, R. C., & Thompson, S. A. (2008). The unique aspects of engineering design. In R. L. Custer, & T. L. Erekson. *Engineering and technology education*. 57th Yearbook, Council on Technology Teacher Education. Woodland Hills, CA: Glencoe, pp 57-76.

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

Wright, T. (1992a). Building a defensible curriculum base. *Journal of Technology Education*, *3*(2), 67-72.

Wright, T. (1992b). Mixing our metaphors. *The Technology Teacher*, *51*(8), 3-4.

Wright, T. (1993). Tom Wright's response to Petrina's reaction. *Journal of Technology Education*, *4*(2). Retrieved from http://scholar.lib.vit.edu/ejournals/JTE/v4n2/wright1.jte-v4n2.html

A Reflection on the Engineering Design Process Models used in Technology and Engineering Education Classrooms and those used in the Engineering Profession

Presented at the 103rd Mississippi Valley Technology Teacher Education Conference, 2016, Chicago, IL

Chapter 15

Edward M. Reeve
Utah State University

Introduction

The purpose of this chapter is to investigate whether the engineering design processes used in technology and engineering education classrooms are an accurate reflection of the models used in industry and other technical fields (i.e., for purposes of this chapter, the field engineering). In this chapter, the terms "engineering design" and the "engineering design process" are considered to be problem-solving approaches that have the same meaning and are defined as:

> The systematic and creative application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems. (ITEEA, 2000/2002/2007)

The chapter begins with a brief review of how the "engineering design process" is taught and practiced in engineering. Then a review of its importance and use in K-12 in technology and engineering education is presented. Next, a discussion is presented to determine whether the design processes used in technology and engineering education classrooms are an accurate reflection of the models used in industry and other technical fields.

The Engineering Design Process in Engineering

Engineering requires a great deal of problem-solving. To solve problems, engineers learn an iterative problem-solving process known as engineering design, or the engineering design process. This section examines how students at the collegiate level learn about engineering design and includes a brief discussion of how it is practiced by professionals.

Learning Engineering Design

Today, engineering students at the baccalaureate level will be familiarized with "engineering design" in introductory as well as upper-division engineering courses. The accrediting board for engineering, known as ABET, identifies a set of general level criteria for accrediting baccalaureate engineering programs. In its discussion on the requirements for engineering curriculum, it notes that students must receive one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study and it defines engineering design as follows:

> Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. (ABET, 2015, p. 4)

ABET accreditation requires that engineering faculty teach engineering design, but does not prescribe a specific model to teach. A popular textbook utilized in the teaching of engineering design is *Engineering Design: A Project-Based Introduction,* 4th Edition (Dym, Little, and Orwin, 2014). This book, suitable for all levels of engineering courses, helps students acquire design skills as they experience the activity of design by doing design projects. In this book, the authors define engineering design as:

> Engineering design is a systematic, intelligent process in which engineers generate, evaluate, and specify solutions for devices, systems, or processes whose form(s) and function(s) achieve clients' objectives or users' needs while satisfying a specific set of constraints. In other words, engineer design is a thoughtful process for generating plans or schemes for devices, systems, or processes that attain given objectives while adhering to specified constraints. (p. 7)

Dym, et al. (2014) further note that that are many design process models and they can be either prescriptive or descriptive. A descriptive model describes what must be done during the design process. They provide examples of simple descriptive models. For example, they present a three-phase model (i.e., (1) Generation, (2) Evaluation, and (3) Communication) and a simple three-stage model that splits up the design process differently and includes the steps of (1) Conceive, (2) Design, and (3) Implement (pp. 19-20).

A prescriptive model prescribes what must be done during the design process. Dym, et al. (2014) present a five-step engineering design process model that is comprised of the following steps:

1. Problem Definition: Detailing Customer Requirement
2. Conceptual Design: Translating Customer Requirements into Engineering Specifications
3. Preliminary Design
4. Detailed Design
5. Design Communication. (pp. 20-23)

In reviewing the introductory textbook entitled, *Thinking Like an Engineer: An Active Learning Approach,*(3rd Ed.), (Stephan, Bowman, Park, Sill, and Ohland, 2015) the authors discuss that there are many different versions of the design process, but note that it is a creative process that requires (1) problem definition, (2) idea generation and selection, (3) solution implementation and (4) testing, and evaluation, and Design is inherently multi-faceted, so any problem addressed will have multiple solutions (p. 57).

In another introductory textbook entitled *Concepts in Engineering* (Holtzapple and Reece, 2005) the authors note that the engineering design method contains the elements of synthesis, analysis, communication, and implementation and present a 10-step engineering design model. This model contains the following 10 steps:

1. Identify the need and define the problem
2. Assemble the design team
3. Identify constraints and criteria for success
4. Search for solutions
5. Analyze each potential solution
6. Choose the "best" solution
7. Document the solution(s)
8. Communicate the solution(s) to management
9. Construct the solution
10. Verify and evaluate (p. 78)

Horenstein (2010) in the textbook *Design Concepts for Engineers* (4th Ed.) presents an engineering design process that he refers to as the "design cycle." He notes that this design cycle model will vary depending on where it is used or how it is taught and that sometimes steps may be omitted, while others might be added (p. 48). The steps presented in this model include:

1. Define the Overall Objectives
2. Gather Information
3. Identify and Evaluate Possible Design Strategies
4. Make a First Cut at the Design
5. Model and Analyze

6. Build, Document, and Test
7. Revise and Revise Again
8. Test the Product Thoroughly (pp. 39-44)

In *Engineering Your Future* (Oakes, Leone, & Gunn, 2006) the authors discuss that the design process can be used for developing a product that will be continuously manufactured, or it can be used for the one-time design of a product. In their discussion on engineering design, they present a 10-Stage Design:

1. Identify the Problem/Product Innovation
2. Define the Working Criteria/Goals
3. Research and Gather Data
4. Brainstorm/ Generate Creative Ideas
5. Analyze Potential Solutions
6. Develop and Test Models
7. Make the Decision
8. Communicate and Specify
9. Implement and Commercialize
10. Perform Post-Implementation Review and Assessment (pp. 352-360)

Applying Engineering Design in Practice

The above section reviews a variety of engineering design models that engineering students learn in their studies. This section tries to obtain a "snapshot" of how engineers apply the problem-solving models in practice in the real world.

A study entitled *Conceptions of the Engineering Design Process: An Expert Study of Advanced Practicing Professionals* conducted by Mosborg, Adams, Kim, Atman, Turns, and Cardella (2005) provided insights into how engineering design was used by practicing professionals. In their study, they discussed how engineering design was taught in engineering textbooks. They noted it was traditionally taught in a linear "block" method, but today it is beginning to be taught as a "cyclical" process. Engineering design examples presented in their study were similar to the models presented in the above section. In their study, they found that practicing engineers (N=19) do use an engineering design process and that most appear to follow the block method. However, they also noted that almost half of the engineers seem to follow alternate representations of the engineering design process as they discussed their approach to solving problems.

Sheppard, Colby, Macatangay, and Sullivan (2006) explored answers to the question: *What is Engineering Practice*? In their review, they note that engineering practice is about "problem-solving" and there are different approaches to solving problems. In their discussions on problem-solving, they note that problems being undertaken by an engineer may take the form of a need, real or perceived, or may be stated as a question. They emphasized that problem-solving in engineering is constraint-based and discuss how "engaging in engineering problem solving often involves parsing and partitioning the problem by identifying sub-problems that can be worked on independently from one another" (p. 432). Furthermore, in their discussion on what engineers do, they note that very little engineering work is solitary, that few engineers are expert in all aspects of the engineering problem-solving process, and many (if not most) engineering problems have timeframes and complexity that require teams of engineers to work on them.

Maffin (1998) completed a study in the UK to investigate how engineering companies use the engineering design practice. In this study, he looked at the context, theory, and practice of using engineering design models. He first did a review of engineering design models and discussed the basic features of all models. These features included such items as the breakdown of the design process into conceptually distinct stages or activities, the subdivision of the overall design problem into sub-problems, and varying emphases on iteration and interaction through the design process. However, he found that there had not been a widespread use by design practitioners of the design strategy proposed by most engineering design models. He contributed this to a lack of awareness of engineering design models and that companies' practices and strategies to solve the problem were often influenced by the context of the design problem.

Section Summary

This section examined how engineering design is taught and how it is practiced. In summary, it appears that engineering design (problem-solving) is a very important part of what engineers learn in their undergraduate studies and what they use in practice. There are also many different engineering design models, but they exhibit similar features. Further review of the models show them to be represented in a linear "block" fashion, but are often discussed as being both an iterative and cyclical process. It appears that engineers use a variety of problem-solving approaches that are similar to what they may learn in their formal training, but it also appears that the process they use is often directed by the nature and context of the problem and customer needs.

The Engineering Design Process in Technology and Engineering Education

Today, teaching the engineering design process in K-12 technology and engineering education, as well as other STEM education subjects is important. In 2005, Lewis noted that "*design* is arguably the single most important content category" set forth in the standards" (i.e., *Standards for Technological Literacy: Content for the Study of Technology [2000])* (p. 37), and championed for engineering design as the primary content area for technology education.

Teaching, engineering design in technology and engineering education has continued to grow in importance and this section presents a brief review of research related to engineering design in the profession, followed by a review of how engineering design is included in national science and technology education standards. Next, a brief review of how engineering design is included in technology and engineering curricula is presented, followed by a short discussion of other organizations involved in the promoting engineering design.

Engineering Design in the Literature

In recent years, there have been a number of studies and reports on the use of engineering design in technology and engineering education. For, example, Asunda and Hill (2007) did a study to investigate the critical features of engineering design in technology education. In their study, they identified the concept of engineering design, the key features of the engineering design process, and critical elements that should be assessed in an engineering design activity. In addition, they developed a rubric that could be used in evaluating the integration of engineering design as a focal point for technology education. They also noted emphasized the importance of critical thinking and reflection about the iterative process and the use of analysis and optimization when using the engineering design process.

Lami and Becker (2013) did a study on "engineering design thinking." In their study, they examined high school students' systems cognitive issues, processes, and themes while they engaged in a collaborative engineering design challenge. In their review of the literature, they noted that engineering design is a process that has no agreed upon definition, that there are multiple K–12 programs and curricula that purport to teach engineering design, and that high school students can engage in engineering design.

Householder and Hailey, (2012) present in a report a comprehensive review of incorporating engineering design challenges into science, technology, engineering, and mathematics (STEM) courses. In their report, they review a few different engineering design models (e.g., those developed by UTeachEngineering, and Massachusetts Department of Education) and present an in-depth discussion on implementing engineering design challenges using the nine-step NCETE engineering design model proposed by Hynes et al. (2011). The steps presented in this engineering design model included:

1. Identify need or problem;
2. Research need or problem;
3. Develop possible solutions;
4. Select the best solution;
5. Construct a prototype;
6. Test and evaluate the solution;
7. Communicate the solution;
8. Redesign;
9. Finalize the design.

Engineering Design in Educational Standards

The teaching of the "engineering design" and the engineering design process is promoted at the national level in educational standards developed for technology and science. In technology and engineering education, the *Standards for Technological Literacy: Content for the Study of Technology* (ITEEA, 2000/2002/2007) promotes the teaching of design and related content in Standards 8-11. In Standard 8, benchmark H, the ITEEA Standards present a "design process," discussed as "technological design," that includes the following steps:

1. Defining a problem
2. Brainstorming
3. Researching and generating ideas
4. Identifying criteria and specifying constraints
5. Exploring possibilities
6. Selecting an approach
7. Developing a design proposal
8. Making a model or prototype
9. Testing and evaluating the design using specifications
10. Refining the design
11. Creating or making it
12. Communicating processes and results. (p. 97)

The ITEEA Standards discuss that there are different engineering design process models and present a general discussion on how they are typically used by engineers. Standard 9 focuses on students developing an understanding of the engineering design process and specifically references the "engineering design process." Standard 9 does not present one specific model, however, Benchmark C states that the engineering design process involves:

1. Defining a problem,
2. Generating ideas,
3. Selecting a solution,
4. Testing the solution(s),
5. Making the item,
6. Evaluating it, and
7. Presenting the results. (ITEEA, 2000/2003/2007, p. 102)

The *Next Generation Science Standards, NGSS* (2013) espouse a commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to grade 12 (NGSS, 2013). In the *NGSS,* they note the term "engineering design" has replaced the older term "technological design" and the *NGSS* uses recommendations from *A Framework for K-12 Science Education* (NRC, 2012) for the teaching of engineering design. The *NGSS* do not refer to engineering design as a process or list a series of problem-solving steps. Rather, they encourage that students learn the core ideas of engineering design that includes the three component ideas described below.

A. Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits.
B. Designing solutions to engineering problems begins with generating a number of different possible solutions, then

evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

C. Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important. (NGSS, 2013, p. 2)

Engineering Design in K-12 Curricula

In national curricula developed for K-12 technology and engineering education, as well as for STEM education, the importance of engineering design is almost always promoted. The publication *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* (NRC, 2009) presents an excellent and detailed review of national curricula efforts in STEM that discusses the importance of engineering design and notes that it is included in most STEM curricula. In this document, the authors define “engineering design” as a purposeful, iterative process with an explicit goal governed by specifications and constraints (p. 82). Furthermore, the document provides recommendations for three principles for the focus of K-12 engineering education: (1) emphasis on engineering design; (2) incorporation of important and developmentally appropriate mathematics, science, and technology knowledge and skills; and (3) promotion of engineering habits of mind (pp. 4-5). Engineering habits of mind are often associated with skills required for the 21st Century and include: (1) systems thinking, (2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) attention to ethical considerations (p. 5).

In reviewing popular national curriculum efforts for use in technology and engineering education, engineering design is an important concept emphasized in curricula where problem-solving was the focus of learning. Most models presented similar features in their approach to solving problems and most models appear to be presented in a cyclical fashion. Examples of curricula where engineering design is emphasized include *Project*

Lead the Way's (PTLW) engineering courses (see: www.pltw.org/our-programs/pltw-engineering), the International Technology and Engineering Educators Association's *Engineering byDesign (EbD)* courses (see: www.iteea.org/STEMCenter/EbD.aspx) and in the Boston Museum of Science Engineering curricula offerings (see: www.mos.org/engineering-curriculum). In addition to national curriculum efforts, States have also developed curricula that provide students an opportunity to learn about applying the engineering design process. For example, see Utah's *Engineering Course* (www.schools.utah.gov/CTE/tech/DOCS/strands/EngineeringTechnology.aspx).

Organizations Promoting Engineering Design

In addition to STEM curricula, there are many organizations promoting the use of the engineering design process in K-12 Education. For example, PBS's Design Squad (http://pbskids.org/designsquad) or Science Buddies (www.sciencebuddies.org), a non-profit organization promoting science, defines the engineering design process as a series of steps that engineers follow to develop a solution to a problem. They identify the steps of the engineering design process as:

1. Define the Problem
2. Do Background Research
3. Specify Requirements
4. Brainstorm Solutions
5. Choose the Best Solution
6. Do Development Work
7. Build a Prototype
8. Test and Redesign

Teach Engineering (www.teachengineering.org), is an NSF supported digital library site that offers standards-based engineering curricula for use by K-12 teachers and engineering faculty to make applied science and math come alive through engineering design in K-12 settings. They promote an engineering design process model that includes the following steps:

1. Ask: Identify the Need
2. Research The Problem
3. Imagine: Develop Possible Solutions
4. Plan: Select a Promising Solution
5. Create: Build a Prototype
6. Test and Evaluate Prototype
7. Improve: Redesign as Needed

For many years NASA and its educational programs have been supporting curricula that promote engineering design and engineering design challenges. Recently they have introduced a new program known as "Beginning Engineering, Science, and Technology or BEST (www.nasa.gov/audience/foreducators/best/edp.html) that promotes teaching the engineering design process to younger audiences. Their engineering design process model, adapted from the Boston Museum of Science engineering design model, includes the following steps:

1. Ask
2. Imagine
3. Plan
4. Create
5. Experiment
6. Improve

Section Summary

This section illustrated the importance of teaching the engineering design process in K-12 technology and engineering education and in STEM education. It showed how the engineering design process is supported in national educational standards, STEM education curricula, and by other organizations involved in STEM education. Although this section did not show one agreed upon engineering design process model, it did show that most models were similar in the features they presented.

Discussion

The purpose of the chapter was to investigate whether the engineering design process models used in K-12 technology and engineering education classrooms are an accurate reflection of the models used in industry and other technical fields (i.e., for purposes of this chapter, the field engineering). In reviewing how engineers learn about and use the engineering design process and how it is presented in technology and engineering education, the author would have to agree that it is a "fairly accurate reflection" of the models being used in industry and technical fields.

In this chapter, one major theme emerged, that is, that problem solving is an important *(if not the most important)* skill that engineers must learn. The chapter also found that there are many engineering design (problem solving) models being taught and used in both the fields of engineering and technology and engineering education. Many models reviewed noted the importance of good teamwork when solving problems and included the basic steps of identifying and describing the problem, brainstorming solutions, choosing a solution, building and testing the solution, and sharing the results. Inherent to all of these steps was the need to use good "decision making" practices. Interestingly, most engineering design models in technology and engineering education were presented in a cyclical fashion, while those in engineering presented in a "block fashion." However, the models discussed in engineering often noted that the process was iterative and not linear.

In the teaching of the engineering design process in K-12 technology and engineering education, most models reviewed were similar in the features they presented to solve problems. These features were also similar to those taught and used in the field of engineering, however in engineering, when solving problems, there seemed to be more of an emphasis on the context of the problem, the needs of the customers, and more emphasis on analysis and constraints related to the problem. Those involved in the teaching of technology and engineering education should consider also emphasizing these points when teaching students how to apply the engineering design process. In addition, based on personal experiences, other important concepts to emphasize would include those related to creativity, ethics, and that it is all right "to fail" as designers often fail many times before succeeding.

Conclusion

Problem-solving, (i.e., engineering design, or the engineering design process) is a very important skill needed in engineering and these skills should be taught in K-12 technology and engineering education. There are many engineering design models used in engineering, and technology and engineering education, but they are very similar in the procedures that they use to solve problems. Those involved in the teaching of K-12 technology and engineering education should continue teaching the engineering design process as currently promoted in the field and other related STEM programs. However, those involved in teaching engineering design in technology and engineering education should consider placing more emphasis on the context of the problem, the needs of the customers, analysis of the problem, and constraints related to the problem.

References

ABET. (2015). *Criteria for accrediting engineering programs.* Retrieved from: http://www.abet.org/wp-content/uploads/2015/10/E001-16-17-EAC-Criteria-10-20-15.pdf

Asunda, P. A., and Hill, R. B. (2007). *Features of engineering design in technology education.* Retrieved from http://ncete.org/flash/research/Critical%20Features%20-%20Asunda_Hill_y1.pdf

Dym, C. L., Little, P., and Orwin, E. (2014). *Engineering design: A project-based introduction,* (4th Ed.) Hoboken, NJ: John Wiley & Sons, Inc.

International Technology Education Association/International Technology and Engineering Educators Association. (2000/2002/2007). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

Horenstein, M. (2010). *Design concepts for engineers* (4th Ed.). Upper Saddle River, NJ: Pearson Higher Education.

Holtzapple, M. T., and Reece, D. W. (2005). *Concepts in engineering.* Boston, MA: McGraw Hill Higher Education.

Householder, D. L., & Hailey, C. E. (Eds.). (2012). I*ncorporating engineering design challenges into STEM courses.* Retrieved from the NCETE website: http://ncete.org/flash/pdfs/NCETECaucusReport.pdf

Hynes, M., Portsmore, M., Dare, E., Milto, E., Rogers, C., & Hammer, D. (2011). Infusing engineering design into high school STEM courses. Retrieved from the National Center for Engineering and Technology Education: http://ncete.org/flash/pdfs/Infusing%20Engineering%20Hynes.pdf

Lammi, M., & Becker, K. (2013). Engineering design thinking. *Journal of Technology Education*, *24*(2), 55–77. Retrieved from https://scholar.lib.vt.edu/ejournals/JTE/v24n2/pdf/lammi.pdf

Lewis, T. (2005). Coming to terms with engineering design as content. Journal of Technology Education, *16*(2), 37-54.

Maffin, D. (1998) Engineering design models: Context, theory and practice. *Journal of Engineering Design, 9*(4), 315-327, DOI: 10.1080/095448298261462

Mosborg, S., Adams, R., Kim, R., Atman, C. J., Turns, J., and Cardella, M. (2005). Conceptions of the engineering design process: An expert study of advanced practicing professionals. *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition.* Retrieved from: https://peer.asee.org/14999

National Research Council [NRC]. (2009). *Engineering in K–12 education: Understanding the status and improving the prospects.* Washington, DC: National Academies Press.

Next Generation Science Standards [NGSS] (2013). *Engineering Design in the NGSS,* Appendix I. Retrieved from: http://www.nextgenscience.org/sites/default/files/Appendix%20I%20-%20Engineering%20Design%20in%20NGSS%20-%20FINAL_V2.pdf

Oakes, W. C., Leone, L. L., & Gunn, C. J. (2006). *Engineering Your Future* (5th Ed.). Okemos: MI: Great Lake Press, Inc.

Sheppard, S., Colby, A., Macatangay, K., and Sullivan, W. (2006). What is engineering practice? *International Journal of Engineering Education*, *22*(3), pp. 429-438.

Stephan, E. A., Bowman, D. R., Park, W. J., Sill, B. L., and Ohland, M. W. (2015). *Thinking like an engineer: An active learning approach, 3rd Edition* Upper Saddle River, NJ: Prentice Hall.

The Mississippi Valley Technology Teacher Education Conference and the Future of the Profession

Chapter 16

Michael K. Daugherty & Vinson Carter
University of Arkansas

Introduction

The Mississippi Valley Technology Teacher Education Conference has been a vital component of both thought and practice in the profession for over 100 years. Initially created by manual arts education leaders in the Midwest, the conference has expanded to serve as an important assembly for leaders in technology and engineering teacher education programs across the nation and world. The themes presented and questions addressed at the annual conference, derived from the membership present at the previous year's conference, manifest themselves as being on the forefront of people's minds as the conference unfolds. Members and guests of the conference are encouraged to engage deeply in discussions of paramount importance to the field as well as unsettled arguments that affect the profession.

While the conference has long served as a proving ground for ideas and research that will eventually find its way into refereed journals and related professional publications, some important ideas and discussions presented at the conference remain unpublished. The papers presented as chapters in this yearbook represent the best snapshots of unpublished research from the Mississippi Valley Technology Teacher Education Conference over the past fifteen years. All of these chapters represent ideas and arguments that were at the forefront of conversation and debate at the time of their presentation. Although, some of the discussions and questions brought to light in the previous chapters have been principally settled or answered, there is historical and future value in reflecting upon the impassioned debates that led technology and engineering teacher education to this point in history.

The Legacy of Technology and Engineering Education

If there is a unifying theme that transitions through all of the disparate chapters included in this yearbook, it is the continuing professional struggle for a lasting legacy, a necessary place, a historical significance, for our field. While members of the profession clearly see the societal relevance and the crucial need for an educational discipline that is principally dedicated to technological literacy, pragmatic instruction, and problem solving, we are often not entirely sure whether anyone outside the profession agrees. Diez' (2002) examined the heritage of the field and challenged the profession to utilize the national energy generated for STEM education to position the technology and engineering education as the educational discipline with the capacity to provide the essential integration component needed bring problem solving, collaboration, and critical thinking into the classroom. Diez also emphasized the importance of preparing teachers to be technologically literate, building a culture of innovative classroom practices, and being advocate for the profession as critical focus areas for technology teacher education as we head into the 21st century. Similarly, Hoepfl (2009) traced the history of the profession and identified opportunities for the future. Both authors offered that technology and engineering education is the central component of the school curriculum for integrating and applying core concepts from adjoining disciplines like mathematics, science, and engineering.

Meanwhile, McAlister (2004) underscored the critical importance of preparing technology and engineering educators to integrate engineering and engineering design content and methods into their classrooms. Interestingly, the recent CTETE Yearbook titled Engineering and Technology Education (Custer & Erekson, 2008) emphasized the importance of engineering in the technology and engineering education classroom and how such an alignment would be critical to the future of our field and would help establish the discipline as a delivery system for STEM education. Remarkably, the integration of engineering and engineering design into the professional dogma became prevalent during the first two decades of the 21st Century. Even the name of the profession has evolved to emphasize this new dedication to engineering design. If there are still members of the profession arguing against the inclusion of engineering and engineering design, they clearly represent a minority opinion. Reeve's (2016) research illustrated the full cycle of implementation through his analysis of the status of engineering design in the technology and engineering education classroom. Although it was clearly an open question at the dawn of the 21st Century, during the succeeding 15 years, the profession has embraced engineering and the engineering design process in the technology and engineering education classroom.

At the same time others were promoting STEM education, integration, and engineering as critical components of our future profession, some were urging members of the field to remember the social and cultural aspects offered by technology and engineering education. Warner (2006) provided the conference with a declaration of the vital importance of humanity's need for technological literacy in the 21st Century. Warner warned that by linking more closely with engineering design, the profession might be at risk of abandoning some of the human aspects that are so important in the design and the creation of technology. Warner also cautioned the profession to avoid abandoning century old ideals that our field should serve as a vital component of the general education curriculum, and not align too closely with particular career preparation programs. These questions are unresolved at this time, but the upcoming revision of the *Standards for Technological Literacy* will likely provide the litmus test on the future direction of our field and the core identities upon which we will build our future.

Continuing with the theme of historical legacy and significance, Welty (2004) addressed gender diversity in the technology and engineering education profession—a problem that has plagued the field since inception. Welty made a definitive case for the lack of diversity and the imperative nature of developing curriculum that is "consistent with the experiences, interests, concerns, and ways of knowing of girls and young women (p. 2)". The rise of State and national STEM education initiatives and projects over the past few years have echoed Welty's sentiments as more and more programs have been developed to attract female students and engage them in STEM fields. While this inherent disciplinary problem has yet to be fully addressed in any comprehensive manner, movement has occurred in an ad hoc fashion. Numerous national commercial curriculum projects, like *Project Lead the Way* have been launched in technology and engineering education classrooms, and the teachers in these programs appear to be much more diverse. This is largely due to the policies of *Project Lead the Way* and similar curriculum projects that encourage teachers from other disciplines (some female dominated) to complete their course training and then teach in a classroom that has traditionally been taught by male educators. While this practice has led to increased numbers of female teachers in technology and engineering education classrooms, it brings with it other disciplinary risks, like underprepared teachers in the classroom.

Three chapters in the yearbook reasoned that the historical legacy and significance of technology and engineering education may be strengthened by cultivating additional external supporters and stakeholders. Householder (2005) maintained that it is critically important for technology educators to form professional relationships with science, mathematics, and engineering educators. He noted that educators in these adjoining disciplines are often unaware of the field of technology and engineering education and the *Standards for Technological Literacy*; however, Householder was quick to point out that these educational communities may be supportive in the future. Householder also directed our attention to the important contributions of external scholars like Gerhard Salinger of the National Science Foundation and Roger Bybee, Chair of the Science Forum, to the field of technology and engineering education. The legacy of Salinger and Bybee's work continue to be significant today. Meanwhile, Gilberti (2006) examined the use of the TIDE model or descriptor to support technological literacy. Gilberti discussed the ITEEA's push to promote the idea of teaching excellence in technology, innovation, design, and engineering or TIDE. Although you might occasionally see or hear the moniker TIDE used to describe an ITEEA initiative, in 2009, ITEEA began to emphasize the role of the profession with the STEM acronym and clearly staking out the role that technology and engineering education play in STEM education literacy. In the interim, Burke (2007) offered his perspective regarding the identity of the professional and the future of technology and engineering education. Interestingly, Burke examines what a technology and engineering education program would look like in 2017. Although 2017 has come and gone, many of his visions have transpired, including a larger emphasis on STEM learning and an engineering focus in the technology education classroom. All three of these chapters illustrate the critical, and continuing, need to promote the field to outside audiences.

Finally, four chapters in the yearbook argued for a future where STEM education would be a central component of technology and engineering education. Iley and Bastion (2007) characterized the importance of preparing technology educators and their work provides a comprehensive list of desirable attributes and competencies along with assessments that may be used in the preparation of teachers. Iley and Bastion make the case that we should be preparing teachers to teach technology and engineering education and that these teachers should support science and mathematics courses, although, they do not specifically use the STEM acronym. Furthermore, they acknowledge that the identity of the profession will be a continual challenge in the 21st century. Wells (2008) proposed that the true potential of technology education can only be fulfilled through STEM education, while Merrill (2010) examined the technology and engineering education profession's perspective toward STEM education and suggested that the field was ready to embrace this challenge. Finally, Daugherty (2011) scrutinized external threats and opportunities for the field and the role that STEM education might play in our classrooms of the future.

Summary

As noted in Chapter 1, it is fascinating to discover how many of the arguments, perceived threats, points of departure, and open discussions, have been in large part settled during the first 15 years of the 21st Century. When considering these presentations in a contemporaneous nature in the time-periods in which they were presented, one can recall thinking that some of these problems might never be resolved. For example, when the *Next Generation Science Standards* were released nationally, most members of the technology and engineering education community were fearful of the resulting negative impact that might befall our profession. However, at this moment, it is apparent that most of the results enacted as a result of that publication have only benefitted our profession. Similarly, many in technology and engineering education were fearful at the prospect of fully introducing engineering and engineering design as a primary component of technology and engineering education—fearing that the profession might be viewed solely as a training program for post-secondary engineering programs. However, most would agree that the resultant has been much more positive. Historian and author David McCullough noted that history doesn't just happen; it is made—made by real people who faced real challenges, who had uncertainty about the future, just as we have today. He also observed that history is not about the past, they lived in their present. They were caught up in the living moment exactly as we are, and with no more certainty of how things would turn out than we have today (McCullough, 2009).

We hope that you have enjoyed the long deserved dissemination of these discussions from previous Mississippi Valley Technology Teacher Education Conferences. We encourage you to utilize these chapters and reflections as you consider the things that we have collectively achieved and the challenges and milestones in our future.

References

Burke, B. N. (2007, November). Perspectives on the future of technology education. *94th Mississippi Valley Technology Teacher Education Conference*. Chicago, IL.

Custer, R. L. & Erekson, T. L., Eds (2008). *Engineering and Technology Education*. Reston, VA: Council on Technology and Engineering Teacher Education.

Daugherty, J. (2011, November). Teaching technology: Are we on the right path? *98th Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Diez, C. R. (2002, November) Technology Education: A rich history and challenges. *89th Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Gilberti, A. F. (2006, November). Technology, innovation, design, and engineering (TIDE) education. *93rd Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.

Hoepfl, M. (2009, November). Tracing technology education's lineage, with an eye toward the future. *96th Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.

Householder, D. L. (2005, November). Perceptions of technology education among science, mathematics, and engineering educators. *92nd Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Iley, J. L. & Bastion, S. E. (2007, November). Highly qualified technology education teachers: Their attributes, competencies, assessment, and preparation for tomorrow's schools. *94th Mississippi Valley Technology Teacher Education Conference*. Chicago, IL.

McAlister, B. K. (2004, November). Are technology education teachers prepared to teach engineering design? *91st Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

McCullough, D. (2009). *The course of human events.* New York: Simon and Schuster.

Merrill (2010, November). Technology education perspectives of STEM education. *97th Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

Reeve, E. (2016, November). A reflection on the engineering design process models used in technology and engineering education classrooms and those used in the engineering profession. *103rd Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

Stricker (2009, November). Expert and novice technological literacy. *96th Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.

Wells, J. G. (2008, November). STEM education: The potential of technology education. *95th Mississippi Valley Technology Teacher Education Conference*. St. Louis, MO.

Welty, K. (2004, November). The diversity imperative: Attending to gender differences in technology and pre-engineering education. *91st Mississippi Valley Technology Teacher Education Conference. Chicago, IL.*

Warner, S. A. (2006, November). The soul of technology education: Being human in an overly rational world. *93rd Mississippi Valley Technology Teacher Education Conference*. Nashville, TN.