Identifying Characteristics of Technology and Engineering Teachers Striving for Excellence Using a Modified Delphi

Teaching excellence is an expectation for teachers oft expressed by policy makers, parents, taxpayers, professional organizations, and students. Preparing a technology and engineering (TE) teacher who strives for teaching excellence is a fundamental mission of TE teacher education programs in the United States. However, a recent focus upon engineering design concepts within the TE curriculum (Gattie & Wicklein, 2007) and urgent calls to align, coordinate, or integrate TE curriculum in K-12 schools within science and mathematics education (Presidents' Council of Advisors on Science and Technology, PCAST, 2010) compels teacher education programs to reevaluate their curricular programs.

Purpose

In 2012, the International Technology and Engineering Educators Association (ITEEA, formerly the International Technology Education Association, ITEA) Council on Technology and Engineering Teacher Education (CTETE, formerly the Council on Technology Teacher Education) Teacher Preparation and Revitalization Committee was tasked to identify the characteristics of a TE teacher striving for excellence. To this end, the committee conducted a Delphi study with the purpose of identifying basic competencies that a pre-service teacher striving for excellence would have upon successfully completing a TE teacher preparation program. This competency profile could assist teacher educators as they evaluate and revise their teacher preparation programs.

Literature Review

The desire for teaching excellence, also referred to as highly effective teaching, is driven by numerous factors, including perceptions of inadequate student achievement in science, technology, engineering, and mathematics (STEM) education (Gonzalez & Kuenzi, 2012) and critics of traditional teacher preparation programs who perceive university teaching degrees as burdensome (e.g., U.S. Department of Education, USDOE, 2002). Possibly the most compelling is that empirical evidence gained through statistical modeling indicates that high quality teaching is an important predictor of student achievement (Aaronson, Barrow, & Sander, 2007).

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Attempts to characterize teaching excellence, especially in terms of the competencies of an exemplary, highly-qualified teacher, are evident within state and national teacher standards (e.g., Council of Chief State School Officers, CSSO, 2011), the scholarly literature (e.g., Office of Educational Innovation and Evaluation, 2008), and teacher evaluation systems (e.g., Grossman, Cohen, Ronfeldt, & Brown, 2014). A broad range of competencies are mentioned, such as "high verbal ability" (USDOE, 2002), maintaining an "effective public relations program" (Roberts & Dyer, 2004), and being "reflective about their own cultural frames of reference" (Rychly & Graves, 2012). However, most include a core set of skills, knowledge, and dispositions related to learners, pedagogy, content (subject matter), communication, and professionalism. Other theorists and practitioners, namely Shulman (1987), conceptualize these teacher competencies as being an integrated, complex set of knowledge and skills known as Pedagogical Content Knowledge (PCK). PCK requires a thorough grounding in the concepts, principles, and frameworks of the subject matter, pedagogy (the processes and methods of teaching), and a deep understanding of how students think and learn. As Shulman (1987) suggests, "PCK, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8).

Focused upon state education agencies responsible for teacher licensing, the Interstate New Teacher Assessment and Support Consortium (InTASC) Model Core Teaching Standards (CCSSO, 2011) consists of 10 standards within four organizational categories: The Learner and Learning, Content, Instructional Practice, and Professional Responsibility. In a recent revision, the CCSSO (2013) characterizes these as professional practice standards that occur along a developmental continuum articulated as learning progressions. Each attempts to differentiate basic competence from more complex teacher practice by capturing clusters of key indicators (performance, essential knowledge, and critical dispositions) that when combined exemplify increasingly more sophisticated teacher practice.

Content Knowledge: Technology & Engineering Education

With historical roots in manual arts, industrial education, and industrial arts education, TE has long been associated with technical and industrial content. Historically, teachers were expected to demonstrate technical competence regarding materials and processes in domains such as woodworking, metalworking, and drafting. Throughout the 1970's and 80's, prominent leaders argued that TE curriculum was concerned with a study of technological systems. The CTTE (as cited in Miller, 1991) indicates that an effective technology teacher would provide laboratory instruction in the study of manufacturing, communication, construction, and transportation systems at a specified level of technical competence" (p. 63).

Later, a call for *technological literacy for all* guided the K-12 content standards called the *Standards for Technological Literacy* (STL, ITEA, 2000). Among the 20 STLs are standards explicitly identifying content related to the attributes and application of design, engineering design, and the relationship of technology to other fields. *Advancing Excellence in Technological Literacy* (ITEA, 2003), a companion set of standards, addressed desired teacher competencies related to professional development, student assessment, and program development. These standards identify competencies of teachers, e.g., assessing student learning that will be consistent with STLs (p. 20).

Now, with increasing expectations that teachers help charge the engineering and science pipeline with innovative designers and entrepreneurs that can maintain a competitive edge in the world marketplace through innovation (PCAST, 2010), there are increasing pressures to more deeply focus TE content upon an engineering pathway that applies the concepts, principles, and processes of science and mathematics. Yet, Litowitz's (2014) survey of 24 TE teacher education programs in the U.S. suggests that a significant proportion of TE teacher preparation programs may require few high-level science and mathematics courses that could build pre-service teachers' competence in these areas. The dynamic nature of the TE content domain makes it difficult to assume where the acceptable range of content competence might lie for a TE teacher striving for excellence.

Methodology

A three round modified Delphi study was used to characterize competencies of a TE teacher striving for excellence. The Delphi research methodology is portrayed as an efficient technique to identify content (Hacker, de Vries, & Rossouw, 2009), critical issues (Wicklein, 1993), and competencies (Scott, Washer, & Wright, 2006) for TE curriculum improvement. The Delphi method was established in the 1950s by the Rand Cooperation, and is a technique used to establish meaning and consensus from experts that may be geographically spread out from one another (Stitt-Gohdes & Crews, 2004).

Participants

Participants for the Delphi panel were purposively selected from TE teacher education faculty, classroom TE teachers, state TE administrators, school administrators, and STEM professionals working outside of TE education. A concerted attempt was made to create a geographically diverse panel. The panel was comprised of members from 16 states and one international participant. Of the 43 potential participants contacted, 23 originally agreed to participate in the study. Due to the low number of classroom teachers that completed the first round, 10 additional teachers were invited to participate; seven teachers agreed to participate in subsequent rounds. Table 1 outlines participation in the Delphi panel.

Table 1
Delphi Panel Participants

	Round One	Round Two	Round Three
TE Faculty	6	7	6
Classroom Teachers	3	9	8
Administrators: State TE & CTE	5	4	3
Administrators: School	2	1	2
STEM Professionals	2	1	1
Total	18	22	20

Instrument Development

During fall 2012, program level goals and outcomes were requested from 10 TE teacher preparation programs in the U.S.; five responded. These elements were compiled along with InTASC standards (CCSSO, 2011) to generate a list of 95 outcome statements. The researchers independently coded each outcome statement using a cross-matrix comparison noting the occurrence of themes. This resulted in 45 discrete issues, concepts, or skills.

The researchers then independently coded each of the 45 emerging issues, concepts, or skills into mega-level organizers representing five types of competencies including the knowledge, skills, and dispositions that enable teachers to demonstrate:

- Pedagogical Competence, i.e., successfully plan and implement effective learning experiences.
- Evaluation and Assessment Competence, i.e., effectively plan, implement, analyze, and interpret an educational outcome or the merit or worth of a learning activity or curricular program, product, or policy.
- Technological Competence, a combination of technological knowledge, technological skills, and technological will (Autio, 2011) which enable people to design, use, manage, assess, and understand technology (ITEA, 2000), including interdisciplinary concepts and principles categorized as STEM.
- Interpersonal Competence, i.e., abilities to adapt to dynamic social situations and effectively interact, communicate, cooperate, and collaborate.
- Professional Competence, i.e., commitment to lifelong learning, abilities to influence others, and contribute to the advancement of the profession.

Overall there was 100% agreement among the researchers on 67% of characteristics with Technological Competence being the most consistent. After collaboratively reconsidering items receiving 75% agreement until consensus was reached, 86 statements of teacher characteristics were included on the round one instrument, including: Pedagogical = 20; Evaluation and Assessment = 16; Interpersonal = 11; Technological=27; and Professional=11.

Results

The purpose of the first round of the study was to solicit panelists' recommendations as to the characteristics of a TE teacher striving for excellence and validate the characteristics gleaned from a review of the TE teacher preparation programs and the InTASC standards. The instrument was organized into five subsections representing the five categories of competencies. Each subsection began with an open-ended question asking panelists to list the most critical knowledge, skills, and dispositions related to that competence. Then, panelists rated the aforementioned characteristics on a 5-point scale (1=Not at All Important to 5=Critically Important). At the end of each subsection, panelists were asked to "list any other competencies that should be on this list."

Round 1 Results & Discussion

Panelists offered 310 responses to the open-ended questions on the round one instrument. After eliminating redundancies and cross-referencing with the original 86 characteristics, 76 of the panelists' responses were deemed unique adding new qualities to the list of characteristics. Table 2 offers examples of these items.

Panelists' ratings of the 86 core characteristics generated consistent averages of 4 or higher for 3 of 5 competence categories, including Evaluation and Assessment, Interpersonal, and Professional Competence. Although planning instruction that aligns with state TE standards (M=4.24, S=.56) and the STLs (M=4.24, S=.66) ranked 15th and 16th, respectively, panelists did not perceive abilities to design curriculum and facilities as critically or very important pedagogical competencies (Table 3). This suggests that the traditional role of the teacher as a curriculum developer (Zuga, 1991) has subsided; this may be in response to the widespread adoption of externally-produced curriculum, such as Project Lead the Way. Relative to technological competence, the panelists' low ranking of "Understanding contemporary systems related to biotechnology, medical technology, nanotechnology, and agricultural technology" supports Litowitz's (2014) contention that there is a "lack of extensive acceptance within the field" to these aspects of technology (p. 78).

Table 2
Round One Panelist Contributions to Open-Ended Questions

Technological Competence	Pedagogical Competence	Evaluation and Assessment Competence	Interpersonal Competence	Professional Competence
61 Responses	73 Responses	57 Responses	58 Responses	61 Responses
8 Unique	19 Unique	21 Unique	11 Unique	17 Unique
Knowledge of certifications available in technical professions Knows how technical information and skills connect to careers and workplace practices	Inspires students' curiosity, creativity, ingenuity, and innovative spirit Anticipates student mistakes when introducing new technologies Creates a learning environment where students are willing to take risks and persist through difficulty	Selects and uses assessment strategies that require students to use inquiry and critical thinking skills Selects and uses assessment tools that meet the needs of business and industry Identifies student characteristics for which baseline data should be collected	Enjoys teaching Demonstrates love and excitement for technology and engineering content Promotes equity in the classroom, including issues of gender, race, disability, and nationality Fosters relationships with business and industry leaders	Possess a degree in an engineering discipline Active in curriculum committees, school boards, and strategic partners Fosters the next generation of teachers Attempts to inform educational policy

Table 3
Round One Results: Low Ratings[1] of 86 Core Characteristics

		M	*SD*
Pedagogical Competence (20 items, *n* = 18)			
Rank	Item		
18	Designs TE curriculum	3.78	.65
19	Plans instruction based upon community needs and priorities	3.72	.83
20	Designs laboratories and classroom spaces	3.61	.85
Technological Competence (27 items, *n*=18)			
Rank	Item		
27	Understands contemporary systems related to biotechnology, medical technology, nanotechnology, and agricultural technology.	3.78	0.18

[1]Less than 4 on a 5-point Importance Scale

Round Two Results and Discussion

The purpose of the second round of the study was to gauge panelists' judgments regarding ONLY those unique characteristics individually provided by the panel in the open-ended response portion from the first round. The round two survey asked the participants to rate each item using a 5-point scale (1=Not at All Important to 5=Critically Important).

The data were analyzed to find the mean and standard deviation of the responses. Twenty-four of the unique items received a mean rating of 4.5 or higher with the highest mean scores occurring for a pedagogical and interpersonal competency.

Nine of the 76 unique items did not receive ratings of 4 or better on a 5-point importance scale (Table 4). Several of these lower rated items might indicate an emerging trend or important concern for teacher educators. Looking across competence categories in Table 4, several characteristics demonstrate direct connections with business and industry through technical certifications, assessments, technical standards, and professional experience. These concerns echo initiatives of the National Research Center for Career and Technical Education and Southern Regional Education Board to develop an induction model for teachers seeking alternative certification to be used by all states (Sass, 2011) or efforts attempting to require that teachers of engineering courses in public schools possess an engineering degree or engineering experience (Virginia Board of Education, 2013). These concerns may emphasize long-held tensions between TE teacher preparation programs dedicated to the mission of *technological literacy for all* with those dedicated to the mission of career education and *workplace readiness*.

Table 4
Round Two Results: Low Ratings[1] of Panelists Unique Recommendations

	Rank	*n*	*M*	*SD*
Pedagogical Competence (19 items)				
Encourages participation in student organizations	18	22	3.95	0.79
Provides opportunities for students to control energy and produce and test products and systems	19	22	3.91	0.75
Evaluation & Assessment (21 items)				
Selects and uses assessment tools that meet the needs of business and industry	20	20	3.95	0.83
Technological (8 items)				
Identifies and applies relevant technical standards, e.g., those of ANSI or ASTM International	21	22	3.91	0.61
Knowledge of certifications available in technical professions	22	22	3.86	0.89
Professional (17 items)				
Shares scholarly work through writing, presentations, and research	14	22	3.82	0.66
Active in curriculum committees, school boards, and strategic partners	14	22	3.82	0.66
Possesses professional experience in business or industry and education	16	22	3.68	0.78
Possesses a degree in an engineering discipline	17	22	3.18	0.66

Round Three Results & Discussion

The purpose of the third round of the Delphi study was to validate the top 50% of the responses from both the first and second rounds. In this final round, the panel was given the full knowledge of the judgments of the panel. For each competency, items were presented in rank order with the Delphi panels' mean response, standard deviation, and the round. Tables 5-9 present the ranked order list of items deemed critically important by at least 50% of the panelists; shaded items were provided by the panel in the open-ended response portion of the round one survey.

Pedagogical Competence. Ten characteristics were considered critically important relative to Pedagogical Competence (Table 5) with the highest agreement among panelists for "Inspires students' curiosity, creativity, ingenuity and the innovative spirit" and "maintains a safe learning environment that promotes the well-being of the learner". While the latter is consistent with a maxim of "do no harm" or beneficence, the former is in concert with a widespread national vision that to be competitive in a global marketplace the U.S. must foster a creative workforce that continuously develops innovative products.

Most of the top-rated pedagogical items have components that are either directly or indirectly consistent to those found in the InTASC (CCSSO, 2011) or ITEA (2003) standards. For example, "Strategically uses a variety of instructional strategies" is reflected in InTASC Standard #8: Instructional Strategies and "Devises learning experiences for students to design, produce, use, and assess technology" is the definition of technological literacy offered by ITEA (2000).

With current emphasis upon STEM education, it is instructive to note two items receiving important, but not critically important ratings, including: "applies appropriate math and science knowledge" (13th in Round 3), and "aligns curriculum and instruction with other subjects at the same grade level" (34th in Rounds 2 & 3). While many of the panelists considered these characteristics important in a TE teacher, the goal of STEM integration and the alignment of subjects were not perceived as critical.

Table 5
Round Three Results - Pedagogical Competence

	A Technology and Engineering Teacher Striving for Excellence …	Critically Important 75-99%
1	Inspires students' curiosity, creativity, ingenuity, and innovative spirit	85%
2	Maintains a safe learning environment that promotes the well-being of the learner	85%
3	Makes subject matter meaningful for students	75%
4	Inspires and motivates students to learn and perform by developing relevant and engaging learning experiences	70%
5	Enhances students' development of reasoning, problem solving, and critical thinking skills	63%
6	Implements relevant real-world learning experiences	55%
7	Devises learning experiences for students to design, produce, use, and assess technology	55%
8	Inspires students to achieve at increasing levels of difficulty	55%
9	Understands how students learn and develop	50%
10	Strategically uses a variety of instructional strategies	50%

Evaluation and Assessment Competence. A teacher who "adjusts instruction based upon assessment evidence" was the highest-ranking item relative to Evaluation and Assessment (Table 6). This competency appears congruent with the current pressures on teachers and districts to adopt evidence-based teaching strategies (Groccia, & Buskist, 2012). Other highly ranked items, were strongly consistent with InTASC Assessment Standard #6 (CCSSO, 2011) and ITEA's (2003) Student Assessment standards.

Table 6
Round Three Results – Evaluation and Assessment Competence

	A Technology and Engineering Teacher Striving for Excellence …	Critically Important 75-99%
1	Adjusts instruction based upon assessment evidence	84%
2	Selects and uses assessment strategies that require students to use inquiry and critical thinking skills	68%
3	Provides opportunities for students to demonstrate learning in a variety of ways	68%
4	Provides timely and useful feedback to students regarding their progress toward learning goals	63%
5	Uses performance-based assessments that reflect real-world problems or contexts	63%
6	Develops valid assessment tools (e.g., tests and rubrics)	63%
7	Plans meaningful, effective assessment experiences for students that measure progress toward important learning goals	58%
8	Helps students learn how to self-assess	53%

The 2nd highest ranked item—"Selects and uses assessment strategies that require students to use inquiry and critical thinking skills" — likely exhibits panelists' value for embedding assessment throughout students' design and problem-solving process (Custer, Valesey, & Burke, 2001) or evidence of a growing practice of assessing students' reasoning abilities through scenario-based assessment as demonstrated within the *Technology and Engineering Literacy Assessment* (National Assessment of Educational Progress, 2014). However, the results of Kelley and Wicklein's (2009) survey of high school teachers suggest that teachers may not emphasize the analysis phase where critical thinking is required (p.19).

Technological Competence. In the third round, the panel rated 20 characteristics in the Technological Competence category; 11of 20 were deemed critically important by the panelists. Three of the most critically important technological competencies concerned the skills required to control hazards and safely use tools (Table 7, #1, 3, & 4). Maintaining a safe educational environment demands an advanced set of knowledge and skills regarding the nature of processing materials and energy. Similarly, Cannon, Kitchel, Duncan and Arnett's (2011, Table 2) survey of educators in Idaho indicated that the 1st and 2nd highest ratings of teaching responsibilities were for proper "safety practices" and "safety attitudes," respectively.

Three other critically important characteristics (Table 7, #2, 5, and 6) spoke to an interrelated set of cognitive and psychomotor skills, including engineering design, problem solving, analysis, modeling, and testing. Although problem solving has long been the focus of curricular goals in industrial arts and technology education, a design process is narrower, having been characterized as the "engineering approach to identifying and solving problems" (Katehi, Pearson, & Feder, 2009, p. 4). For both, analysis typically refers to a fundamental cognitive skill required to decompose, break-down, and isolate elements of the problem during problem solving or design. While modeling and testing provides the problem solver or engineer with the empirical evidence used to assess or make design decisions.

Given that Ritz's (2009) Delphi study identified the *must have* goal for technological literacy programs as describing "social, ethical, and environmental impacts associated with the use of technology" (p. 59), readers may be interested in parallels in the current study. Although not deemed critically important by 50% of the panelists during Round 3, "know and apply systems thinking (e.g., systems are interrelated)" and "know that technical systems interact with and affect other systems, including economic, political, and environmental systems" ranked 10th and 12th, respectively.

Supporting Litowitz's (2014) survey of TE teacher preparation programs, these results also demonstrate a lower acceptance of agricultural, biotechnologies, medical technologies, and nanotechnologies in the field of technology and engineering education, which obviously vary based upon state-level curriculum standards.

Table 7
Round Three Results – Technological Competence

	A Technology and Engineering Teacher Striving for Excellence …	Critically Important 75-99%
1	Understands and appropriately controls hazards, including materials, processes, equipment, and energy	84%
2	Knows and is able to apply an engineering design process to design a potential solution	68%
3	Possesses the knowledge and ability to competently and safely use a variety of modern and traditional technologies	68%
4	Safely uses a variety of tools in order to process materials and energy	63%

5	Develops and implements solutions to open-ended problems	58%
6	Can analyze a prototype or create a model to test a design concept	58%
7	Exemplifies a spirit of inquiry, creativity, and innovation	53%
8	Understands how technological progress promotes the advancement of science, technology, engineering, and mathematics	53%

Interpersonal Competence. In round three, eleven interpersonal competencies were deemed critically important by the panelists (Table 8), the highest being "exemplifying sound ethical behavior" which is consistent with InTASC (CCSSO, 2013) Standard #10. The panel also agreed that a TE teacher must possess the interpersonal abilities to "think critically and analyze a problem" and "demonstrate flexibility in accommodating and adjusting to unexpected problems." Also referred to as classroom management, behavior management, conflict resolution, and counseling skills, variations of interpersonal competencies are sometimes identified as "needs" in surveys of graduates from TE teacher education programs (Hill & Wicklein, 2000) and practicing secondary teachers (Cannon, Kitchel, Duncan, & Arnett, 2011).

Table 8
Round Three Results – Interpersonal Competence

	A Technology and Engineering Teacher Striving for Excellence …	Critically Important 75-99%
1	Exemplifies sound ethical behavior	90%
2	Demonstrates the ability to think critically and problem solve	84%
3	Demonstrates flexibility in accommodating and adjusting to unexpected problems	75%
4	Demonstrates love and excitement for technology and engineering content	75%
5	Is respectful of differences	70%
6	Promotes equity in the classroom, including issues of gender, race, disability, and nationality	70%

7	Enjoys teaching	60%
8	Exhibits a positive attitude	60%
9	Understands and values diversity	60%
10	Listens to and considers the contributions of others	55%
11	Fosters relationships with school colleagues, parents, and people in the larger community	50%

Professional Competence. Nine of 14 professional competencies presented to panelists during the third round were deemed critically important (Table 9). The ability to "exemplify sound ethics" was, once again, the highest ranked item. Characteristics such as "making decisions based on professional standards", "staying current with professional issues", and "understanding the role of technology and engineering in STEM" were also highly rated. These are reflected in InTASC's (CCSSO, 2013) critical disposition that states "a teacher understands the expectations of the profession including codes of ethics, professional standards of practice, and relevant law and policy" (p. 41).

The panel also proposed that a TE teacher "advocates for technology and engineering education's role in the K-12 curriculum and community" with a 68% agreement of critical importance. This is closely reflected by the ITEA's (2003) Management Program Standard that advises that "teachers promote technology programs and technological literacy as essential components of education to parents, the local school board, and civic and economic development groups (p. 93).

With 32% agreement of critical importance, the Delphi panel identified that TE teachers should "accept leadership opportunities within the profession" and "share resources and best practices with others." This is a strong indication that the panelists agree with Ritz and Martin (2013) that the "advancement of a profession relies heavily on the participation of its members" (p. 65).

Table 9
Round Three Results – Professional Competence

	A Technology and Engineering Teacher Striving for Excellence …	Critically Important 75-99%
1	Exemplifies sound ethics	89%
2	Make decisions based upon professional standards and ethical criteria	74%
3	Seizes opportunities to stay current with professional issues, technical developments, best practices, and educational research	74%
4	Demonstrates an understanding of the role of technology and engineering in STEM education	74%
5	Advocates for technology and engineering education's role in the K-12 curriculum and the community	68%
6	Actively seeks out opportunities for professional growth; pursues life-long learning	63%
7	Demonstrates abilities to learn about new technologies	53%
8	Models best practices of the profession	53%
9	Possesses a teaching license or teaching credentials from the state	53%

Study Limitations

Several limitations existed within this Delphi study. The first instrument was derived from only five programs, thus it may not be representative of all TE teacher preparation programs. In addition, the relative value of mega-level competencies was not verified. Finally, the Delphi panel was populated with a diverse set of educational professionals; the combination may not be representative of the population of TE professionals.

Conclusions & Recommendations

This Delphi study was an attempt to characterize the qualities of TE teachers in the U.S. who strive for excellence. A questionnaire was developed from a review of the valued outcomes of TE teacher education programs and standards. A Delphi panel consisting of professional educators rated these outcomes and offered their own characterizations. After three rounds, these results indicate a clear focus upon learners and strong parallels to InTASC (CCSSO, 2011) and ITEA (2000 & 2003) standards. The highest ranked characteristics deemed important by at least 80% of the panelists for pedagogical competence were "inspires students' curiosity, creativity, ingenuity and innovative spirit" and "maintains a safe learning environment that promotes the well-being of the learner". For evaluation and assessment competence, it was "adjusts instruction based upon assessment evidence". "Exemplifies sound ethical behavior" and "demonstrates the ability to think critically and problem solve" were the highest ranked interpersonal competencies. For professional competence, the highest ranked was that a teacher "exemplifies sound ethics". Lastly, the highest ranked technological competence was that a teacher "understands and appropriately controls hazards, including materials, processes, equipment, and energy".

These results indicate that *teaching excellence* requires an interrelated set of skills, knowledge, and dispositions. In addition, the panelists' revealed values that were not explicit in the original outcome statements, technological literacy is a valued mission, and the expectations of teacher responsibilities may be narrowing.

Interrelated Skills, Knowledge & Dispositions

The results of this study support Shulman's (1986; 1987) and Mishra and Koehler's (2006) conceptualization of Pedagogical Content Knowledge in that panelists did not assign skills, knowledge and dispositions into mutually-exclusive categories; instead several parallels were drawn between pedagogical and technological competencies. First, the panelists associated the technical knowledge and skills required to safely use tools and control hazards (Table 7, #1, 3, & 4) with the pedagogical disposition and skills required to "maintain a safe learning environment that promotes the well-being of their learners" (Table 5, #2). Second, the emphasis upon enhancing "students' …problem solving… skills" (Table 5, #5) and devising learning experiences for students to design technology (Table 5, #7) is parallel to the panelists' value for technological competencies of being able to apply an engineering design process (Table 7, #2), and to develop and implement solutions to open-ended problems (Table 7, #5). Third, a parallel exists between a critically important technological competence—"exemplifies the spirit of inquiry, creativity, and innovation" (Table 7, #7)—and the highest rated pedagogical competence of "inspires students' curiosity, creativity, ingenuity, and innovative spirit" (Table 5, #1) . This prominence suggests that the panelists have internalized these qualities and have accepted the call to promote innovation and entrepreneurial activity in an attempt to enhance the competitive edge of the U.S. in a world marketplace.

Technological Literacy

There is substantial evidence among the pedagogical, technological, and assessment competencies that *technological literacy* is a valued mission for teachers pursuing excellence. The ITEA's (2000) definition of technological literacy—*design, produce, use, and assess technology*—appears as the 8th

critically important pedagogical competence. However, the critical importance of engineering design (Rank 2nd) and lower importance of systems thinking (Rank 10th) and "knowing that technical systems interact with and affect other systems, including economic, political, and environmental systems" (Rank12th) among technological competencies may suggest a reprioritization of the essential goals reported within Ritz's (2009) Delphi study.

Narrowing Teacher Expectations

Beyond the highest rated items, the results of current study highlights issues of perceived less importance by TE professionals. This study suggests that the traditional role of a TE teacher is narrowing to an implementer of curricula because competencies related to fulfilling roles of curricular developer, curriculum evaluator, and facility developer were not among those competencies judged to be critically important.

Recommendations to Teacher Educators and Researchers

The competency profile that emerged from this study could assist TE teacher educators as they evaluate and revise teacher preparation programs in a profession that continues to evolve and remain dynamic. Of special interest to teacher educators are the unique competencies suggested by the panel because these were not prominent among the outcome statements of the teacher preparation programs originally reviewed by the researchers. Teacher educators might evaluate the extent to which their curriculum provides pre-service teachers with opportunities to:

- experience, compare, and use assessment strategies that demand the application of inquiry and critical thinking skills;
- engage in professional activities, including service, presentations, and research;
- analyze the role of TE as part of integrated STEM education; and
- analyze and develop strategies to resolve interpersonal problems (social and behavioral) that might arise in the classroom relative to issues of gender, race, disability, and nationality.

Consistent with the idea that pedagogical content knowledge represents an integrated and complex set of teacher competencies related to content knowledge and pedagogical skills, teacher educators should also consider the integrative nature of the mega-level competencies—pedagogy, evaluation and assessment, technological, interpersonal, and professional—examined in this study. One recommendation for additional research is to develop a model that depicts the interrelationships among mega-level competencies and then test how this model could be used to guide TE teacher preparation programs.

Researchers should explore how exemplary teachers inspire ingenuity, creativity, and innovation among their students. Future research should also seek to identify competencies directly related to the delivery of STEM-integrated curriculum, especially as it applies to technical skills and mathematics and science knowledge.

Although this study investigated the characteristics of TE educators striving for excellence, it did not analyze the development of these characteristics. Many different factors contribute to the development of desired teacher competencies including teacher experience, preparation programs, work experiences, and the certification route taken by the educator (Rice, 2003). The researchers recommend further study into the different factors that contribute to the development of ideal TE teaching competencies.

References

Aaronson, D., Barrow, L., & Sander, W. (2007). Teachers and student achievement in the Chicago Public High Schools. *Journal of Labor Economics, 25*(1), 95-135.

Autio, O. (2011). The development of technological competence from adolescence to adulthood. *Journal of Technology Education, 22*(2), 71-89.

Cannon, J. G., Kitchel, A., Duncan, D. W., & Arnett, S. E. (2011). Professional development needs of Idaho technology teachers: Teaching and learning. *Journal of Career and Technical Education, 26*(1). Retrieved from http://scholar.lib.vt.edu/ejournals/JCTE/v26n1/cannon.html

Council of Chief State School Officers. (2013, April). *InTASC: Model core teaching standards and learning progressions for teachers 1.0.* Washington, DC: Author.

Council of Chief State School Officers. (2011, April). *Interstate teacher assessment and support consortium (InTASC) model core teaching standards: A resource for state dialogue*. Washington, DC: Author.

Custer, R. L., Valesey, B. G., & Burke, B. N. (2001). An assessment model for a design approach to technological problem solving. *Journal of Technology Education, 12*(2), 5-20.

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

Gonzalez, H. B., & Kuenzi, J. J. (2012, August 1). *Science, technology, engineering, and mathematics (STEM) education: A primer.* Congressional Research Service (Report No. 7-5700, R42642). Retrieved from http://fas.org/sgp/crs/misc/R42642.pdf

Groccia, J. E., & Buskist, W. (2012). The need for evidence-based teaching. In W Buskist & J. E. Groccia (Eds.). *Evidence-based teaching. New directions in teaching and learning*, no. 128 (pp. 5-11). San Francisco, CA: Jossey-Bass.

Grossman, P., Cohen, J., Ronfeldt, M., & Brown, L. (2014). The test matters: The relationship between classroom observation scores and teacher value added on multiple types of assessment. *Educational Researcher, 43*(6), 293-303.

Hacker, M., de Vries, M. J., & Rossouw, A. (2009). *CCETE project: Concepts and contexts in engineering and technology educatio*n. Hofstra University and Delft University of Technology. Retrieved from http://www.hofstra.edu/pdf/academics/colleges/seas/ctl/ctl_finalreport_ccete_nov_6.pdf

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

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

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

Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. National Academy of Engineering and National Research Council. Washington, DC: The National Academies Press.

Kelley, T. R., & Wicklein, R. C. (2009). Examination of assessment practices for engineering design projects in secondary technology education. *Journal of Industrial Teacher Education*, *46*(2), 6-25.

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

Miller, C. D. (1991). Programs to prepare teachers of technology education. *The Journal of Epsilon Pi Tau, 17*(1), 59-70.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

National Assessment of Educational Progress. (2014). *Technology & engineering literacy assessment*. Retrieved from http://nces.ed.gov/nationsreportcard/tel/

Office of Educational Innovation and Evaluation, Kansas State University. (2008). *Exemplary teacher characteristics: National survey results and alignment with the DeBruyn Institute for Teaching Excellence® core beliefs*. Retrieved from Netsuite.com

Presidents' Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future*. Executive Office of the President of the

United States. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf

Rice, J. K. (2003). *Teacher quality: Understanding the effectiveness of teacher attributes*. Washington, DC: Economic Policy Institute.

Ritz, J. M. (2009). A new generation of goals for technology education. *Journal of Technology Education, 20*(20), 50-64.

Ritz, J., & Martin, G. (2013). Perceptions of new doctoral graduates on the future of the profession. *Journal of Technology Studies, 39*(2).

Roberts, T. G., & Dyer, J. E. (2004). Characteristics of effective agriculture teachers. *Journal of Agricultural Education, 45*(4), 82-95.

Rychly, L., & Graves, E. (2012) Teacher characteristics for culturally responsive pedagogy. *Multicultural Perspectives,14*(1), 44-49.

Sass, H. B. (2011). Advancing a new image of CTE via high-quality teacher preparation. *Techniques: Connecting Education and Careers, 86*(4), 24-27.

Scott, D. G., Washer, B., & Wright, M. (2006). A Delphi study to identify recommended biotechnology competencies for first-year/initially certified technology education teachers. *Journal of Technology Education, 17*(2), 44-56.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-23.

Stitt-Gohdes, W. W., & Crews, T. B. (2004). The Delphi technique: A research strategy for career and technical education. *Journal of Career and Technical Education, 20*(2), 55-67.

U.S. Department of Education, Office of Postsecondary Education, Office of Policy Planning and Innovation. (2002). *Meeting the highly qualified teachers challenge: The secretary's annual report on teacher quality.* Washington, DC. Retrieved from https://www2.ed.gov/about/reports/annual/teachprep/2002title-ii-report.pdf

Virginia Board of Education. Advisory Board on Teacher Education and Licensure. (2013, June 27). *Licensure regulations for school personnel*. Virginia: Virginia Board of Education. Retrieved from http://www.doe.virginia.gov/boe/meetings/2013/06_jun/agenda_items/item_i.pdf

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.

Zuga, K. (1991). Technology teacher education curriculum courses. *Journal of Technology Education, 2*(2).