Contents

From the Editors

Many Thanks

This issue of the *Journal of Technology Education* (*JTE*) occurs as the editorship transitions from Chris Merrill to us, Mary Annette Rose and Jim Flowers. We have agreed to serve as coeditors for three years. This issue of *JTE* contains articles from both editorships.

Our heartfelt gratitude is offered to Chris Merrill on behalf of the entire technology and engineering profession and others who have gained from *JTE* over the past decade. Chris had agreed to serve as editor for five years, though he ended up serving for 10. In truth, he is still serving *JTE*, both in assisting us during the transition and in facilitating the printing of *JTE* at Illinois State University.

We also offer thanks to the members of the *JTE* Review Board, and welcome Sharon Brusic as its newest member. These dedicated professionals, and several others who are not members of the review board, carefully review manuscripts, both judging their acceptability and making insightful recommendations that help authors improve their work.

Thanks are also due to the authors who have submitted manuscripts to *JTE* over the years. The quality of this journal hinges on the decisions of good researchers and writers to submit manuscripts to *JTE*. We would like to remind potential authors that while *JTE* focuses on research articles, it also publishes book reviews, editorials, guest articles, comprehensive literature reviews, and reactions to previously published articles.

Changes

With the change in editorship, there are a few changes to the management process of *JTE*. Please direct all future correspondence to the editors at **jte@iteea.org**.

Open-access is not changing. *JTE* began at Virginia Tech, where its founding editor, Mark Sanders, was the foremost champion in establishing *JTE* as an open-access journal that did not charge either online readers or authors. With Jim LaPorte as the associate editor, they did not just establish a journal, but in doing so, elevated the field. After the editorship transitioned from Mark to Jim LaPorte, and then to Chris Merrill and to us, Virginia Tech still remains the online repository for *JTE*.

Based on a recommendation from the *JTE* Review Board and approval by the *JTE* Management Board, we have signed a memorandum of understanding with Virginia Tech Publishing formalizing Virginia Tech as the online repository for *JTE* articles. In addition, we will soon begin to use their online manuscript management system through Ubiquity Press to facilitate the submission and review of manuscripts and the preparation of the online versions of articles.

While *JTE* is financially supported by the Council on Technology and Engineering Teacher Education and the International Technology and Engineering Education Association, there is no charge for the use of this journal management system or article hosting. Over the past four months, we have worked with Robert Browder from Virginia Tech Publishing and Aaron McCollough from Ubiquity Press to prepare materials needed for online submission and review of manuscripts. Ubiquity Press offers several services to streamline the review process, allowing both authors and editors to track the review and editorial process while expanding analytics.

During this transitional period, manuscripts should be submitted as email attachments sent to *JTE* Editors at jte@iteea.org.

When we start using Ubiquity Publishing's manuscript management, authors will submit manuscripts through a website (to be listed in the next issue of *JTE*). An editor will evaluate the appropriateness of the manuscript to the scope, standards, and submission guidelines of *JTE*. Those manuscripts slated for peer review will then be stripped of information that identifies authorship and checked for plagiarism. Next, three or more peer reviewers will be assigned, and they will access the manuscript and upload their decisions and comments using a secure system that ensures blind review and confidentiality. An editor will then synthesize reviewers' comments, and authors should receive results in a timely fashion, getting information on where their manuscript is in the system. To facilitate the organization of information provided to authors from reviewers, we have already begun using document line numbers so that authors can see the list of reviewers' comments and suggestions organized by line number rather than by reviewer.

In This Issue

This issue contains articles on a variety of topics. Andrew Hughes and Eddie Partida look at the function of professional development to improve the metacognitive awareness of preservice STEM teachers. Given the traditional emphasis on cognitive outcomes, it is worth asking ourselves if we have ever deliberately attempted to influence students' metacognitive awareness and the effectiveness of those attempts.

Noemi Mendoza-Diaz, Bin Mai, Jessica Martinez, Sami Jabarkhail, and Deyanira Garcia compare online to face-to-face, and technical to nontechnical classes. The COVID-19 pandemic occurred after this study took place, but it certainly raises questions regarding students who found themselves in a course format they had not selected. Do teachers need to change their understanding of such students' expectations?

Johnny Moye, Philip Reed, Ray Wu-Rorrer, and Douglas Lecorchick continue a long-standing tradition of identifying key issues and trends as perceived by Technology and Engineering Education (TEE) stakeholders. Among the issues classified as "student-centered foci" were equity and inclusion. These have been long-standing problems of TEE; neither TEE enrollment nor the ranks of TEE teachers have been diverse regarding gender and ethnicity.

As our awareness of the divide created by inequities and barriers increases, we should conduct a critical assessment of our own habits, the curriculum, our school's practices, and our field. We should identify the biases and barriers that differentiate and divide. These make TEE less welcoming to many, often resulting in the exclusion of a more diverse pool of talented teacher candidates, university faculty, and secondary school students. As TEE becomes more welcoming, we will surely benefit from the diversity of ideas and energy this would bring.

The research and theoretical literature in TEE are sorely in need of systematic analyses of diversity challenges in our profession and potential strategies to overcome these challenges. The *JTE* editors welcome research manuscripts, comprehensive literature reviews, and scholarly position papers that examine issues of diversity, equity, and inclusion as they relate to TEE curriculum, instruction, and learning experiences.

Derek Sherman, Tejasvi Parupudi, Nathan Mentzer, Amelia Chesley, Dawn Laux, and Sweta Baniya suggest that an integrated approach to the development of students' communication skills can be effective in postsecondary STEM classes. This is an argument for curricular integration which emphasizes the importance of coplanning and coteaching with peers from different disciplines. This illustrates how the development of coherent, integrated curriculum requires multiple months and a high degree of collaboration.

A Vehicle for Dialog

With *JTE* having just two issues per year, it may seem cumbersome to attempt to use it as a vehicle for dialog, debate, and positive cognitive dissonance. However, we are asking you to do just that. It is your critical and creative insight that helps all of us move forward in many directions. If you have an insightful position paper that challenges the reader's thinking, submit it to *JTE*. This would also help document the evolution of the debates within our field, adding value for emerging leaders and researchers.

Mary Annette Rose & Jim Flowers

Promoting Preservice STEM Education Teachers' Metacognitive Awareness: Professional Development Designed to Improve Teacher Metacognitive Awareness

Andrew John Hughes & Eddie Partida

Abstract

This quantitative portion of a convergent complementarity, mixed-methods, exploratory study describes the design and implementation of a 5-week preservice teacher professional development (PD) experience and the associated Metacognitive Awareness Inventory (MAI) measures before and after the experience. The PD experience was designed to explicitly address participants' domain-general and domain-specific knowledge and regulation of cognition through a highly integrated academic and clinical preparation regimen centered on a cognitive coaching model. The study participants comprised preservice STEM education teachers ($N = 11$) enrolled in a dual teaching certification and Master's in Education program. The findings showed an increase in participants' regulation of cognition based on all utilized factor structures of metacognitive awareness, but not all factor structures indicated a change in participants' knowledge of cognition over the study period.

Keywords*:* metacognition, metacognitive awareness, professional development, preservice STEM education teachers, teacher preparation

Improving science, technology, engineering, and mathematics (STEM) education is a national priority (Parker et al., 2016). In recent years, STEM education in the United States has begun a transformation in response to concerns about there being a lack of needed focus on college and career readiness (Budget Act, 2013; National Research Council [NRC], 2012; NGSS Lead States, 2013). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Framework; NRC, 2012) put forth a vision for how science (and, arguably, engineering) education should be transformed. The Framework has since been operationalized through the development of the *Next Generation Science Standards* (NGSS). Despite the NGSS's focus on promoting inquiry-based teaching in science classrooms, preparing preservice STEM education teachers to deliver such ambitious

Hughes, A. J., & Partida, E. (2020). Promoting preservice STEM education teachers' metacognitive awareness: Professional development designed to improve teacher metacognitive awareness. *Journal of Technology Education, 32*(1), 5-20. https://doi.org/10.21061/jte.v32i1.a.1

instruction remains a major challenge for teacher preparation programs (Osborne, 2014; S. Wilson et al., 2015; S. M. Wilson, 2013).

There is a wide consensus that successful implementation of the Framework and the NGSS requires K–12 STEM educators to allow students to practice and apply the range of skills that scientists and engineers use when engaged in inquiry and problem solving (Kaderavek et al., 2015; NRC, 2012; Pratt, 2007). Yet, Osborne (2014) suggested that:

> the goals of engaging in inquiry have been conflated with the goals of laboratory work such that, in the eyes of many teachers, the primary goal of engaging in inquiry is not to develop a deeper understanding of the whole process of inquiry but to provide a means of supporting their rhetorical task of persuading their students of the validity of the account of nature that they offer. (p. 178)

An inquiry and problem-solving approach will require a broad-spectrum change in K–12 STEM education, which necessitates that students and teachers develop a plethora of skills and abilities, including those under the metacognitive umbrella (Schraw et al., 2006; White et al., 2009). These metacognitive skills and abilities include knowledge of how (declarative), knowing that (procedural), and knowing why (conditional) as well as regulatory skills like asking questions, defining problems, planning, modeling, analyzing, interpreting, evaluating, and others (Osborne, 2014). Inquiry-based approaches to STEM teaching are inherently complex; therefore, teachers must have a sophisticated and coherent metacognitive skillset that often takes years to develop if they develop at all (Osborne, 2014; White et al., 2009). Preservice teacher preparation and in-service teacher professional development (PD) programs often do not focus on metacognition despite the evidence stating the importance of metacognition to both teaching and learning (Duffy, 2006). Teacher metacognitive awareness has become understood as a requirement given the complexity of teaching and learning inherent in inquiry-based STEM classrooms (Hughes, 2017; Osborne, 2014).

The power of the mind to think about and regulate one's own cognition is the key to both learning and teaching others (Pintrich, 2002; Saavedra & Opfer, 2012). "High achieving students have been found to possess more metacognitive awareness and engage in more self-regulatory behavior than low achieving students" (Hartman, 2001a, p. 33). Georghiades (2004) and Gourgey (1998) argued that learning involving the application of metacognitive skills promotes deeper thinking, enhanced learning, and the ability to transfer learning into varying contexts. Metacognitive skills represent the synergy between knowledge and regulation of cognitive processes. Furthermore, metacognitive skills contribute to learning performance over and above intellectual ability (Schraw, 1998; Veenman et al., 2006). As suggested by Sternberg (1998), anyone still questioning "the importance of metacognition to student success need only" review the literature (p. 127). Georghiades (2004) indicated, using John Flavell's reasoning, that it was not a question of a student's ability to be metacognitive but rather a question of how a student was taught to be metacognitive.

Teachers play an important role in helping students develop metacognitive awareness (MA). The teachers' level of MA is a determining factor in their ability to promote students' MA (Kramarski & Michalsky, 2009; Prytula, 2012; Pucheu, 2008). It can be inferred from the metacognitive literature (e.g., Georghiades, 2004; Gourgey, 1998; Hartman, 2001c) that teachers improve their teaching practices and student learning when they evaluate the interaction between student metacognitive functioning and other student attributes. Effective teaching entails: the knowledge of cognition necessary to create and sustain the type of environment that will improve student learning; the knowledge and selection of appropriate strategies, skills, and abilities based on varying situations; the knowledge of how, when, and why to adjust the difficulty of a given task based on each student's level of understanding; the knowledge to select and implement effective learning strategies; and the teacher's ability to use their knowledge of cognition to benefit students (Bransford et al., 2000; Hartman, 2001b; Lin et al., 2005; Schraw, 1998; N. S. Wilson & Bai, 2010).

Additionally, effective teaching involves the regulation of cognition when teachers: plan, set goals, and allocate resources for instruction; organize the learning structure to promote cognitive restructuring based on the elaboration and summarization processes that ideally happen when students combine old and new information; monitor their own and their students' cognitive processes and strategy effectiveness; debug what did not work; and evaluate the effectiveness of their teaching practices and overall performance (Hartman, 2001b; Kramarski & Michalsky, 2009; Lin et al., 2005). All of these identified skills needed for effective teaching are processes within a metacognitive framework.

Professional Development

The position that metacognitively aware teachers will have improved learning capability, teacher practices, and their ability to help students develop their MA has prompted interest in teacher preparation and PD programs specifically designed to enhance MA (Hughes, 2017; Prytula, 2012). To make the indicated teaching and learning improvements, these programs will need to focus on teaching with and for metacognition (Hartman, 2001c). Schools have started to add aspects of metacognition into teacher preparation and PD. Despite PD including some aspects of metacognition, recognized as metacognitive experiences, these aspects are often more of an add-on rather than a specific focus (Hughes, 2015).

Exacerbating the problem of PD lacking a focus on MA is the indication that lower levels of MA are a reason that teachers are often apathetic about PD and are unable to transfer content from PD into effective classroom practices (Bransford et al., 2000; Hughes, 2017; Pucheu, 2008). Hughes (2017) indicated that teachers need MA or the PD needs to develop MA to help ensure active participation and completion of PD programs. Pucheu (2008) indicated that teachers require metacognitive capabilities to transfer material from PD training into effective classroom practices. Teachers' perspectives toward PD and their ability to transfer learning from PD training may be addressed by designing PD with a specific encompassing focus on improving levels of MA (Hughes, 2017).

PD is accepted to be vital for improving teacher effectiveness only when it is strategically planned based on the suggested characteristics of effective PD. "The term *professional development* (PD) refers to teachers' improvement or growth of skills and knowledge, primarily with the aim of improving student achievement (Guskey, 2003; Loucks-Horsley, Hewson, Love, & Stiles, 1998)" (Hughes, 2017, p. 26). Suggested characteristics of effective PD include: strategic planning; challenging goals; adequate, flexible, and structured time; self-reflection; evaluation; feedback; collaboration; follow-up; continued support; and operational objectives leading towards long-term goals for improved student achievement (Hughes, 2015). Guskey (1991) identified that the process for instilling change in teachers made designing PD particularly complicated. Due to the complicated nature of designing PD and the overall complexity of the educational environment, it is difficult to identify precise elements that make PD effective (Guskey, 2003). However, the literature does describe characteristics that warrant consideration during the planning stages of PD programming. Mundry (2007) stressed that even without a consensus on characteristics of effective PD, there is adequate knowledge about learning to "guide the design and implementation" of PD programs (p. 1).

Characteristics of Effective Professional Development Practice

The abundance of questions relating to the incorporation of certain characteristics deemed essential for effective PD can become onerous. Characteristics like adequate time for critical reflection, follow-up, knowledge-building, collaboration, and coaching from expert teachers can be challenging to implement but have had positive outcomes for science teachers (Mundry, 2007). The PD literature has increasingly identified various forms of coaching as an effective means to improve teaching practices. With the current educational climate of accountability and a recognized need to improve the teaching and learning of STEM, coaching was deemed an essential design attribute of the PD regimen.

Cognitive apprenticeship is a constructivist approach to coaching characterized by scaffolding assistance provided to a new teacher by a more experienced teacher with the aim of making tacit cognitive and metacognitive knowledge and processes explicit (Dennen & Burner, 2008). Costa and

Garmston (2002) expounded on coaching strategies in educational settings by defining "cognitive coaching" as a cyclical process designed to improve a teacher's instructional effectiveness by becoming more reflective about their teaching. Cognitive coaching has positive effects on teacher PD when implemented in collaborative settings characterized by high levels of interpersonal and organizational trust (Garmston et al., 1993; McLymont & da Costa, 1998). Other positives include improvements in reflective practice, increased MA, and knowledge about and implementation of targeted instructional strategies (Batt, 2010; Bjerken, 2013).

Developing Metacognitive Awareness

The literature on metacognition addresses developing domain-general versus domain-specific MA. Schraw (1998) expressed "that cognitive skills tend to be encapsulated within domains or subject areas, whereas metacognitive skills span multiple domains" (p. 116). Although Schraw (1998) presented evidence to support his claim, Hartman (2001b) argued that cognitive and metacognitive skills are quite intertwined for students and teachers related to teaching and learning science. Schraw (1998) and Hartman (2001b) agreed on the relationship between metacognition and cognition only in the early stages of one's MA development.

The literature on MA also suggests the need to consider the complex, diverse, and malleable notions of metacognition (Hughes, 2019). That is to say, the MA literature defines a variety of constructs and noninclusive processes that underlie metacognition. These constructs are generally grouped into two broad categories: knowledge and regulation (or control) of cognition. If the goal is for a teacher to teach with and for metacognition, they will need to have: (1) an understanding of the importance of metacognition, (2) an awareness of their own and their students' metacognitive processes, (3) techniques to improve their own and their students' knowledge of cognition, (4) regulation of cognition, (5) an ability to foster an environment that promotes metacognitive development, and (6) the ability to implement domain-general (transferrable) and domain-specific MA development practices (Hartman, 2001b; Schraw, 1998).

There continues to be more discussion related to teachers' development of MA, mostly due to the evidence that a student's MA is related to their teachers' MA (Wilson & Conyers, 2016; Wilson & Bai, 2010). However, this discussion has been put to little action in preservice teacher preparation programs or in-service teacher PD (Duffy, 2006). Duffy (2006) indicated that teacher training tends to ignore the complexities of teaching; "Instead, the talk is about 'teacher *training*,' which carries the implication that teaching is a mechanical matter of implementing technical acts in a predetermined manner" (p. 299).

Methodology

The aim of this research study was to understand preservice STEM education teachers' development of MA through the context of PD specifically designed to improve MA. In this article, only the quantitative data analysis is presented. In subsequent publications, the results of qualitative data analysis, including observations, interviews, performance evaluations, focus-groups, and think-alouds, will be presented.

Professional Development Program

The 5-week PD was designed between late fall 2016 and summer 2017. The focus of the PD was improving teachers' ability to teach with and for metacognition. Metacognition was addressed during the PD in both domain-general and STEM-domain-specific knowledge and regulation of cognition. The PD was also designed around many of the suggested characteristics of effective PD, including explicitly communicating and implementing a strategic plan, positive expectations, and coaching and collaboration, which led to follow-up and continued support (Hughes, 2015). The PD had appropriately structured time that provided additional flexible time for the further development of metacognitive skills and inquiry-oriented teacher practices. There were two components to the PD: clinical and academic. The total combined time between the clinical and academic components was 160 hours—120 hours and 40 hours, respectfully.

The PD involved university professors, instructors, mentor teachers, and preservice STEM education teachers. For the clinical experience, university professors designed the curricular themes around which preservice teacher participants developed classroom materials. The two instructors were science and mathematics teachers with an average of 9 years of teaching experience in Grades 6–12 and about 3 years of teaching experience in teacher preparation programs. There were six mentor teachers with an average of 5 years of teaching experience in middle and high school science and mathematics. Together, the instructors and mentors worked collaboratively with the preservice teachers to develop their metacognitive skills and practices as well as inquiry-oriented STEM education teaching practices.

The PD approached and expressed teaching as a complex process that, when well-planned, still required fluidity with on-the-spot debugging and adjustment based on varying situations. The PD had closely linked clinical and academic experiences asking participants to operationalize learning into teaching practices. Furthermore, coaching was utilized as a part of the PD to increase participants' translation of carefully designed PD experiences into deeper knowledge as well as connecting this knowledge with effective classroom practices and metacognitive development (Kinnucan-Welsch, 2006).

Prior to the start of the PD, instructors and mentor teachers were extensively trained in: (a) coaching and, more specifically, cognitive coaching of preservice teachers, (b) MA, (c) teaching with and for metacognition, and (d) teaching metacognitively both generally and in the STEM domains. The cognitive coaching training included the use of a lesson plan facilitation guide, a formal teaching observation protocol, and a postlesson discussion guide. The MA training included defining related terms, learning the importance of MA, learning strategies to develop knowledge and regulation of cognition, creating environments that promote MA, the explicit modeling of thinking with both actions and verbally, and STEM-specific metacognitive strategies.

The clinical component of the PD involved participants teaching STEM enrichment classes to students in Grades 6–9 while under the tutelage of the instructors and university-selected, trained mentor teachers. The academic component involved study participants and mentor teachers attending biweekly methods-teaching seminars that were led by instructors. Both the clinical and academic components were specifically designed to help preservice teachers engage in cycles of planning, teaching, assessment, and reflection with emphasis placed on developing MA at each stage. Based on the already developed curriculum themes, preservice teachers were expected to develop and deliver daily lessons, assessments, and overall classroom experiences for students under the careful guidance and support of the mentors and instructors who continuously worked towards the strategic plan and goals by maintaining alignment between the clinical and academic components of the 5-week PD.

Participants in the Professional Development Program

The participants in this study were California preservice STEM education teachers working to obtain their preliminary mathematics or science teaching credential. All participants were expected to receive their preliminary, single-subject credential shortly after completing a 15-month Teacher Education Credential and Master of Arts in Education graduate program. The 5-week long PD program signified the first 2 months of the 15-month program. Shortly after completing the PD program, participants began teaching as either an intern or resident. Teachers with internships were hired by the school district and were considered the teacher of record for the courses taught. Teachers with residencies worked under the tutelage of a supervising teacher for an entire academic school year.

Measuring Metacognitive Awareness

For this study, the Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994) was used to collect pre- and post-treatment quantitative data on the participants' level of MA before and after the 5-week PD. The data was used to compare the participants' pre- and post-PD levels of MA in eight factor structures (Table 1). The MAI is a self-reported questionnaire with 52 items and, in this case, a fully labeled Likert-type scale. Metacognitive awareness consists of two main components, knowledge of cognition (KOC) and regulation of cognition (ROC). However, the MAI has had various composite structures based on multiple approaches to aggregating data, and this information is not always presented clearly (Harrison & Vallin, 2018). MAI data has been aggregated into a single omnibus structure referred to as MA, various two-composite structures (usually either knowledge and regulation of cognition or Schraw and Dennison's (1994) exploratory two-factor structures), and eight-composite structures based on the subcomponents presented by Schraw and Dennison (1994).

Table 1

Factor Structures of Items on the Metacognitive Awareness Inventory

Meta-cognitive Awareness	Knowledge of Cognition	Regulation of Cognition	EFA Factor 1	EFA Factor 2	Uni-dimensional MRCML model	KOC MRCML model	ROC MRCML model
All 52	3, 5, 10, 12, 14, 15, 16, 17, 18, 20, 26, 27, 29, 32, 33, 35, 46	1, 2, 4, 6, 7, 8, 9, 11, 13, 19, 21, 22, 23, 24, 25, 28, 30, 31, 34, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 48, 49, 50, 51, 52	3, 5, 7, 9, 10, 12, 13, 15, 16, 17, 18, 20, 25, 26, 29, 30, 31, 32, 33, 39, 42, 45, 46, 51, 52	1, 2, 4, 6, 8, 11, 14, 19, 21, 22, 23, 24, 27, 28, 34, 35, 36, 37, 38, 40, 41, 43, 44, 47, 48, 49, 50	6, 8, 10, 16, 20, 21, 24, 26, 27, 32, 33, 35, 39, 40, 41, 43, 44, 50, 51	10, 16, 20, 26, 27, 32, 33, 35	6, 8, 21, 24, 39, 40, 41, 43, 44, 50, 51

Note. EFA = exploratory factor analysis; MRCML = multidimensional random coefficients multinomial logit; KOC = knowledge of cognition; and ROC = regulation of cognition.

Each of these various structures has combined the 52 items from the MAI in different ways, sometimes based on exploratory factor analysis (EFA). Schraw and Dennison (1994) used EFA to produce two-factor structures with

25 items moderately aligned with knowledge (Factor 1) and regulation (Factor 2) dimensions. Although more appropriate factor analysis exists (e.g., item-response theory [IRT] and confirmatory factor analysis [CFA]), researchers have continued to use EFA to examine the MAI's internal structure. Harrison and Vallin (2018) used the multidimensional random coefficients multinomial logit (MRCML) model to analyze the MAI while simultaneously using a CFA model. The use of MRCML and CFA identified items from the MAI that did not fit with the KOC and ROC dimensions, and those items were removed. The MRCML model's final reliability was .78 for knowledge and .82 for regulation dimensions (Harrison & Vallin, 2018).

Procedures

The study began with Institutional Review Board (IRB) approval on June 6, 2017. In compliance with the IRB Human Subjects Committee guidelines, this study was conducted under the supervision and approval of the California State University of San Bernardino. The risks to subjects participating in the study were minimal and reasonable in relation to expected benefits. The PD program had a total of 11 preservice teachers, nine females and two males. After participants made an informed decision to participate, each was assigned a unique identifying number that was used to encrypt their pre- and post-PD MAI data. The participants were sent an email with a Qualtrics link to the MAI. The MAIs were completed and returned by participants both before starting and after finishing the PD experience.

Data Analysis

The analysis of the data began with entering of participants' self-reported values on the MAI into Statistical Package for the Social Sciences (SPSS). After entering the data, the assumptions of the Wilcoxon Sign Ranked Sum Test were checked and verified. The assumptions of dependent samples, random and independent data pairs, and ordinal-level measurement were easily verified. The assumption of homogeneity of variance required the use of the nonparametric Levene's test, which tested the null hypothesis that the variances were equal for each factor structure (see Table 2). The results indicated that the homogeneity assumption was valid for the MA data collected with the MAI.

Then, each participant's level of MA was determined by the mean of their responses to the items from each factor structure from the MAI (see Table 1). For example, each participant's awareness of their knowledge of cognition is the mean value calculated based on the participant's answers to the 17 items that correspond with the knowledge of cognition component. As indicated in Table 3, the pre- and post-PD means of each participant's responses for each factor structure were compared using the nonparametric dependent samples Wilcoxon Sign Ranked Sum Test.

Table 2
Nonparametric Levene's Test for Equality of Variances for Factor Structure of Data from the Metacognitive Awareness Inventory

Factor Structure	*F*-Statistic	*p*-value
Metacognitive Awareness	.011	.919
Regulation of Cognition	.007	.933
Knowledge of Cognition	.015	.904
EFA Factor 1	.026	.873
EFA Factor 2	.024	.878
Uni-dimension MRCML model	.011	.919
KOC MRCML model	.002	.961
ROC MRCML model	.021	.885

Note. EFA = exploratory factor analysis; MRCML = multidimensional random coefficients multinomial logit; KOC = knowledge of cognition; and ROC = regulation of cognition.

Table 3
Comparison of Pre- and Post-Test Data Using Wilcoxon Sign Ranked Sum Test (N = 11)

	Mean		Std. Dev.		Min.		Max.			Asymp. Sig.
Factor Structure	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Z-stat.	(two-tailed)
Meta-cognitive Awareness	3.906	4.192	0.270	0.236	3.48	3.77	4.48	4.56	-2.936	0.003
KOC	4.107	4.380	0.281	0.246	3.76	4.06	4.76	4.71	-2.404	0.016
ROC	3.808	4.101	0.315	0.265	3.34	3.54	4.34	4.49	-2.937	0.003
EFA Factor 1	4.175	4.415	0.294	0.185	3.68	4.04	4.68	4.60	-2.671	0.008
EFA Factor 2	3.632	4.062	0.490	0.379	2.63	3.11	4.32	4.53	-2.938	0.003
Uni-dimension MRCML model	3.842	4.091	0.348	0.275	3.37	3.53	4.58	4.42	-2.655	0.008
KOC MRCML model	3.955	4.091	0.346	0.322	3.50	3.50	4.63	4.50	-1.079	0.281
ROC MRCML model	3.755	4.109	0.528	0.327	2.60	3.30	4.50	4.40	-2.586	0.010

Note. EFA = exploratory factor analysis; MRCML = multidimensional random coefficients multinomial logit; KOC = knowledge of cognition; and ROC = regulation of cognition.

Results

The Wilcoxon Sign Ranked Sum Test was used to compare the participants' pre- and post-PD measurements on eight different factor structures. In Table 3, the asymptotic significance column illustrates that seven of the eight-factor structures were statistically significant at an alpha level of .05. The only factor structure that was not significant at an alpha of .05 was the knowledge of cognition MRCML model with a *p*-value of .281.

Discussion

The first finding from this study was expected: The results indicated that the preservice STEM education teacher participants increased their MA during the PD program. Hughes (2017) indicated that not only should the PD focus on MA, but the PD should focus on both MA development and utilizing characteristics of effective PD recommended from the literature. It is also suggested that higher levels of MA help participants translate academic experiences into clinical practices (Hughes, 2017; Pucheu, 2008). Relating students' learning needs to the teacher's ability to address those needs was also used to further invoke active participation. Although the PD experience was not designed to be self-regulated, as in Hughes (2017), it is similarly believed that MA development positively impacted participants' self-regulation and successful completion of the PD.

The second finding from this study is that the only MA factor structure from Table 3 without statistical significance was the knowledge of cognition MRCML model with a *p*-value .281. This suggests that the participants' reported knowledge of cognition on this factor structure was similar on both the pre- and post-PD measurement. While reflecting after an academic session, the university faculty, instructors, and mentor teachers noted participants' lack of knowledge related to cognitive strategies, skills, and abilities (declarative knowledge); use of strategies and techniques to improve learning (procedural knowledge); and when and why to use strategies (conditional knowledge). This anecdotal perceived lack in pedagogical content knowledge (PCK) and knowledge of cognition was represented in the quantitative data. Although knowledge of cognition and PCK was being covered throughout the PD, through reflection, it was determined that most of the time in the PD was focused on the regulation of cognition (planning, monitoring, organizing, information management, debugging, and evaluating). There were thorough discussions between the mentoring teachers, instructors, and faculty about the expected level of PCK and knowledge of cognition that a preservice teacher should possess. There was agreement that more time needed to be spent explicitly covering PCK and knowledge of cognition to ensure each preservice teacher participant's future success.

Conclusions

The intent of this study was to assess the potential of a specific PD program to influence teachers' self-reported MA. Prior to collecting data, it was believed that the PD would lead to higher levels of MA. Based on the MAI data presented in this article, that would appear to be the case. Although this study does not portend to make causal claims about whether the change in participant's MA can be attributed to any particular design feature of the PD experience, this study offers a promising line of research currently absent in the literature on teacher PD in general and STEM education teacher preparation in particular. Future studies employing experimental or quasi-experimental approaches are needed to make such claims. Intuitively, it makes sense that MA would mediate the effect of a PD program on effectiveness, especially given the expansive role that MA plays in complex learning. Pursuing this line of inquiry would be a positive step towards linking PD to MA, content knowledge, and PCK development and, ultimately, laying a path forward for how to improve STEM education teacher effectiveness.

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About the Authors

Andrew J. Hughes (andrew.hughes@csusb.edu) is Assistant Professor in the Career and Technical Education Program at California State University San Bernardino.

Eddie Partida (eddie.partida@cgu.edu) is Interim Director of the Teacher Education Department and STEM Coordinator in the Teacher Education Program at Claremont Graduate University.

Face-to-Face and Online Classes in a Technology Management Program: A Comparative Study

Noemi Mendoza-Diaz, Bin Mai, Jessica Martinez, Sami Jabarkhail, & Deyanira Garcia

Abstract

This study compared students' expectations, perceptions, and grades in two undergraduate technology management courses at a university in the United States. One course was a technical course taught by a single instructor in an online course section and in a face-to-face section, and the second was a nontechnical course taught by a different instructor in an online and in a face-to-face section. Different concerns were evident between online and face-to-face students and between those in a technical or nontechnical section of a course. For the technical course sections, grades were higher in the online section.

***Keywords**:* online education; student expectations; technology management

The advent of technology in the classroom, paired with the development of the Internet, has marked a new era in the way universities offer undergraduate education. Online instruction has increased exponentially, to the extent that almost all universities offer at least one type of program in the online format. However, technical and engineering programs have delayed the incorporation of online instruction because of the widespread belief that STEM content is not easily taught in formats other than face-to-face (F2F). The most compelling reason is the nature of their curriculum in which laboratory experimentation is central (Bourne et al., 2005). Another challenging fact to note is the higher rates of attrition in STEM fields for the online formats of instruction, around 30% to 40% (Wladis et al., 2015).

Technology management, for obvious reasons, is one type of program that has benefitted from the availability of online instruction. Most of these programs are traditionally taught in colleges of engineering or business. It is in the colleges of business that most management of information systems programs reside; this affords opportunities for alternative modes of instruction available to nontraditional audiences. However, the existing literature lacks sufficient insights into how students perceive these two major modes of course delivery, and few studies have investigated the impacts of delivery modes for technical and nontechnical courses.

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That is the gap this study is attempting to fill. This article presents an exploration of online and face-to-face modes of instruction in a Technology Management undergraduate program for technology-based and non-technology-based content. The program offers flexibility in that the same two classes are offered in both formats every semester to freshman and sophomore students. Also, the program is housed in the college of education, which provides an additional layer of complexity worth investigating.

Literature Review

Ernst (2008) compared traditional and hybrid online groups from the perspective of students' performance (a test) and perceptions (online survey). The course was part of a Technology Education program and focused on imaging technology. He found that both formats, traditional and hybrid online, had similar student learning outcomes. Previously, Ndahi (2006) studied the extent to which laboratory courses were delivered via distance education in technology and engineering programs in the United States and the United Kingdom via a purposive sample. At the time, he found that 48.8% of technology and engineering departments sampled offered distance education courses, and of those, 12.2% were laboratories. It is important to note the difficulty he found in the implementation of hands-on activities in online laboratories because hands-on activities are central to engineering and technology programs, as noted above.

Huang et al. (2015) described the difficulty of providing equivalent experiences between an online mechanical engineering laboratory and an onsite laboratory but found similar learning outcomes in students. Bourne et al. (2005) and Froyd et al. (2012) claimed no significant difference between online and on-campus engineering students, as measured by test scores. More recently, Saleheen et al. (2018) found an actual increase in students' performance when provided with an entry-level electric circuit online laboratory called VOLTA.

On the other hand, Bir (2019) found that online pedagogy had a negative effect on students' academic performance when compared with the traditionally taught group in a course on the mechanics of materials. Wladis et al. (2015) studied students who succeeded in online STEM classrooms and found that older students did significantly better, women did significantly worse, and Black and Hispanic students may do worse in STEM courses than their White and Asian peers in both online and face-to-face formats. Driscoll et al. (2012) talked about the never-ending debate between proponents and detractors of online education, noting the dangers of the "McDonaldization" in this format.

In a meta-analysis comparing distance education and classroom instruction, Bernard et al. (2004) found no differences between formats across multiple disciplines. These findings seem to point to the themes that Downs (2014) identified as prevalent in the assessment of online undergraduate programs: "(a) informal feedback from the students and faculty, (b) student satisfaction surveys,

[and] (c) student grades and performance information" (p. 1). These limiting assessment factors seem to contribute to the widespread idea that it is more the quality of the instruction and its design that really contributes to a successful online education experience rather than the format or medium of delivery. This is reinforced by exemplary cases such as Embry-Riddle Aeronautical University, which provides quality elements of a worldwide engineering program (Herron et al., 2012).

Background and Research Question

Early in the 21st century, the College of Education and Human Development at Texas A&M University launched a visionary Technology Management (TCMG) undergraduate program housed in the Department of Educational Administration and Human Resource Development (EAHR), although technology management programs are usually housed in colleges of technology, engineering, or business. With the rapid expansion of computers in the classroom seen in the 90s, the need to provide support to the new technologies in schools, including students, teachers, and administrators, brought about this program. Given the unique origin and location of this particular program, it integrates a human component into the highly technical degree plan. As its mission states, the program has a commitment "to advancing integrated knowledge of human development, management, and technology competencies within a dynamic and rapidly evolving environment through innovative teaching, research, and service" (Texas A&M University, Department of Educational Administration and Human Resource Development, 2019).

The curriculum consists of general university courses in the first year, while following years are a combination of management, human resource development, and technology classes. Students majoring in technology management obtain a minor in business, provided by the Mays Business School at Texas A&M University, and students from other programs also have the opportunity to obtain a minor in Technology Management. The TCMG program includes six mandatory human resource development classes, starting with EHRD 203: Foundations of HR Development, which is also taken by HRD majors. There are nine technology classes offered by the EAHR department, including TCMG 308: Security and Ethics in the Digital World.

The EHRD 203: Foundation of Human Resource Development class is devoted to facilitating a working knowledge of the field of Human Resource Development (HRD). Among many skills, at the end of the course, students should be able to: (1) describe the field of HRD and provide a historical perspective of its development; (2) describe a model of employee behavior and various motivational theories and discuss how knowledge, skill, ability, and attitude influence employee behavior; (3) discuss organizational learning, adult learning theory, and the role of learning styles and strategies in learning; (4)

elaborate on the purposes and advantages of needs assessments and identify the attributes (all the way through to evaluation) of different kinds of HRD programs; (5) describe organization development and change in relation to models of change and OD theories; and (6) discuss diversity within the context of HRD (Texas A&M University, 2018a).

The TCMG 308: Security and Ethics in the Digital World class is devoted to introducing: cybersecurity, analysis, threats, and risks from the environment; development of appropriate strategies to mitigate impact; ethics of extraordinary administrative access; ethics of digital forensics; and implications to society. Among many skills, at the end of the course, students should be able to:

> (1) apply the different security technology for securing personal and business information systems and resources including Anti-virus, Firewalls, VPNs, IDS, cryptology-based security solution, access control, and others; (2) access and use information ethically and legally during oral and written communication while analyzing and discussing critical issues in information systems security; and (3) gain hands-on experience of some important information security tools. (Texas A&M University, 2018b)

This study sought to understand the way that undergraduate students perceive online instruction in technical (TCMG 308) and nontechnical (EHRD 203) classes compared to their face-to-face counterparts. It also sought to understand how these perceptions relate to actual performance—grade obtained. Both classes, EHRD 203 and TCMG 308, are offered every semester in both formats, face-to-face and online. This study was designed to investigate the following research questions:

1. How do online instruction students' perceptions compare to equivalent face-to-face instruction for technical and nontechnical topics in a technology management program?
2. How does online instruction students' performance compare to equivalent face-to-face instruction for technical and nontechnical topics in a technology management program?

In order to address these questions, during the fall of 2018, two instructors had the opportunity to teach the same class in the two different formats, and data were collected for those classes. The analysis and findings are presented in this article.

Research Methods

This study used a mixed-methods approach with two phases. The first phase involved an online survey given at the beginning and the end of the fall 2018 semester to four student groups: (1) the Foundations of HRD face-to-face group,

(2) the Foundations of HRD online group, (3) the Security and Ethics in the Digital World face-to-face group, and the (4) Security and Ethics in the Digital World online group. The second phase involved a statistical analysis of final grades for the four groups.

In the initial qualitative phase of the study, an online survey was provided to the students in a pre–post fashion. The survey items are shown in Table 1. The respondents of the surveys are shown in Table 2. The survey was voluntary and did not request any demographic information. IRB approval was obtained, and confidentiality was maintained for all participants.

Table 1
Items in the Online Survey Applied to All Groups

Presurvey items	Postsurvey items
1. What do you expect from this class?	1. Were your expectation for this class met? Please elaborate.
2. Do you have concerns about this class? If so, what are they?	2. Do you have concerns about this class? If so, what are they?
3. How do you feel about the format (online or face-to-face) of this class?	3. How do you feel about the format (online) of this class?
4. If you were to take this same class in a different format, what would be your expectations?	4. If you were to take this same class in a different format (face-to-face), what would be your expectations?
5. What grade do you expect to obtain at the end of this semester?	5. What grade do you expect to obtain at the end of this semester?

Table 2
Number of Participants Returning Surveys

	F2F		Online	
	Pre	Post	Pre	Post
Foundations of HRD	39	30	27	6
Security and Ethics in the Digital World	9	5	10	5

The final quantitative phase of the study was an analysis of final grades of the four groups. The focus of the analysis was the performance within the same content (technical and nontechnical) but in a different format (online vs. face-to-face). The descriptive statistics of these groups are shown in Tables 6 and 7 and will be discussed later.

Qualitative Analysis

In order to answer the first research question, a qualitative analysis of students' perceptions was performed. Interpretive naturalistic inquiry (Lincoln & Guba, 1985), in the form of content analysis, was used as the initial method of research. Content analysis, as a form of qualitative analysis, looks at the perceptions of participants and creates categories of common assertions. If more details are provided on each category, subcategories are formed until a point of saturation is reached. This means that participants' prompts are exhaustively analyzed until they do not provide any new or relevant information (Creswell & Poth, 2017; Holsti, 1969; Lincoln & Guba, 1985). Two coders were used for the qualitative analysis. These coders met regularly with the first author of this paper; the interrater reliability for their analysis was 73%, using Holsti's coefficient (Holsti, 1969).

Because the number of participants varied in the groups, the analysis was normalized based on the totality of participants per group, i.e., the percentage of respondents. This provided a statistic by which to compare groups. Categories from this content analysis that were shared by both classes and in both formats are shown in Table 3. Identification of common topics showed that some students in each of the face-to-face courses mentioned taking the course for the purpose of earning credit and for utilization in their future careers in the presurveys. It also showed that concerns, such as workload, were more prevalent in the technical class in both formats (60% face-to-face cybersecurity in the postsurvey, 40% grading in the postsurvey, 30% workload in the presurvey) and in the postsemester online intervention for the HRD (50% on receiving feedback).

One example of postsemester concerns for the online HRD class (when asked about their expectations for the other class format) was: “My expectations would be that the professor would be more interactive and engaged with the class.” Students in both formats seemed to prefer the format they chose for the class; the postsurvey for the face-to-face HRD class was 63% and 100% for the online cybersecurity class. They expected more interaction in the online format of the nontechnical class (66% postsurvey for the online HRD group) but expected to learn more in the technical face-to-face class (40% in the online cybersecurity postsurvey).

Another example of these concerns was mentioned by a participant on the postsurvey for the online cybersecurity class; when asked about their expectations for the face-to-face class (other format), they replied: “I would expect more real-life scenarios and a more in-depth learning outcomes [sic] with the hands-on labs. As well as more feedback and direction and focus on important material.” Grade expectations seemed to be higher for the technical class, regardless of the format, with 88% of face-to-face students and 90% of online students "expecting an A.”

Table 3
Preliminary Analysis of Categories/Themes Shared by Both Classes and Formats

	Foundations of HRD				Security and Ethics			
	Face-to-face		Online		Face-to-face		Online	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Class Expectations								
To get credit	6%	-	4%	-	**11%**	-	-	-
Future career/courses	**20%**	-	4%	-	11%	-	-	-
Concerns								
No concerns	21%	6%	29%	33%	**77%**	-	30%	40%
Understanding material	26%	-	15%	-	11%	**60%**	20%	-
Grading	3%	-	-	-	-	-	-	**40%**
Workload	5%	-	15%	-	-	20%	**30%**	20%
Class style F2F vs online	2%	-	3%	-	-	-	-	**20%**
Receiving feedback	-	3%	3%	**50%**	-	-	20%	-
Instructor	-	-	3%	-	-	-	**10%**	-
Format of the Class								
Prefer F2F	62%	**63%**	29%	-	44%	20%	30%	-
Prefer Online	15%	16%	74%	50%	11%	20%	90%	**100%**
Hybrid	-	3%	3%	-	11%	-	**30%**	-
Waste of time	-	10%	-	-	-	**20%**	-	-
Did not like class format	-	6%	-	17%	-	**20%**	-	-
Different Class Format								
Same expectations	23%	**43%**	11%	-	33%	40%	30%	20%
Expect to learn more	13%	0%	15%	-	-	**40%**	-	20%
More interaction	-	3%	19%	**66%**	-	20%	-	-
Less challenging	-	16%	-	-	-	-	**40%**	-
Less interaction	-	3%	-	-	-	-	**10%**	-
Grade Expected								
Expect an A	71%	87%	37%	66%	88%	80%	**90%**	80%
Expect a B	5%	13%	3%	16%	11%	**20%**	10%	**20%**
Expect A or B	**20%**	-	15%	-	-	-	10%	**20%**

Table 4
Analysis of Exclusive Information for the HRD Nontechnical Class

Theme	Survey Item	F2F Pre	F2F Post	Online Pre	Online Post
To learn how to teach HRD	1	**6%**	-	-	-
To learn how to hire and recruit	1	-	-	**4%**	-
Business aspect of HRD	1	**3%**	-	-	-
Management	1	**6%**	-	-	-
To learn how to train	1	**8%**	-	-	-
To learn to be responsible	1	-	-	**4%**	-
To learn how to interact with people	1	-	-	**4%**	-
Well conveyed information from instructor	1	-	3%	4%	**33%**
No expectations	1	-	**3%**	-	-
Class be easy to navigate	1	**13%**	3%	-	-
Get more instructor feedback	2	-	-	-	**50%**
Being presented to by students	2	21%	**23%**	-	-
Confusion	2	15%	**26%**	11%	-
Working in a group	2	-	-	**3%**	-
Not an engaging environment	3	-	**3%**	-	-
Active learning model	3	-	**3%**	-	-
No preference	3	**21%**	3%	-	-
More in-depth	3	-	-	**22%**	-
Self-paced class	3	**2%**	-	-	-
Enjoy class more	3	**5%**	-	-	-
More detailed instructions	4	5%	-	7%	**33%**
More real-life scenarios	4	-	-	-	**33%**
Traditional format (not active learning)	4	**2%**	-	-	-
Higher expectations	4	-	-	-	**33%**
More resources	4	-	**20%**	7%	-
More in-class time	4	**7%**	-	-	-
More work	4	**5%**	-	-	-
Confusion	4	**5%**	-	-	-
F2F lectures online	4	**10%**	-	-	-

Note. Survey items by number are shown in Table 1.

Analysis for the HRD (nontechnical) class is shown in Table 4. Given that the majority of participants were located in these classes, the categories exclusive to these groups were more varied and populated. In general terms, this table provides more granular information of the results in Table 3. Students' changes in perceptions between pre- and post-survey seemed more relatable to the dissatisfaction about instructor's feedback (50% postsurvey in the online class) as well as the desire for more detailed instructions and more real scenarios (33% on each for the postsurvey in the online class).

Analysis for the cybersecurity technical class is shown in Table 5. The categories shown in this table were specific to the technical class and also provided a more granular analysis. The totality of the respondents for the face-to-face format explicitly stated they expected to learn about cybersecurity at the end of the course (100% postsurvey). The majority of the respondents for the online format felt that the course met their expectations. One example is the following assertion: "Taking this course online, I feared that I wasn't going to be able to learn the material properly, but the hands-on lab and the additional material helped add more understanding than just the textbook" (Postsurvey online cybersecurity student).

Table 5
Analysis of Exclusive Information for the Security and Ethics Technical Class

	Face-to-face		Online	
	Pre	Post	Pre	Post
Expect to learn about cybersecurity	55%	**100%**	70%	-
To learn ethics	22%	-	**40%**	-
To learn cybersecurity vulnerabilities	-	-	**10%**	-
To learn about digital world	**11%**	-	-	-
To understand human factors with confidential information	**11%**	-	-	-
Course met expectations	-	-	-	**80%**
Course did not meet expectation	-	-	-	**40%**

Quantitative Analysis

After the perceptions of students were analyzed, the second part of the analysis focused on answering the second research question relating to performance indicators—the grades for each of the sections. Tables 6 and 7 show the descriptive statistics for the four groups, HRD and Cybersecurity courses in both formats. The nontechnical classes' averages were in the 90s scale, whereas the technical classes' averages were in the 70s and 80s.

Given the differences in variances, Welch's *t*-tests were used to test for differences between the nontechnical classes (Foundations of HRD). At an alpha level of $\alpha = 0.05$, results show that there was no significant difference in terms of performance between the face-to-face and the online formats for the nontechnical class ($t(75) = 1.44$). Similarly, Welch's *t*-tests were used to test for differences between the technical classes (Security and Ethics). Results for the technical class show that students in the online format (*M* = 82.3, *V* = 77.9) compared to those in the face-to-face format (*M* = 75.8, *V* = 95.1) demonstrated significantly higher scores, t (53) = -2.71, *p* = .05.

Table 6
Descriptive Statistics for the Nontechnical Classes (Foundations of HRD)

					95% CI			
	N	*M*	*SD*	*SE*	Lower Bound	Upper Bound	Min	Max
F2F	39	92.59	5.79	.93	90.71	94.47	71.00	100.00
Online	40	90.50	6.90	1.11	88.26	92.74	76.00	100.00
Total	79	91.53	6.48	.73	90.08	92.98	71.00	100.00

Table 7
Descriptive Statistics for the Technical Classes (Security and Ethics)

					95% CI			
	N	*M*	*SD*	*SE*	Lower Bound	Upper Bound	Min	Max
F2F	27	75.77	9.75	1.88	71.90	79.62	55.71	90.00
Online	33	82.08	8.86	1.54	78.93	85.22	61.43	94.29
Total	60	79.24	9.72	1.25	76.73	81.75	55.71	94.29

Discussion

The impacts of delivery modes (i.e., face-to-face and online) on student learning experiences have been extensively studied in the literature. However, the nature of the course content (i.e., technical course contents and nontechnical course contents) as a moderating factor on these impacts has been under-investigated. In this article, we presented our efforts in addressing this significant gap in the current literature.

We selected two courses (one technical and the other nontechnical) that offered both face-to-face and online sections from a major U.S. university and collected data on the student learning experience. The interpretation of results suggests that students generally preferred the format they selected, showing a level of comfort they had prior to the semester intervention; therefore, it could be assumed that students were familiar with their format of choice. For the nontechnical class, Foundations of HRD, students seemed to share the same concerns as those already reported in the literature, such as lack of instructors' feedback or lack of real-world scenarios. Students in both formats of the Foundations of HRD class outperformed students in the technical class. Students in both formats of the Foundations of HRD class were also more vocal than students in the technical class, who tended not to share their post-intervention perceptions. Regardless of the format, students in the technical classes were more concerned about learning, grades, and assignments than students in the nontechnical classes.

The grade performance for students in the online technical class was significantly higher than that of the students in the face-to-face technical class (with a mean 6.31 percentage points higher). This may be explained by the following:

1. Students in the technical online environment are more tech-oriented and, therefore, could be more proficient and resourceful when it comes to technical content, or
2. Students in technical online environments are less time-constrained, not bound by class meeting time, and, therefore, could invest more time.

This result is a new contribution to the existing literature of online vs. face-to-face environments (e.g., Bernard et al., 2004; Sitzmann et al., 2006) in which students' learning attitudes and performance in technical vs. nontechnical courses had not been explicitly studied. Literature in the field of online training is consistent in the way that online classes are perceived as being flexible but with equivalent accountability (Mupinga et al., 2006; Chen et al., 2010). It is somewhat surprising that when it comes to technical content, the expectations of better quality increase. For example, when asked about perceptions about the format other than the one chosen on the postsurvey, one student in the Security and Ethics class replied: "I would want more involvement in terms of lectures. My peers in the online section said that it's just looking at the PowerPoint, and that's it. More involvement for online would be beneficial."

Moving technical and nontechnical content to an online format has repercussions. It could be assumed that students enter the cyber or physical classroom with attitudes and perceptions that do not always hold true when compared to their actual performance. More specifically, speaking about nontechnical content, students were more open to raising concerns, but their actual performance was graded high. It can also be assumed that technical content seems to add concerns for students overall and that those concerns seem to hold true, specifically for those students in the face-to-face format, given the constraints of a traditional classroom for a highly technical class.

Educators can apply these findings by realizing that students who select a particular course type and delivery mode may well carry with them different expectations and attitudes than those who select a different delivery course or a different delivery mode. Since there was an indication of students having been comfortable with their course's mode of delivery, an implication may be that when students are forced to take a course in a non-preferred delivery mode, as has happened often during the COVID-19 pandemic, educators should not expect students to have the same degree of comfort. Educators can also use these results when planning a technical course transition from traditional F2F to an online format. An online format is nontraditional for many courses focused on technical content, yet students in online technical courses may have increased expectations of better quality. With the opportunities that synchronous and asynchronous online education afford, especially in COVID-19 times, educators worldwide should be well versed in educational technologies that facilitate different instructional formats

There were several limitations of this study, including the preexisting differences between groups, the assumed equivalence in the way instructors approached instruction, as well as the instructional design for each class. Further analysis should consider these important aspects of traditional and online instruction. Given the widespread perception that technology management belongs in the social sciences, the location of the program in the College of Education may also add another layer of complexity.

Regardless of these limitations, the authors consider this analysis a contribution to the conversation already occurring regarding technical content in online formats. The literature is indeed scarce about online technical instruction.

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About the Authors

Noemi Mendoza-Diaz (nmendoza@tamu.edu) is an Assistant Professor in the Department of Educational Administration & Human Resource Development at Texas A&M University.

Bin Mai (binmai@tamu.edu) is an Assistant Professor in the Department of Educational Administration & Human Resource Development at Texas A&M University.

Jessica Martinez (jessica.martinez@tamu.edu) is a Doctoral Student in the Department of Educational Administration & Human Resource Development at Texas A&M University.

Sami Jabarkhail (samij@tamu.edu) is a Doctoral Student in the Department of Educational Administration & Human Resource Development at Texas A&M University.

Deyanira Garcia (deyagarcia@tamu.edu) is a Doctoral Student in the Department of Educational Administration & Human Resource Development at Texas A&M University.

Current and Future Trends and Issues Facing Technology and Engineering Education in the United States

Johnny J. Moye, Philip A. Reed, Ray Wu-Rorrer, & Douglas Lecorchick

Abstract

Determining trends and issues is important for the health of any profession. The purpose of this research was to determine the current and future trends and issues facing technology and engineering education (TEE) in the United States (U.S.). The researchers used a three-round Modified-Delphi method to solicit information from technology and engineering education stakeholders across the U.S. In the first round, participants listed what they felt were current trends, future trends, current issues, and future issues facing TEE. The second round was designed to prioritize trends and issues. In the third round, participants were presented with one table for each current and future trend and issue and asked to identify if they felt each was essential or non-essential for technology and engineering leaders to address. Two hundred sixty-eight participants responded in the third round, and the resulting trends and issues were categorized into eight themes: 1) teacher shortage; 2) secondary and university TEE programs; 3) funding programs and teachers; 4) curriculum; 5) technology and engineering education identity and relevance; 6) collaborative efforts; 7) teacher certification and development; and 8) student-centered foci.

Keywords: Technology and engineering education, Delphi technique, trends, strategic planning

Education is continually changing because of research, practice, societal trends, and issues. For example, 64% of the public in the U.S. feel there is too much emphasis on standardized testing, and "less than half of adults (42%) say performance on standardized tests is a highly important indicator of school quality" (*Phi Delta Kappan*, 2017, p. K5). Public opinion may be a factor in shaping the future use of standardized testing. How do such broad societal and educational trends and issues impact TEE? These points, among others, are opportunities for the TEE profession to reassess, then formulate a strategic plan to address such concerns. In this study, TEE stakeholders identified current and future trends and issues specific to TEE in the U.S.

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Literature on Trends and Issues in Technology Education

Research to discern trends and issues in technology education has a well-documented history. Schmitt and Pelley (1966) conducted a comprehensive survey of industrial arts programs, teachers, students, and curriculum in the U.S. Their report provided a national snapshot of the profession and set the tone for the paradigm shift from industrial practice to technology. Conducting a thorough review of the profession in the U.S., Sanders (2001) used some of Schmitt and Pelley's (1966) questions, items from the Standards for Industrial Arts Programs study (Dugger, et al., 1980) as well as questions from surveys conducted by the periodical, *School Shop/Tech Directions*, in 1986, 1989, 1990, and 1991. Sanders (2001) concluded that the profession was undergoing a significant transition but still had firm roots in its industrial past.

Periodic reviews and synthesis of literature from 1966 to 1994 have also outlined trends and issues in TEE. Dissertations, journal articles, and other publications were reviewed and classified to provide the profession with a clear picture of where things stood and opportunities (Dyrenfurth & Householder, 1979; Householder & Suess, 1969; McCrory, 1987; Streichler, 1966; Zuga, 1994). Similar reviews of graduate studies have also been valuable in tracking trends and issues (Foster, 1992; Jelden, 1981; Reed, 2001; Reed & Sontos, 2006; Volk, 1997). Reed and LaPorte (2015) discerned the profession's long-term and emerging trends by analyzing the special interest sessions of the conferences of what is now known as the International Technology and Engineering Educators Association (ITEEA) from 1978-2014. These studies consistently showed that the profession has focused on curriculum (e.g., content, content development) and professional development activities, such as teacher certification.

Between 2001 and 2015, several studies were conducted on the status of technology (and engineering) education in the U.S. (Dugger, 2007; Meade & Dugger, 2004; Moye, et al., 2015; Newberry, 2001). Numerous studies were conducted between 1989 and 2015 on the supply of, and demand for, technology and engineering teachers in the U.S. (Akmal, et al., 2002; Daugherty, 1998; Hoepfl, 2001; Moye, 2009; Moye, 2016; Ndahi & Ritz, 2003; Ritz, 1999; Weston, 1997; Wright & Custer; 1998; Wright & Devier, 1989); these studies documented a downward trend in the number of technology teachers.

Using a modified Delphi technique, Wicklein took a different approach to identify critical problems and issues facing technology education in the U.S. (1993, 2005). The participants in Wicklein's 1993 study consisted of a purposefully selected panel of experts, whereas his 2005 study used a stratified sample of teachers, teacher educators, and administrators. In his 1993 study, Wicklein found the following three overarching themes: (a) curriculum needs, (b) knowledge base concerns, and (c) interdisciplinary approaches to teaching. The 2005 study produced four themes: (a) teacher recruitment concerns, (b) inadequate understanding of technology education, (c) curriculum design and development, and (d) procuring adequate funding for technology programs.

In 1996 Wicklein and Hill conducted a study to "identify a concise list of constraints representative of the issues and problems facing Technology Education" (p. 31). Their results revealed eight factors similar to the data found in Wicklein's 1993 and 2005 studies. These were: (a) funding, (b) academic content, (c) program vitality, (d) leadership, (e) research base, (f) teacher supply, (g) identity, and (h) integration. Katsioloudis and Moye (2012) studied issues and problems facing TEE in the Commonwealth of Virginia, uncovering five areas of concern: (a) administrators'/counselors' lack of understanding, (b) secondary student enrollment, (c) better marketing needs, (d) TEE teacher program closures, and (e) lack of research showing benefits of TEE. Reed (2006) conducted a review of literature that spanned a 12-year period between Wicklein's 1993 to 2005 studies and included published literature and graduate research. The findings indicated that the top five problems and issues identified by Wicklein were being addressed by the profession but at varying degrees. Clearly, with the passage of 15 years since Wicklein's 2005 study, there is a need to update national research on TEE's trends and issues in the United States.

Purpose

The purpose of this research was to determine the current and future trends and issues facing TEE in the U.S. During the 2019-2020 academic year, the researchers used Wicklein's study, *Identifying Critical Issues and Problems in Technology Education Using a Modified-Delphi Technique* (1993), to guide this study. Rather than studying problems and issues, the researchers focused on trends and issues.

The researchers sought answers to the following four questions:

1. What trends currently impact the TEE profession?
2. What issues currently impact the TEE profession?
3. What trends will most likely impact the TEE profession in the next three to five years?
4. What issues will most likely impact the TEE profession in the next three to five years?

A *trend* was defined for research subjects as a general direction in which TEE is developing or changing. An *issue* was defined as something of "importance relating to at least two points of view that are debatable or in dispute with technology [and engineering] education" (Wicklein, 1993, p. 56). *Current* was defined as of the present time. Lastly, the *future* was defined as a projected period of time between now and the next three to five years.

Methodology

The researchers used a modified Delphi method to solicit information from TEE stakeholders in the U.S. A stakeholder was considered someone with a vested interest in TEE, such as TEE teachers, teacher educators, and administrators. Hsu and Sandford (2007) identified that "the Delphi technique is a widely used and accepted method for gathering data from respondents within their domain of expertise" (p. 1). The Delphi technique was selected because stakeholders were geographically dispersed, it is a cost-effective method that can be conducted electronically, and it provides sufficient time for participants to reflect and comment. Additionally, Delphi studies typically range from three to five rounds, depending on the level of consensus the researchers seek (Hsu & Sandford, 2007).

Participants

While Hsu and Sandford (2007) noted that there is no exact standard for selecting Delphi participants, they did recommend that participants should be selected from among the stakeholders within the area being researched. Following Wicklein's (1993) methodology, the researchers of this study requested that ITEEA members nominate experts in the field of TEE. After two rounds of soliciting potential experts, 100 names were received. Of those, only 26 agreed to participate, and they did not sufficiently represent diverse demographics and all four ITEEA geographic regions. To compensate for these limitations, the researchers invited additional stakeholders, as Wicklein had done in his 2005 study, where his research goal was to "ascertain the perspectives of classroom teachers, university professors, and supervisors of technology education" (p. 6).

Requests for participants were sent via ITEEA communications, including the IdeaGarden listserv and STEM Connections newsletter. Once all ITEEA regions were well represented, the Delphi study began. The number of participants varied during the three rounds. In round one, 320 stakeholders participated, with 33% identifying as 9-12th grade TEE teachers (see Table 1). In round one, 68.5% of participants identified as male and 31% as female. Two hundred eighty-three (88.4%) of the respondents identified as White/Caucasian; eight (2.5%) as Hispanic/Latino, seven (2.2%) as Black/African American, six (1.9%) as Asian/Asian American, and one (.3%) as American Indian/Alaska Native. Four (1.3%) reported mixed races, and 11 (3.4%) participants preferred not to identify their race.

The researchers asked participants to report in which state they were employed. Three hundred-fifteen responded with 192 (60.9%) responses from ITEEA Region 1 (Eastern), 37 (11.7%) from Region 2 (East Central), 53 (16.8%) from Region 3 (West Central), and 33 (10.5%) in Region 4 (Western). Middle school and high school TEE teachers and TEE teacher educators represented 70% of respondents. All percentages were rounded and, although the numbers indicate a cross-section of regional stakeholders, they may not be representative of ITEEA members in those regions or of TEE stakeholders in those regions.

Procedure

In the first round, participants were provided definitions for *current*, *future*, *trends*, and *issues* and asked to list what they felt were current trends, future trends, current issues, and future issues facing TEE in the U.S. The researchers organized the responses from round one into the four trends and issues categories (i.e., current and future trends, current and future issues) to be used in round two (Hsu & Sanford, 2007).

Table 1

Stakeholder Participation by Role

Position	Round I		Round III	
	n	%	n	%
TEE Participants				
9-12 Teacher	106	33	91	34
Teacher Educator	66	21	59	22
6-8 Teacher	50	16	52	19
State Administrator	15	5	8	3
Local Administrator	12	4	12	4
Teacher Candidate	10	3	9	3
PreK-5 Teacher	10	3	7	3
Non-TEE Participants				
Business Leader	6	2	5	2
9-12 Teacher	7	0.0	1	0.0
6-8 Teacher	2	0.0	2	0.0
PK-5 Teacher	4	0.0	2	0.0
Administrator	9	0.0	12	0.0
Others	23	0.1	8	0.0
TOTAL	**320**	**100**	**268**	**100**

The second round was designed to prioritize each trend and issue in each of the four trends and issues categories. The researchers emailed participants a cover letter and link to four tables showing categorized trends and issues. Participants were asked to indicate how much they agree or disagree with each trend or issue as being important for technology and engineering leaders to address. Participants indicated their agreement on a five-point scale ranging from 1 to 5 (1 = *strongly disagree* to 5 = *strongly agree*). After round two, the mean of each trend and issue was calculated, then ranked from highest to lowest.

In the third round, participants were asked to identify if they felt each trend and each issue were essential or non-essential for technology and engineering leaders to address. The means of each trend and each issue were tabulated and ranked. Based on that data, the researchers created four tables. Each table contained columns comparing the mean of each key descriptor found in rounds two and three. Using the resulting data, the researchers categorized the trends and issues into eight different themes.

Results

In the initial round, 320 participants submitted a total of 3,612 trends and issues. Of those responses, the researchers classified 801 as current issues, 565 as future issues, 1,402 as current trends, and 844 as future trends. The researchers consolidated similar items and placed the responses into the four categories, resulting in 20 current trends, 21 future trends, 17 current issues, and 20 future issues. These trends and issues became the inputs for rounds two and three.

The purpose of round two was to determine what participants felt were the most important current and future trends and issues. Despite email reminders, there were only 176 participants in round two, which represented 55% of the respondents in round one. This may have been a result of survey fatigue. Anticipating further declines in participation, the researchers decided to limit the study to three rounds (Hsu & Sandford, 2007). This decision was also based on the strong means from round two, which indicated high levels of agreement among participants. On a five-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), the 20 current trends had means ranging 3.52-4.66. The 21 future trends had means ranging 3.62-4.62. The 17 current issues had means ranging 3.50-4.45. The 20 future issues had means ranging 3.68-4.59.

In the final round of this study, participants were asked if they considered each of the key descriptors to be essential or non-essential for TEE leaders to address in future strategic planning. Two hundred sixty-eight stakeholders responded. The number of judgments as *essential* and *non-essential* were calculated, resulting in percentages used to rank inputs from most to least essential. The resulting 78 trends and issues were categorized by the researchers into themes, similarly to previous studies (Katsioloudis & Moye, 2012; Wicklein 1993; Wicklein, 2005; Wicklein & Hill, 1996). Current and future trends and issues are shown in Table 2, categorized by eight themes. The left column identifies each individual theme. The row following each theme identifies specific trends and issues associated with that theme. The number preceding each trend and issue is the round three ranking.

Table 2
Trends and Issues Facing Technology and Engineering Education – Categorized into Themes

Theme	Current Trend	Future Trend	Current Issue	Future Issue
Critical Teacher Shortage	#1 Teacher shortage	#1 Teacher shortage	#1 Low recruitment of teachers	#1 Teacher shortage
Curriculum	#2 Hands-on projects: Students doing more	#3 Project-based learning / hands-on projects: Need more, promote importance	#2 Project-based learning / hands-on projects: Need more, promote importance	#7 Interdisciplinary / STEM approach: TEE role
	#6 College preparation: TEE role	#8 TEE course / curricular content: What should be taught	#7 STEM education: TEE role	#9 TEE course / curricular content: What should be taught
	#7 TEE course / curricular content: What should be taught	#9 Integrative STEM Education: TEE role	#10 TEE course / curricular content: What should be taught	#11 Occupation preparation: TEE role
	#9 Integrative STEM Education: TEE role	#14 TEE standards: Need to be updated	#15 TEE standards: Need to be updated	#12 TEE standards: Need to be updated
	#12 Computer Science Education: TEE teaching more	#15 Occupation prep: TEE role	#17 Industrial arts to TEE: Slow change	#14 College preparation: TEE role
	#14 Occupation preparation: TEE role	#16 College prep: TEE role		#15 TEE teaching methodology: Need focus
	#17 Elementary TEE: Need focus			
	#19 Robotics Instruction: Becoming popular			
Secondary & University Program Closures	#5 TEE funding: Lack of	#7 TEE funding: Lack of	#8 TEE funding: Lack of	#6 TEE funding: Lack of
		#13 TEE teacher compensation: Low compared to industry	#14 Teacher compensation: Low compared to industry	#13 Teacher compensation: Low compared to industry
Funding: Programs & Teachers	#5 TEE funding: Lack of	#7 TEE funding: Lack of	#8 TEE funding: Lack of	#6 TEE funding: Lack of
		#13 TEE teacher compensation: Low compared to industry	#14 Teacher compensation: Low compared to industry	#13 Teacher compensation: Low compared to industry

Continued on Page 42

Table 2, continued from Page 41

TEE Identity & Relevance	#4 Administrators & counselors: Misunderstand / lack of TEE support	#11 Poor public relations for TEE	#6 Identity: What is TEE	#4 TEE validity / relevance: Lack of public understanding
	#11 TEE marketing / public relations: Inadequate		#11 Stigma: TEE being an elective course	
Collaborative Efforts	#13 TEE taught by other teachers: e.g., science, librarians	#6 Business, industry, & political support for TEE: Lack of	#5 Collaboration: Community / Business / Industry	#5 Collaboration: Community / Business / Industry
		#17 TEE taught by other teachers, e.g., science, librarians	#13 Collaborate: Teachers of other content areas	#16 Collaborate: Teachers of other content areas
Teacher Certification / Development	#8 TEE teacher preparation: Inadequate / inappropriate	#10 TEE teacher professional development: Needs improved	#9 Teacher professional development: Needs improved	#8 TEE teacher preparation: Inadequate / inappropriate
	#18 Inadequate / ineffective TEE leadership	#12 TEE teacher preparation: Inadequate / inappropriate	#12 TEE teacher preparation: Inadequate / Inappropriate	#10 TEE teacher professional development: Leadership role
		#18 TEE leadership & leadership training: Inadequate		#18 TEE teacher certification: Alternate vs. traditional
Student-Centered Foci	#10 High school graduation requirements: Restrictions on TEE	#20 TEE Student Diversity / Equity / Inclusion: Improve	#16 TEE Student Diversity / Equity / Inclusion: Improve	#19 TEE Student Diversity / Equity / Inclusion: Improve
	#16 TEE Student Diversity / Equity / Inclusion: Improve	#21 Student development of critical thinking & problem solving skills: TEE role		
	#20 Standardized student testing: Becoming focus			

Discussion

The purpose of this research was to determine the current and future trends and issues facing the TEE profession in the U.S. Using Wicklein's 1993 and 2005 studies as guides, this study addressed four research questions: What trends currently impact the TEE profession? What issues currently impact the TEE profession? What trends will most likely impact the TEE profession in the next three to five years? Lastly, what issues will most likely impact the technology and engineering profession in the next three to five years?

The critical shortage of technology and engineering teachers has been of concern for many years (Wicklein, 1993, 2005; Volk, 1997; Moye, 2009, 2016) and was identified in this study as the top priority for leaders to address. Why does this problem persist? The profession has not adequately addressed this problem. Perhaps leaders are looking at the wrong variables and using ineffective strategies. The proliferation of makerspaces in PK-12 schools, technical competitions, engineering design in *Next Generation Science Standards* (NGSS Lead States, 2013), and other initiatives are a clear affirmation that TEE is valued (Reed, 2018). The *Phi Delta Kappan* (2017) survey of the public's attitudes toward public schools showed that 82% of respondents view TEE as an important indicator of school quality. Clearly, the profession must rectify the teacher shortage in light of the valued content the field offers.

Directly related to the teacher shortage is the closure of many secondary school and university programs. Wicklein (2005) stressed,

> The most obvious conclusion from this research is the concern and crisis over the insufficient quantities of qualified new technology educators entering the instructional rank…. the dilemma over recruitment and preparation of new technology teachers coming from university programs dwarfs all of the other concerns. (p. 8)

Both secondary school and university programs require a large physical footprint, are costly to maintain, and will close if there are too few students or teachers to populate those programs. However, the profession has shown growth in elementary school TEE, which tends to take an integrative approach (Reed & LaPorte, 2015). Perhaps secondary school and college/university programs should re-conceive the costly, large laboratory approach as there are many proven alternative approaches for TEE (Helgeson & Schwaller, 2003; Petrina, 2007).

Funding for programs and teachers is complex in the U.S. since education is largely a state and local endeavor. However, the recent passage of Perkins V, the Strengthening Career and Technical Education for the 21st Century Act (2018), continues federal funding for states that classify TEE under career and technical education (CTE). To address funding concerns at all levels, teacher educators and administrators may want to increase pre-service and in-service education on funding and grant requests. Having robust information on federal, state, local, and private funding may alleviate concerns and strengthen program funding.

Curriculum, more so than funding, is a state and local endeavor in the U.S. However, the TEE profession, through the work of ITEEA, has received federal grant funding over the past thirty years to develop content standards (ITEEA, 2000, 2020). S*tandards for Technological and Engineering Literacy: The Role of Technology and Engineering in STEM Education* (STEL) is structured so it can be adapted to state and local educational models (ITEEA, 2020, pp. 16-17). Like funding, a continuous professional development effort should be made to help stakeholders understand STEL, other standards (e.g., NGSS), and contemporary curricular topics (i.e., makerspaces, robotics, student organizations).

The identity and relevance of TEE was a theme with diverse trends and issues. The public, administrators, and counselors seem to be groups that, according to participants in this study, need to be better informed. ITEEA's (2000, 2020) standards projects have provided a unified vision and content. Still, the National Academies (Katehi & Pearson, 2009) and the National Assessment Governing Board (National Assessment for Educational Progress, n.d.) suggested there are problems and issues related to identity and relevance. The profession needs to take a systemic approach to address identity and relevance.

Participants' comments concerning collaboration were mixed. Many asserted that TEE is collaborative by nature, while others felt threatened that groups like science teachers and library media specialists were becoming more active in delivering traditional TEE learning activities and content. Collaboration should be embraced because it may result in more students and stakeholders becoming involved in TEE programs and courses. Some states have developed plans that promote the integration of science, technology, engineering, and mathematics (STEM) education (Indiana Department of Education, 2018; Virginia STEM Education Commission, 2020). The profession must do a better job of defining and promoting collaboration within the field and more broadly through initiatives such as *$STEM^4$: The Power of Collaboration for Change* (Advance CTE, et al., 2018).

Participants identified that TEE teacher preparation programs are inadequate and need to be improved. This theme is interrelated to others, so there may be symbiotic solutions. For example, the Praxis Technology Education assessment (Educational Testing Service, 2020) is based on outdated curriculum organizers, which may contribute to identity problems and curricular issues. If licensing guidelines require teacher preparation programs to use this assessment, then the program is inadequate and needs improvement, as do the assessment and licensure guidelines.

The theme labeled *student-centered foci* was broad, including topics such as diversity, equity, TEE practices, and inclusion, among others. Like many trends and issues, communicating a clear vision of TEE based on research, practice through professional development and outreach can address student-centered foci concerns. Many of these student-centered foci trends and issues apply across education, not just TEE, and therefore addressing them does not fall solely on the TEE profession.

The findings of this study reflect the findings from previous research (Wicklein, 1993, 2005; Wicklein & Hill, 1996; Katsioloudis & Moye, 2012). Technology and engineering educators at all levels need to work on these trends and issues, but a first step is understanding what work has already been done. For example, Reed (2006) reviewed the professional literature between Wicklein's 1993 and 2005 studies and found that all identified problems and issues were being addressed at varying levels. Similar research should be conducted to determine what has and has not been done more recently to address these persistent trends and issues. Such research may indicate that some trends and issues are being addressed but the ways they are being addressed may need to be communicated more effectively. Additionally, since some trends and issues have consistently been identified in the literature, perhaps TEE needs to come to terms that some are actually foundational benchmarks of the discipline. For example, the profession's ongoing fascination with curriculum may be a result of educational progress or technological advances. The profession may need to embrace these persistent trends and issues as standard measures to shape TEE through strategic planning.

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About the Authors

Johnny J. Moye (jmoye@iteea.org) is Senior Fellow at the International Technology and Engineering Educators Association in Reston, Virginia.

Philip A. Reed (preed@odu.edu) is Professor and Technology Education Program Leader at Old Dominion University in Norfolk, Virginia.

Ray Wu-Rorrer (wurorrerr@fccps.org) teaches at Mary Ellen Henderson Middle School in Fairfax, Virginia.

Douglas Lecorchick (lecorchickd@berea.edu) is Assistant Professor at Berea College in Berea, Kentucky.

Oral Communication in an Integrated STEM and Humanities First-Year Experience

Derek Sherman, Tejasvi Parupudi, Nathan Mentzer, Amelia Chesley, Dawn Laux, & Sweta Baniya

Abstract

This study looks at Purdue University's Integrated First-Year Experience of Design Thinking in Technology, Fundamentals of Speech Communication, and First-Year Composition and its effects on oral communication. We examined whether this three-course integration inspired by writing-across-the-curriculum and communication-across-the-curriculum would lead students to develop more effective oral communication skills than a nonintegrated course. Frameworks for 21st century skills and the National Association of Colleges and Employers (2017) have pinpointed the importance of oral and written communication skills and initiatives. Still, research has produced mixed results on how well universities are preparing students for the workplace. Our study investigated whether the integrated program had better end-of-semester group oral presentations than student groups enrolled only in our Design Thinking in Technology course. A quasi-experimental design and post-only analysis revealed that integrated sections had more effective oral presentations than the nonintegrated sections.

Keywords: First-year integration, oral communication, communication across the curriculum, transfer, 21st century skills frameworks

Introduction

Research indicates that formal course integration can improve student learning across disciplines. Often, institutional efforts to support interdisciplinary, integrated pedagogy are seeking to address specific skills gaps. For example, researchers have recognized a significant disparity between employers' expectations and graduates' demonstrated communication skills, empathy and audience awareness, and critical thinking abilities (Liu et al., 2014; Radermacher et al., 2014). Multiple research angles have indicated that interdisciplinary pedagogical integration may improve student learning experiences and enhance students' likelihood of transferring strong oral communication skills (Bannerot et al., 2010; Brizee & Langmead, 2014; Morton & O'Brien, 2005; Paretti, 2008). Furthermore, 21st century skills frameworks

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(e.g., ABET, 2014) have provided guidance in addressing skills that prepare students for future coursework and the workplace. There remain, however, many unanswered questions about the effectiveness of interdisciplinary integration, particularly in terms of its impact on oral communications. This research investigated the effectiveness of one interdisciplinary integration on oral communication development through a writing-across-the-curriculum and communication-across-the-curriculum framework effort at Purdue University.

Practices in writing-across-the-curriculum (WAC) and communication-across-the-curriculum (CAC) inspired our work as we proposed an integrated framework in partnership with Purdue's Lamb School of Communication, Department of English, and Polytechnic Institute. Sharing similar goals and outcomes, WAC and CAC practices "have come together in a more strategically collaborative manner—in research and practice" (Dannels & Housley Gaffney, 2009, p. 126). WAC/CAC frameworks advocate practices that mimic the disciplinary or workplace situations that students may experience in their future coursework and careers while attempting to address the various 21st century skills frameworks' deficiencies described by Jang (2016).

Our previous integrated research (Chesley et al., 2018) combined written and oral communication in the context of real-life problem-solving in a Design Thinking in Technology course. Within the present study, we focused on the oral communication skills of student teams. We suggested that the communicative and integrated elements of First-Year Composition, Fundamentals of Speech Communication, and Design Thinking in Technology coalesce to provide students with a greater opportunity to develop essential oral communication skills that employers seek from graduates.

First, we illustrate how 21st century skills frameworks are informative yet deficient in terms of their use. Next, we discuss the potential that active learning pedagogies and WAC/CAC practices have in addressing these deficiencies. Last, we describe Purdue University's first-year integrated experience and consider evidence that it fosters oral communication skills.

The Need for Verbal Communication: Existing Frameworks and Implementation

Students in STEM must gain 21st century skills to succeed in a competitive world. Results from a Gallop Poll (as cited in Sidhu & Calderon, 2014), however, suggested that only 11% of business leaders believed that higher education institutions are effectively preparing graduates with skills and competencies aligned with workforce needs. On the other hand, 96% of chief academic officers believed that graduates are career-ready. Universities should mend this stark misalignment through better skill-building initiatives such as implementing 21st century skills frameworks.

Various frameworks characterize important workplace skills, such as the Framework for 21st Century Learning that was crafted around the 4Cs:

communication, collaboration, creativity, and critical thinking (Trilling & Fadel, 2009). The importance of oral and written communication skills was also emphasized by the National Association of Colleges and Employers (2017).

Working with the *Occupational Information Network,* Jang's (2016) analysis found that the five highest-rated skills for 21st century learning were: (a) “critical thinking,” (b) “reading comprehension,” (c) “active listening,” (d) “speaking,” and (e) “complex problem-solving” (p. 291). Additionally, the most important work activities included: (a) “getting information,” (b) “making decisions and solving problems,” (c) “interacting with computers,” (d) “communicating with supervisors, peers, or subordinates,” and (e) “updating and using relevant knowledge” (p. 291). It is important that universities acknowledge these workplace skills and activities and for frameworks to incorporate them within their standards.

However, Jang (2016) suggested that each framework has deficiencies. For example, Jang argued that ABET’s engineering criteria for 2015–2016 have shortcomings in the "domains of working with an organizational system, ill-defined problem solving, and time, resource, and knowledge management" (p. 295). How do institutions that adopt this framework intend to address this deficiency and its relationships to oral and written communication? Lucas (2019) argued that "Expansive education, learning power and new pedagogies for deeper learning all shift the debate away from the **what** to the **how** of learning, focusing at least as much attention on pedagogy as on skills or capabilities or dispositions" (p. 15). Therefore, university programs should push the conversation toward pedagogy.

Combining Active Learning With Writing and Communication Initiatives

Although some frameworks may be complementary to 21st century skills, they can lack clarity on how to incorporate workplace skills in STEM curricula. Freeman et al. (2014) showed that active learning in STEM disciplines improves student performance, as evidenced by higher examination scores and reduced failure rates than traditional lecturing. Active learning involves in-class discussions and activities with teamwork as intrinsic components, making it different from traditional lecturing. A 21st century curriculum must be conducive toward active learning because it is necessary for students to demonstrate the ability to work in cross-functional and diverse teams. Chi (2009**)** suggested that curricula should include interactive learning or activities that incorporate instructional and joint dialogues (i.e., consultations with experts and peers on projects and activities.) Interactive learning that employs instructional and joint dialogues creates a shared understanding among collaborators from which new conceptions may emerge (p. 87).

Potentially, WAC models may serve as an intervention for addressing the deficiencies of 21st century skills frameworks. Writing to learn and writing in the disciplines, sometimes referred to as writing to communicate, are the two guiding practices of WAC. McLeod (2012) argued that writing to learn "encourages teachers to use writing as a tool for learning as well as a test for learning" (p. 151). Writing to learn is usually an informal and ungraded approach to writing, including activities such as journals, annotations, and response papers (WAC Clearinghouse, 2019a).

On the other hand, writing in the disciplines uses the language practices of a particular domain and goes beyond the self as the audience (McLeod, 2012, p. 153). Activities for writing in the disciplines are more formal and require students to write in the genres and styles of a particular discipline, including project proposals, journal articles, and other works. (WAC Clearinghouse, 2019b). Bazerman (1992) argued that WAC helps students to "use them [disciplinary languages] more effectively as individuals and as members of the disciplinary groups" (p. 1847).

Like WAC, CAC relies on two principles: that "communication is too important to be taught in a single course, and that learning occurs best through the cognitive processes associated with message formation" (Steinfatt, 1986, p. 464). Central to both WAC and CAC is communication in a particular discourse community. For an oral communication model, Dannels (2001) proposed four "theoretical principles: 1) oral genres are sites for disciplinary learning[,] 2) oral argument is a situated practice, 3) communication competence is locally negotiated, and 4) learning to communicate is a context driven activity" (p. 147). Communication courses that build in these four theoretical principles alongside STEM-based frameworks for 21st-century learning while supplementing student learning with active learning pedagogy may be more effective.

The Instructor's Role in Frameworks

Successful application of the 21st century skills framework relies heavily on the instructor's role and goals for the course. Paretti (2008) stated that faculty must have a strategy in the classroom to help students understand the functions of the assignments by relating them to professional contexts. Winsor's (1996) *Writing Like an Engineer: A Rhetorical Education*, for example, provided insight into how workplace communication, writing, and classroom frameworks create a professional context for the four students she interviewed. Winsor's discussion focused on four areas: the socialization of engineering students, audience issues, relationships between text and reality, and students' self-visualization as engineers. Winsor's work recognized the role that the instructor plays in socializing students into the discourse community—groups who share similar values and methods of communication—although this is not her focus. It is the instructor's responsibility to create a classroom context and activities that support workplace and discourse community communication because this exposure allows students to become active members of that discourse community. Dannels' (2001) four theoretical principles for communication and Winsor's (1996) four areas of focus provide instructors with a basis for developing a classroom climate that focuses on oral communication within a discourse community.

Conrad's (2017) study further suggested that communication courses in the disciplines require specific teaching strategies. Three teaching implications were born out of Conrad's research: (a) "engineering faculty need to be responsible for teaching discipline-specific writing skills in their courses" (p. 210), (b) instructors and students should analyze samples of effective practitioners' writing (p. 210), and (c) feedback needs to pinpoint "that inaccurate, ambiguous, or error-ridden sentences are as problematic for engineering as inaccurate, ambiguous, or error-ridden calculations" (p. 211). Instructors who are members of the discourse community are better prepared to create authentic activities, introduce written and oral communication examples, and provide relevant feedback.

First-Year Integration Programs and Their Role

The American Society for Engineering Education's Committee on Evaluation of Engineering Education (1955/1994) report, known as the Grinter Report, called for an effort to integrate work in the humanities into STEM programs, which a WAC/CAC framework offers. One pivotal goal for integrated courses, as stated by the Committee on Integrated STEM Education, is improving 21st-century skills among students (Honey et al., 2014, p. 32), and thereby potentially improving conceptual learning (p. 52). First-year seminar courses, residential and academic learning communities, and various forms of course integration are common strategies for increasing student engagement, retention, and overall academic success.

Scholars in many disciplines have investigated various types of integration and other first-year programs, initiatives, and techniques (e.g., Bannerot et al., 2010; Paretti, 2008). Some of these involved institutions' writing centers and writing in the disciplines programs. Other course integrations were driven by cross-disciplinary collaborations and initiatives. CAC frameworks have fostered oral communication in fields such as business (Jankovich & Powell, 1997), animal science (Orr, 1996), design education (Morton & O'Brien, 2005), engineering (Dannels, 2002), and theatre and education (Friedland, 2004). For example, in a 2002 study about a CAC framework, Dannels found that "Learning to speak like an engineer was not just about negating filler words or nervous gestures, but rather about the complex ways orality was tied to the situated values, norms, and audiences of engineering" (p. 266).

Northwestern University integrated design thinking with communication in a freshman-level program (Colgate et al., 2004). The Design Thinking & Communication courses were cotaught by engineering and writing faculty, and students worked in teams to address projects submitted by actual clients (Northwestern University, 2019b). This course required students meet five objectives: (a) "study a problem from multiple perspectives"; (b) "learn how to frame the design challenge properly”; (c) “ideate, prototype, and iterate solutions”; (d) “communicate their ideas clearly in design reviews, reports, and presentations”; and (e) “learn from the overall design process how to create value, prepare for their careers, and participate more fully in society” (Northwestern University, 2019a). The course utilized active pedagogy, communication, and real-world problems to address workplace skills.

The Integrated First-Year Experience Program

This study took place at Purdue University, a public university in the Midwestern United States with an undergraduate enrollment of more than 30,000 students. The study was situated within the Integrated First-Year Experience program, which aimed to provide realistic problem-solving scenarios that would enhance students' design thinking and oral communication. By connecting the curriculum across disciplines and university colleges, educators expected to see measurable improvements in the composition, communication, and critical thinking habits of students in all technology majors. The principles and practices of WAC/CAC and integrated pedagogy across the humanities and STEM courses are well-suited for these goals and offer opportunities to increase students' effectiveness in and preparedness for workplace communications.

The program brings together three required introductory courses at Purdue University: First-Year Composition, Fundamentals of Speech Communication, and Design Thinking in Technology. The general education curriculum requires all students to take First-Year Composition and Fundamentals of Speech Communication. Design Thinking in Technology is a core requirement for all students in Purdue’s Polytechnic Institute.

Students in Design Thinking in Technology grapple with complex problems affecting our planet and use the design process to research, develop, and propose innovative, realistic solutions to those problems. Although critical thinking is a more common term related to the most crucial skills needed by college graduates, the term *design thinking* has entered discussions to reflect a more active, solution-oriented mindset. Design thinking encompasses the strategic, practical, situated processes of conceiving and actualizing new, innovative solutions to problems using iteration and testing. By the end of their semester of Design Thinking in Technology, students should have developed the crucial values of teamwork and ethical, human-centered design.

Community and teamwork are also important active-learning elements of the integrated courses. Fundamentals of Speech Communication gives students opportunities to practice and improve their oral communication skills, including interpersonal communication and collaboration in small groups. Students plan and present informative and persuasive speeches individually and in teams. In First-Year Composition, students analyze, critique, and practice creating their own written and multimodal compositions. Students also compose texts in multiple media and modes, review and revise their own and their peers’ compositions, and practice performing research and analysis using diverse sources.

In this integrated program, each Design Thinking in Technology section functions as a central point in a trio of integrated courses and serves as the discourse community studied. A student enrolled in the Integrated First-Year Experience will spend time with a group of the same 20–25 students enrolled in Design Thinking in Technology and First-Year Composition or in Design Thinking in Technology and Fundamentals of Speech Communication.

Instructors in Design Thinking in Technology worked with English and communication instructors to collaboratively explore and implement ways of connecting and reinforcing the curriculum in their courses. The partnerships among the three disciplines aimed to foster improvement in students' composition, writing, oral presentation, and design-thinking skills. The instructors agreed to a set of extra teaching expectations for a small stipend, including the following.

1. Instructors participated in a 2-hour orientation workshop prior to the semester. Instructors engaged in coteaching dialogs to establish relationships within their trios.

2. Instructors met weekly for at least ten meetings during the semester to coplan:
   i. Major student deliverables,
   ii. Continuity of instruction between trio members,
   iii. How student teams will be formed, and
   iv. Details of the integrated projects.

3. Instructors cotaught on four occasions (minimum):
   i. The first week of class to introduce what the integration means for students,
   ii. Any time during the semester at the intersection of the three disciplines,
   iii. Introduction of the final project, and
   iv. Final project presentations.

Our program used the following process for course development: (a) consult 21st century frameworks and use WAC/CAC practices to address the lack of clarity in oral and written communication skills, (b) design a course in which instructors use WAC/CAC practices and design thinking, and (c) implement active pedagogy, including collaboration and instructional and joint dialogues, as suggested by Chi (2009).

Methods

Our priority for this study was to learn whether the integration described here helped students demonstrate stronger oral presentation skills. The following research question guided this study: "Do technology student teams who take an integrated design course deliver higher quality presentations than those who do not?" The data collected and analyzed included final project presentations from integrated and nonintegrated sections of the Design Thinking in Technology courses during the fall 2016 semester.

We employed a quasi-experimental design and post-only analysis to investigate the effects of the described integration and compared the results with the nonintegrated sections. Because students self-enrolled in sections of Design Thinking in Technology, we cannot assume that students were similar across sections regarding key variables. However, we assumed that student groups were similar enough to warrant this study design. Also, we did not determine whether individual students delivered more effective presentations based on their integration or nonintegration status. Rather, we assessed groups of students and their collaborative ability to demonstrate effective communication skills.

Implementation and Data Collection

Technology and communication instructors introduced the final design project to the integrated sections. Instructors explained the purpose of the integrated project, as well as the purpose of the in-class presentation. Instructors emphasized that the collaborative team presentation should meet two goals: the presentation should persuade their audience to support their design recommendations (i.e., their solution), and it should convincingly demonstrate that the students have done their due diligence in developing a solution by following a structured and valid process.

Instructors provided comparable directions to students in the nonintegrated sections of Design Thinking in Technology with a few differences. Instructors stipulated that presentations should be 5 minutes in length with an additional 2–3 minutes for questions and answers. Nonintegrated sections had a shortened length requirement because of time constraints. In both integrated and nonintegrated sections, instructors expected each team member to play an active role in the presentation.

At the end of the 8-week final project, the final presentations of student teams were video recorded by the instructor and shared at the conclusion of the semester. The research team screened a total of 100 video recordings and eliminated 16 recordings for which adequate analysis was not possible due to the poor quality of the image or audio. After screening, the sample consisted of 82 presentations, 35 from the integrated sections and 47 from the nonintegrated sections.

Data Analysis

Instructors of the integrated sections adapted a rubric based on criteria from Morgan and Natt's (2013) Effective Presentations' "Speech Evaluation Form A: Persuasive Presentations" (p. A63). These criteria are shown in Table 1. The only change instructors made included the addition of criterion from the text's "Outline Checklist: Persuasive Presentation" (p. A57) that suggested the "use of a variety of supporting materials." Course instructors of both the integrated and nonintegrated sections assessed students' presentations with this rubric.

Table 1
Criteria for Pursuasive Presentations

Introduction	Body	Conclusion
• Captured attention • Stated thesis • Related topic to audience • Established speaker credibility • Previewed main points • Provided transition to body while introducing speakers	• **Organized main points clearly and logically (clearly outlining innovation/solution 1 and 2)** • Included transition between main points • Used accurate, relevant, and timely supporting materials in sufficient quantity • Used a variety of supporting material (statistics, examples, narratives) • Cited sources accurately in speech • Used well-reasoned arguments • Avoided logical fallacies • Used persuasive language	• Provided transition to conclusion • Restated thesis • Summarized main points • Ended with a memorable final thought (clincher)

Note. Adopted from Morgan, M., & Natt, J. (2013). *Effective presentations* (3rd ed.) (p. A63). Cengage.

The rubric's criteria were validated through its 10 years of use in Purdue's School of Communication, with approximately 200 sections offered per year and 20–24 students in each section. Student performance for each of the 18 criteria in Table 1 was assessed using a Likert-based scale (1 = *Unacceptable; Criteria is absent* to 5 = *Excellent; Criteria meets or exceeds expectations and meets major audience expectations*). The total scores possible ranged from 18 to 90. Instructors also provided students with a "Course Standards and Philosophy" statement in their Fundamentals of Speech Communication syllabus that conformed to the rubric's evaluative remarks.

A trained communications instructor on the research team mentored two graduate student researchers to use the Persuasive Presentation rubric to analyze the final sample of presentation videos. To develop consistent ratings among evaluators, these graduate student researchers engaged in three consecutive rounds of review, discussion, and negotiation. A Cronbach's alpha value of 0.889 between the raters indicated a good level of consistency (Santos, 1999) on sixteen presentations, 20% of the data. After a good level of consistency was achieved, one researcher evaluated all 82 blinded presentation videos, noting the average scores for presentations in both the integrated and nonintegrated sections.

Results

A Levene's Test for Equality of Variances revealed that the scores for presentations in both the integrated and nonintegrated sections were homogenous ($p > .05$). Therefore, an independent samples *t*-test was run for mean difference between the groups at a 95% confidence interval. A significant difference existed in the scores for the integrated (M = 62.40, $SD = 9.65$) and non-integrated (M = 48.06, $SD = 9.359$) sections; $t(-6.771) = 80$, $p < .001$. The mean difference between the integrated and nonintegrated sections was 14 points, representing a difference of approximately 15 percentage points. These results suggest that student groups in the integrated version of the course have developed significantly stronger communication skills than students who take the courses separately.

Discussion

At the end of their 8-week final project, students in the integrated versions of Design Thinking in Technology and Fundamentals of Speech Communication showed presentation scores 15% higher than scores in the nonintegrated courses. A 15% difference is both statistically and practically significant because it represents a difference of about one and one-half letter grades.

Nowacek's (2011) research on transfer showed that integrated models in which instructors communicate with each other regularly might foster transfer more readily. We theorize that students in the integrated sections approached the final presentations for their design projects with better preparation in using communication skills, transferring knowledge and practices from Fundamentals of Speech Communication to Design Thinking in Technology. Students in integrated sections may have obtained a deeper understanding of the design project because of the expansive frame (Engle et al., 2012) and the explicit connections that instructors created between design thinking and communication. Activities within individual classrooms and shared activities between courses may have further propelled the integrated group's success.

Instructors in both courses, Design Thinking in Technology and Fundamentals of Speech Communication, referenced each other's course, and encouraged students to make connections between courses. Students in the nonintegrated sections did not have this consistent referral to other classes.

Given the quasi-experimental nature of this study, several other factors may explain the differences between comparison groups. The comparison groups consisted of intact sections of a course; there was no selection or assignment to treatment conditions. Data were not gathered to enable the assessment and control of preexisting characteristics of students and groups or the possibility that students were concurrently enrolled in a nonintegrated Fundamentals of Speech course. There were different time limits for presentations, and the instruction may not have been consistent for comparison groups. However, five of the six instructors involved in this study taught both integrated and nonintegrated sections, which enhanced the consistency of the treatment.

Future Research

We plan to continue our investigation of implementing WAC and CAC principles into first-year experience courses, especially in terms of promoting transfer via expansive frames, explicit skill teaching, and relationship to students' future careers. Future research should seek to confirm the results of the current study by employing a more rigorous research design that helps control for alternative explanations of learning transfer. We will examine more closely the pedagogical and collaborative integration between only two courses by analyzing subcomponent scores of the Persuasive Presentation rubric. Such a breakdown of scores could provide insights into areas that may need further pedagogical support. Additionally, future research could study written communication differences between integrated and nonintegrated sections.

Conclusion

In conclusion, this quasi-experimental study examined the end-of-semester presentation skills of student groups in integrated and nonintegrated sections of a college freshman level Design Thinking in Technology course. A program-supported pedagogical approach within the integrated sections required instructors to meet and collaborate on the final project and apply WAC/CAC principles; therefore, these results demonstrate the potential benefits that expansive frames and explicit skill teaching may have on students' abilities to transfer oral communication skills. Students in the nonintegrated groups may or may not have had a communication or composition course. If they had, it was unrelated to their design course, so transfer may have been more difficult for these students. Because students in the integrated courses scored significantly higher on their presentation than students in the nonintegrated sections, we will continue to offer integrated sections to foster student learning and transfer as resources permit.

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About the Authors

Derek Sherman (sherma11@purdue.edu) is a fifth-year PhD student at Purdue University.

Tejasvi Parupudi (tejasvi@utdallas.edu) is a Post-Doctoral Research Associate at The University of Texas at Dallas.

Nathan Mentzer (nmentzer@purdue.edu) is an Associate Professor of Technology and Engineering Education at Purdue University.

Amelia Chesley (amelia.chesley@erau.edu) is an Assistant Professor of Technical and Professional Writing at Embry-Riddle Aeronautical University.

Dawn Laux (dlaux@purdue.edu) is an Associate Clinical Professor of Computer and Information Technology at Purdue University.

Sweta Baniya (baniya@vt.edu) is an Assistant Professor of Rhetoric, Professional, and Technical Writing at Virginia Polytechnic Institute and State University.

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