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Flexible and Job-Embedded Professional Development for In-Service Technology, Design, and Engineering Educators

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ABSTRACT

Technology, design, and engineering (TDE) eduction teachers have less access to quality professional development than other Science, Technology, and Mathematics (STEM) educators.

To address this need, the *Transforming Teaching through Implementing Inquiry* (T2I2) project created an online professional development system for TDE secondary educators. The online professional learning experiences, defined by National Board for Professional Teaching Standards (NBPTS), reinforce and introduce instructional practices that promote student learning. For this study, two groups of teachers, selected from five states (Illinois, Kentucky, Ohio, North Carolina, and Virginia), completed the T2I2 curricular units and submitted artifacts/evidence of practice. Analysis of the artifacts, using the non-parametric Wilcoxon-signed-ranks Test, provides evidence that the teachers within the pilot studies demonstrated proficient abilities to manage, monitor, and adjust learning environments; contribute to a learning community; and increase their self-assessment following the completion of the curriculum. These results led the authors to suggest further use of the learning platform with in-service teachers in related STEM disciplines that face comparable pedagogical challenges.

INTRODUCTION

The importance of quality teacher learning opportunities cannot be overstated. Teacher quality is consistently noted as a critical factor that impacts student learning (National Research Council [NRC], 2010). Effective professional development that affects teacher quality requires flexible, job-embedded, results-driven learning experiences, which are focused on content that integrates directly into classrooms and builds a community of learners (Ernst, Segedin, Clark, & DeLuca, 2014; Garet, Porter, Desimone, Birman, & Yoon, 2001; National Staff Development Council [NSDC], 2001; Schlang, 2006; Weiss & Pasley, 2006). Changes in teacher practice require time, with some states mandating as many as 19 professional development days annually (Ernst, Clark, DeLuca, & Bottomley, 2013; Jacob & McGovern, 2015). Such time is well spent when this work results in improving teaching skills and pedagogical content knowledge (Li, Ernst, & Williams, 2015).

National STEM education initiatives (Science, Technology, Engineering, and Mathematics) education initiatives call for high quality professional development for STEM educators; however, professional learning experiences for technology, design and engineering (TDE) educators pale in comparison to professional development for other STEM disciplines. Often these are characterized as less comprehensive and perceived to have little value (DuBois, Farmer, Gomez, Messner, & Silva, 2009; Li, Ernst, & Williams, 2015; NRC, 2009). Professional development for these TDE educators is often found to be inadequate and limited (National Academy of Engineering, 2009).

The lack of technology education National Board for Professional Teaching (NBPT) certified teachers, and an increasing shortage of TDE educators further accentuates the need for quality professional development and an enhanced pipeline for this group of educators (NBPT, personal communication, October 2012). To address the shortage, thirty-nine states (78%) utilize alternative routes, such as career-switcher programs, to licensing TDE educators (Ndahi & Ritz, 2003). Targeted professional learning experiences and supported networks are needed to sustain and build teacher practices of newly qualified teachers.

This demonstrated need for professional development that focuses on improving TDE educators' teaching skills and pedagogical content knowledge was the impetus behind the development and implementation of the *Transforming Teaching through Implementing Inquiry* (T2I2) project. T2I2 is an online professional development system for grades 6-12 TDE educators. The system content targets implementation and instructional practice, as defined by NBPTS, in support of quality classroom indicators for the promotion of student learning. T2I2 professional development is research-informed, interactive, and object-oriented, built upon professional learning frameworks developed and refined within prior studies such as Visualization in Technology Education (VisTE) and the Tech-Know Project (Ernst & Clark, 2007; Ernst, Taylor, & Peterson, 2005). These frameworks utilize state-of-the-art course content management and collaboration software to provide clear, challenging, connected, and coherent professional learning experiences for educators that encourage critical reflection on practice and self-evaluation through "sustained opportunities over a substantial time interval" (Mundry, 2007; NRC, 2011). Utilizing this web-based platform, T2I2 was designed to introduce, reinforce, and develop TDE educators' abilities in regard to the art and practice of teaching.

Research Hypotheses

This study's five investigational hypotheses address teachers in the pilot groups' abilities to manage, monitor, and adjust their learning environments; to develop reflective self-assessment strategies; and to increase contributions to the broader learning community.

Research Hypothesis 1: A teacher's ability to manage learning environments was deemed proficient following the use of the T2I2 professional development materials.

Research Hypothesis 2: A teacher's ability to monitor learning environments was deemed proficient following the use of the T2I2 professional development materials.

Research Hypothesis 3: A teacher's ability to adjust learning environments was deemed proficient following the use of the T2I2 professional development materials.

Research Hypothesis 4: A teacher's ability to contribute to the learning community was deemed proficient following the use of the T2I2 professional development materials.

Research Hypothesis 5: A teacher's ability to increase self-assessment was deemed proficient following the use of the T2I2 professional development materials.

The teachers' skills and abilities were documented through written and video artifacts, similar in design to artifacts developed for NBPT certification.

STUDY PARTICIPANTS AND METHODOLOGY

For the first year of the two-year pilot study (2012-2013), 190 applicants applied to participate from a five-state (Illinois, Kentucky, Ohio, North Carolina, and Virginia) list-serve recruitment. All candidates were middle or high school teachers identified as not holding Technology Education NBPT certification. From the applicant pool, eight middle school and eight high school teachers were randomly selected to participate in the first year of the pilot study. For the purposes of this research, these sixteen teachers agreed to: (a) complete 17 Learning Objects within the T2I2 curriculum and (b) submit artifacts/evidence of practice, upon the completion of this work. The 17 Learning Objects are clustered into the following four units: Demonstration Lesson, Fostering Teamwork, Assessment of Student Learning, and Documented Accomplishments. These units were based upon NBPTS' expectations. Learning Objects are modular lessons that contain materials and information created by a team of TDE NBPT-certified teachers, TDE teacher educators, and in-service veteran TDE K-12 educators. Learning Objects provide a research-informed basis for each topic through the "Impact on Learning" sections, a step-by-step implementation approach through the "Procedures in the Classroom" sections, and specific methods to identify if the process has been successfully implemented through the "Determine Success" sections. As teachers finish each Learning Object they complete a five-question post assessment quiz to check for understanding. Upon the completion of all Learning Objects within a unit, pilot teachers submitted written and/or video artifacts as evidence to document their abilities to implement newly learned practices. The post-assessment quizzes offered formative assessment to the research team. The assessment of the artifacts addressed the research hypotheses.

Teachers for the second year of the pilot study (2013 - 2014) were, once again, selected from the five project states. An additional sixteen pilot study teachers, eight middle school and eight high school, were randomly selected from 141 applicants. Teachers within this second pilot group agreed to complete the same tasks identified for the original group. For both pilot groups, teachers were introduced to the T2I2 website, resources, and project expectations through an introductory webinar run in early September of each academic year. Following the webinar, teachers were offered support from the T2I2 team through monthly email contacts and Skype office hours. Work for each pilot group was targeted to be completed by March of each year.

Quantitative research methods were employed to form the basis of this research using data from both pilot groups. Data collected includes the mean for each Learning Object's post-assessment and average number of attempts. Data addressing the five research hypotheses was derived from teacher artifacts, four written commentaries and two video commentaries, scored by an NBPT-certified teacher using an adapted rubric and four-point scoring system. Researchers used non-parametric statistical analysis to determine a teacher's ability to manage, monitor, and adjust the learning environment in his/her classroom; contribute to a learning community; and increase self-assessment.

This study was initially proposed as a treatment and control study. However, after negotiation with the sponsoring entity, it was determined that the project would be better poised to increase the treatment group to broaden impact. Based upon this guidance, a directional study was planned to examine teacher proficiency.

Instrumentation

The pilot teacher outcome data, in the form of teacher artifacts, were measured by NBPTS criterion-referenced metrics, targeting the teachers' abilities to manage, monitor, and adjust a learning environment to improve instruction; conduct self- assessment; and contribute to a learning community. The criterion-referenced metrics were organized around four entries where project Learning Object alignment has been achieved. The Learning Objects, grouped into units, are lessons that introduce and apply specific content, practices and pedagogy for participating teachers. A unit is a logical grouping of several individual Learning Objects. The pilot teachers were expected to complete all units, but, within the T2I2 system, the units do not have to be completed sequentially.

The scoring instances (n) varied depending upon the teacher artifacts submitted and determined to be complete by the project evaluation team. The research hypotheses, related units and Learning Objects, and NBPTS artifacts are found in Table 1. The first and fourth research hypotheses are addressed through evidence acquired from the written commentary and video artifacts submitted following completion of Learning Objects within the Demonstration Lesson unit. These Learning Objects introduce the following topics: Designing Standards-Based STEM, Lab and Class Management, and STEM Curricula. The second research hypothesis is addressed through evidence found within the written commentary and video artifacts following completion of the Fostering Teamwork unit that includes Learning Objects that introduce: Best Practices; Classroom Quality, Enhancing Classroom Creativity, Implementing Learning Activities Multiculturalism in the Classroom, and Working with Special Populations. Research hypothesis three is addressed following the teachers' submission of the written commentary after completing the Assessment of Student Learning unit that contains Learning Objects focusing on Action Research, Adapting Instruction, Data Analysis, Formative Evaluation Techniques, and Initial Student Evaluation. The final research hypothesis was addressed by analyzing evidence submitted by teachers in the form of a description and analysis, following the teachers' completion of the Documented Accomplishments unit that contains the Professional Organizations, School and Community, and Student Organizations Learning Objects.

An NBPT-certified assessor reviewed all of the submitted artifacts using an adapted four-point rubric ranging from (4) performance provides clear, consistent, and convincing evidence to (1) performance provides little or no evidence. The NBPTS metrics identifies teacher proficiency as (3) performance provides clear evidence. Teachers were provided written feedback from this review. Proficiency (3) was the level of performance identified within each directional research hypothesis.

TABLE 1: T2I2 teacher artifacts aligned with hypotheses, units, and learning objects

Hypotheses	*Unit and Learning Objects*	*NBPTS Artifacts*
Research Hypothesis 1: H0 - A teacher's ability to manage learning environments was deemed proficient following the use of the T2I2 professional development materials.	**Demonstration Lesson:** Designing Standards Based STEM; Lab and Class Management; STEM Curricula	Entry 2.1: Video Capture
Research Hypothesis 2: H0 - A teacher's ability to monitor learning environments was deemed proficient following the use of the T2I2 professional development materials.	**Fostering Teamwork:** Best Practices; Classroom Quality; Enhancing Classroom Creativity; Implementing Learning Activities; Multiculturalism in the Classroom; Working with Special Populations	Entry 3.1: Video Capture Entry 3.3: Written Commentary
Research Hypothesis 3: H0 - A teacher's ability to adjust learning environments was deemed proficient following the use of the T2I2 professional development materials.	**Assessment of Student Learning;** Action Research; Adapting Instruction; Data Analysis; Formative Evaluation Techniques; Initial Student Evaluation	Entry 1.4: Written Commentary
Research Hypothesis 4: H0 - A teacher's ability to contribute to the learning community was deemed proficient following the use of the T2I2 professional development materials.	**Demonstration Lesson:** Designing Standards Based STEM; Lab and Class Management; STEM Curricula	Entry 2.3: Written Commentary
Research Hypothesis 5: H0 - A teacher's ability to increase self-assessment was deemed proficient following the use of the T2I2 professional development materials.	**Documented Accomplishments:** Professional Organizations; School and Community; Student Organizations	Entry 4.1: Description and Analysis

Additional information and insight into the teachers' impressions and views about the project was gathered through interviews with the participating teachers. Teachers were emailed to schedule a brief phone interview. Interviews were conducted with select pilot teachers – both teachers who had completed all Learning Objects and units, and those who had not. While not all teachers had joined the project with the intention of becoming Nationally Board Certified, all teachers interviewed reported clear alignment of the learning objectives with NBPT requirements and found this to be an attractive characteristic of the project. Another positive aspect of participating in the project, noted by interviewed teachers, was access to the comprehensive resources provided through the project website. Teachers reported using these resources in their classrooms throughout the year.

DATA AND ANALYSIS OF FINDINGS

Data was analyzed utilizing quantitative research methods. The two years of pilot data was collected from the assessment of the teacher artifacts and analyzed as a test of hypothetical value conducted using the non-parametric Wilcoxon-signed-ranks Test. The five research hypotheses were tested to determine the teachers' abilities to monitor, manage, and adjust learning environments; contribute to learning communities; and increase self-assessment. The specified parameter for this study was a median ≥ 3 with 3 indicating a proficiency level as described and determined by NBPTS. The results of the data analysis for each of the five research questions are displayed in Table 2.

The Wilcoxon-signed-ranks Test was compared to the associated critical value based on the sample size of the participants. The participant data for the sample size was less than 50, denoting that no normal approximation with the continuity correction was necessary and the reported p-value is exact. The critical alpha value was set at 0.05 for this investigation (Noymer, 2008). The calculated p-values for the tests were determined to be larger than 0.05. The number of instances vary dependent on the number of constructs within each outcome variable.

All five research hypotheses were directional hypotheses described by the notation H1: $\Theta \geq 3$. Analysis of the pilot data resulted in the researchers failing to reject each positive directional hypothesis and suggests that participation in the T2I2 professional development sequence supports the educator's ability to monitor, manage, and adjust the learning environment; contribute to the learning community; and increase the teacher's self-assessment.

Although outside of the investigational hypotheses, teacher use and access data was also collected and analyzed as formative assessment and used for refinement of the Learning Objects within the four units. Teacher user data, seen in Table 3, included assessment scores and teacher trials. Data were collected using analytics features of the T2I2 professional development system online architecture. End-of-unit quizzes were offered as teacher participant "self-checks" to identify areas of developing competency. Each

TABLE 2: Research hypothesis examination using the Wilcoxon-signed-rank test

Research Hypothesis	*n = scoring instance possible*	*n for test*	*Median Est.*	*Wilcoxon Stat.*	*p-value*	*Method*
RH1	33	18	3.5	126	0.9476	Normal Approximation
RH2	33	24	3	88	0.9444	Normal Approximation
RH3	39	32	3	279	0.2377	Normal Approximation
RH4	37	26	3	67.5	0.9982	Normal Approximation
RH5	33	21	3	77	0.8684	Normal Approximation

TABLE 3: T2I2 professional development system teacher user data

Teacher User Data		
Units	*Mean Quiz Scores*	*Average Number of Attempts*
Assesment of Student Learning	94.50	4.50
Demonstration Lesson	100.00	3.83
Fostering Teamwork	98.46	3.15
Documented Accomplishments	97.78	3.22

quiz could be taken as many times as the teacher participant desired.

Teacher access data focused on total unit view, average unique unit views per day, and average time spent on the unit. Teacher access data were also collected using analytics features of the T2I2 professional development system online architecture. This enabled the materials development team to supplementally identify potential problem areas or specific information that was presented in a complex or inefficient fashion, warranting recurrent access or elevated duration. This data for the pilot is seen in Table 4.

The summer following the second pilot study was spent revising many aspects of the curriculum, from the number of pilot teachers to the content of the Learning Objects. Concentrated efforts modified Learning Objects within two of the four units: Assessment of Student Learning and Documented Accomplishments. These two units were the basis of the Field Study that was conducted during the 2015-2016 academic year.

Implications

Data analysis indicates that the sample population of teachers who completed T2I2 professional development was supported in their ability to manage, monitor, and adjust learning environments. The pilot group also increased its ability for self-assessment and its contributions to the learning community. The anticipated end product of this initiative is an evidence-informed system that broadens TDE teachers' instructional abilities.

Framing the coursework following coherent and national standards-based topics purposefully produced units and Learning Objects appropriate for the broader STEM in-service teacher population. Mean quiz scores greater than 94% suggest teacher competency following the completion of the Learning Objects. Total unit views ranging from 200 to 1000 demonstrate the frequency of use and entry into the system, suggesting teacher diligence in attending to the completion of this professional development.

From this study, the research team has evidence that job-embedded and flexible professional development supports the needs of in-service teachers in TDE education, and may meet the needs of teachers in other STEM disciplines. Teachers within the sample demonstrated that asynchronous learning promoted self-reflection resulting in more robust analysis of their practice.

The development of the T2I2 platform provided a venue for easy delivery of professional development content reinforced through networking and collaboration. Digital tools and platforms, like the one developed for this project, allowed for continuous customization, real-time access, and delivery to select and targeted populations (Zepeda, 2015). Teachers' classroom and professional practices were reinforced by leveraging the granular and repositionable teacher learning cyber infrastructure.

The first pilot year of the T2I2 project yielded changes and improvements for the subsequent pilot year. The various data collected show connections between the implementation of T2I2 and positive teacher classroom practices, though the low number of teacher participants does not allow results to be generalized to wider populations.

TABLE 4: T2I2 professional development system teacher access data

Teacher User Data			
Units	***Total Unit Views***	***Average Unique Unit Views per Day***	***Average Time Spent on Unit (seconds)***
Assesment of Student Learning	1001	3.65	203.4
Demonstration Lesson	395	1.59	170.2
Fostering Teamwork	376	2.00	359.4
Documented Accomplishments	205	0.95	176.2

CONCLUSIONS

Based upon this study, the authors recommend further development of this flexible professional development platform to not only address the busy schedules of in-service TDE teachers, but also to provide professional learning experiences for in-service teachers in related STEM disciplines. There are stark similarities to professional learning needs between technology and science education. Science educators face comparable pedagogical challenges and could benefit from similar professional development opportunities (Bybee, 2001). Given these similarities, this model and infrastructure provides a venue and platform that could serve as a tool for STEM educators to interact with each other, focusing on topics with common objectives. This would result in a more holistic educational experience for students, clearly following the course set by the Next Generation Science Standards.

The T2I2 platform and units created a robust network of TDE teachers. The next step for this networking may bring participating teachers' students together for cross-state collaboration, offering another opportunity to implement key educational outcomes developed within the Learning Objects.

The authors recommend continued teacher needs' assessments to identify additional topics for inclusion within the T2I2 units and Learning Objects. TDE educators come to the field with a variety of prior experiences that shape their learning needs pertaining to content and practice. The authors also recognize this diversity and suggest tailoring future T2I2 units and Learning Objects to meet these varied needs.

The current study focused on the TDE teachers' acquisition of the learning inherent within the T2I2 curriculum, considering in-progress data collection gauging: (a) how teachers use knowledge of their students to design assessments; (b) how assessment relates to course learning goals; (c) how problem-solving can be incorporated into assessment design; (d) how instructional development further fosters teamwork of students while establishing a safe and encouraging learning environment; and (e) and participation in professional activities and individual accomplishment. Further study could advance the teachers' implementation of acquired learning.

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Computer Science and Technology and Engineering Education: A Content Analysis of Standards and Curricular Resources

By Tyler S. Love and Greg J. Strimel

ABSTRACT

Recently there has been overwhelming political and financial support to include computer science (CS) in K-12 school curricula across the United States. With such strong support for CS it has been questioned where the subject would be best situated in already crowded K-12 curricula. Some have proposed integrating it within secondary level technology and engineering (T&E) courses (Ernst & Clark, 2007, 2009; Wright, Rich, & Leatham, 2012) or using CS courses in place of T&E education classes (Maryland State Department of Education [MSDE], 2016). To better inform decisions regarding CS in T&E education, this study used a multiple comparative case study (Yin, 2014) to analyze the alignment of subconcepts from the K-12 CS Framework with benchmarks from the International Technology and Engineering Educators Association's (ITEEA) Standards for Technological Literacy (STL). Additionally, a content analysis was conducted to examine curricular resources that claimed to teach CS concepts while addressing components of the STL's designed world. The purpose of the study was to investigate similarities and differences among both the CS and T&E standards and to identify curricular resources that successfully addressed multiple STL while integrating CS concepts. The findings revealed that there was limited alignment between the computational thinking and programming-focused CS framework and the broader engineering design and technology systems-focused STL. However, some curricular resources successfully used CS concepts to address many standards from the designed world section of the STL. From these findings, implications and recommendations for integrating CS within T&E education were provided.

Keywords: technology and engineering education, computer science, standards

INTRODUCTION AND BACKGROUND

Including computer science (CS) education within K-12 curricula in the United States has received increased support in recent years. This may be in response to the rapidly growing demand for preparing individuals to address critical issues such as cyber security attacks. Such support for CS has been demonstrated in various aspects. In 2016, President Obama introduced his "Computer Science for All" initiative. The goal of this new initiative was to empower all students from kindergarten through high school to learn CS concepts and be equipped with the computational thinking skills deemed necessary for success in a technological society. To achieve this goal, President Obama called for $4 billion in funding for states and $100 million directly for school districts to train teachers and expand access to CS (The White House, 2016). Also in 2016, the National Science Foundation (NSF) made $120 million available over five years and the Corporation for National and Community Service (CNCS) committed up to $17 million over a three-year period to support CS education (The White House, 2016). Furthermore, the Computer Science Education Coalition, composed of 43 members ranging from industry (i.e., Google, Amazon, Microsoft, and IBM) to nongovernment organizations (i.e., Computing Research Association and the Association for Computing Machinery), has actively encouraged Congress to invest millions of dollars in K-12 CS education (Computer Science Education Coalition, 2016). Since 2015, 20 state policies supporting CS education have successfully passed legislation and eight more state policies are pending as of 2016 (Code.org, 2016). As a result of this increased attention and support, programs, such as the Hour of Code, which is a series of one-hour online tutorials to introduce students to coding, have continued to develop. More than 200,000 educators worldwide now implement the Hour of Code program in their schools (Code.org, 2016).

Graduation Requirements

In response to the growing emphasis on the critical need for more student exposure to CS and the increased national support for K-12 CS education, various states that have allowed CS coursework to be used to fulfill high school graduation requirements. The number of states allowing CS to fulfill high school graduation requirements has increased from 12 in 2012 to 33 in 2016 (Code.org, 2016). The majority (20) of these states count CS courses to toward mathematics graduation credit requirements, whereas fewer states count CS courses as graduation credits in mathematics or science (10), science (1), mathematics or foreign language (1), and technology and engineering (T&E) (1) (Code.org, 2016). In addition to allowing CS coursework to fulfill high school graduation requirements, some states (Arkansas, Texas, and West Virginia) have passed legislation to require schools at various grade levels to offer at least one computer science course (Iowa and New Jersey are currently awaiting final signatures requiring all secondary schools to offer CS) and seven states have established CS standards (Code.org, 2016). Moreover, in 2016 Chicago Public Schools approved a policy requiring all high school students to complete CS coursework as one of their core graduation requirements (Chicago Public Schools, 2016).

Teacher Preparation

However, requisite to requiring CS course offerings and enabling CS courses to fulfill graduation requirements is finding qualified educators who are prepared to teach these courses. The New Hampshire Department of Education noted that the biggest challenge for their *CS for all New Hampshire* initiative has been recruiting and training teachers, because finding enough individuals to meet the demands for CS-related jobs and finding enough qualified individuals who will teach CS go hand in hand (Duffort, 2016). Wright, Rich, and Leatham (2012) also raised the concern for finding quality CS teachers by highlighting that there was a CS certification exam for high school teachers in some states but no general requirements for CS teacher certification in most states. The Computer Science Teachers Association (CSTA) (2013) also reported that two states require a certification or license to teach any CS courses, seven states require training to teach Advanced Placement (AP) CS courses, and 13 states offer a certification, licensure, or supplemental endorsement, but they do not require teachers to obtain these credentials to teach CS courses. Further complicating matters, the CSTA reported that CS courses in which the certifications or endorsements were offered, were often delivered via a variety of high school departments, which included CS, business, mathematics, T&E education, fine and practical arts, library science departments, and career and technical education (CTE) departments. In recognition of this, the K-12 CS Framework (2016) acknowledged the need to train educators for teaching CS and provided guidelines for professional development. The Framework suggested developing a CS teacher licensure exam for endorsement, instituting CS as a CTE pathway, or requiring CS as part of existing T&E education pathways.

Defining CS and T&E Education

T&E education (formerly technology education) has long battled the stigma of being mistaken for instructional or educational technology (Dugger & Naik, 2001; ITEEA, 2016). The K-12 CS Framework defined CS as “the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society” (Tucker et. al, 2006, p. 2), whereas T&E education:

> Includes major areas that have characteristics that define it and distinguish it from others. Some examples of major areas that could be included in a taxonomy of the designed world are medical technologies, agricultural and related biotechnologies, energy and power technologies, information and communication technologies, transportation technologies, manufacturing technologies, and construction technologies…they represent the dynamic and the broad spectrum of technology that permeates our world today. (Dugger & Naik, 2001, p. 31)

Regardless of the differences in the definitions, many people continue to confuse CS with T&E education. This was evident in Khoury's (2007) survey of 45 states, which found that many individuals did not have a clear definition or understanding of CS and confused it with technology education or industrial technology.

CS within T&E Education

Despite this confusion, some T&E education researchers have advocated for the inclusion of CS within T&E education. Clark and Ernst (2008) believed that incorporating CS was "a truly new way of seeing what technology education can do to support both state and federal initiatives in education" (p. 26), and that it would "allow for the integration of science and technological literacy to occur through the study of data visualization and the development of both virtual and physical models" (p. 21). Additionally, they found that CS could assist with drop-out rates, 21st-century skills (Clark & Ernst, 2008), and the development of scientific and technical visualization skills related to communications, medical, biotechnology, transportation, and energy and power technologies (Ernst & Clark, 2007, 2009).

Wright et al. (2012) declared that CS, specifically programming literacy, should be incorporated as part of T&E education and the STL "much like construction technology, manufacturing technology, medical technology, and so forth are included" (p. 6) because they "may increase critical-thinking and problem solving abilities" (p. 8). Wright et al. (2012) defined programming literacy as "being able to effectively, efficiently, and safely interact, use, and manipulate communication technologies" (p. 5), and highlighted that because technology is constantly evolving, new and effective technological areas, such as CS, should be integrated within T&E education. They believed that programming literacy had a significant relationship with many fields of technology and that the social, political, economic, and environmental impact has an affect on the world. Given the definition and applications of computer programming they suggested similar to Ernst and Clark (2007, 2009) that CS not be viewed as a replacement for T&E education, rather that it be considered and incorporated as one of the designed world components, specifically within information and communications technologies.

Policy Changes

The misconception that CS is the same as T&E education and the ambiguity of how to best integrate the two has had an effect on policy changes and instructional decisions made in some states. Specifically the state of Maryland is the only state to count CS toward the T&E education graduation requirement (Code.org, 2016), and there have been changes made by the Maryland State Department of Education (MSDE) that have affected what constitutes as T&E education coursework. In January of 2016, MSDE revised their technology education standards, which were based on the International Technology and Engineering Educators Association's (ITEEA) Standards for Technological Literacy (STL), to include CS with the addition of Standard 5, "Students will be able to apply computational thinking skills and computer science applications as tools to develop solutions to engineering problems" (p. 20). In addition to this new standard, MSDE also added a CS pathway to the list of preapproved courses that satisfied the T&E graduation requirement, giving school systems the option to offer CS classes in lieu of T&E education courses (MSDE, 2016, p. 6). However, Love, Dunn, and Tomlinson (2016) indicated that the CS classes that were preapproved by MSDE fell short of covering all core technologies (biotechnology, electrical, electronics, fluid, materials, mechanical, optical, structural, and thermal) and components of the designed world (medical/agricultural/biotechnology, energy and power, information and communication, transportation, and manufacturing and construction technologies) as mandated by the Code of Maryland (COMAR) 13A.04.01.01 (MSDE, 2016).

RESEARCH QUESTIONS

The preapproval to use CS courses in lieu of T&E education classes can be of concern for T&E education programs facing a critical teacher shortage (Love, Love, Love, 2016).

Furthermore, it can misrepresent T&E education as solely the use of computers, electronic devices, programming, and coding. As specified in COMAR (MSDE, 2016) and clarified by Dugger and Naik (2001), T&E education is focused on the broader scope of technology – providing technological literacy for all students while introducing them to the various core technologies, designed world components, and immersing them in the engineering design process. The different definitions of CS and T&E, yet the sometimes interchangeable use of CS for T&E courses led the researchers to develop the following questions to examine the relationship between the two content areas:

> *1. To what extent does each of the K-12 CS Framework subconcepts for grades 9-12 align with the STL benchmarks for grades 9-12?*
>
> *2. To what extent do select curricular resources integrate CS concepts in alignment with the designed world components of the STL?*

METHODOLOGY

To provide rigorous qualitative data examining the alignment of the standards, a multiple comparative case study (Yin, 2014) was conducted. A multiple comparative case study analyzes for similarities, differences, and patterns across two or more cases that share a common focus or goal. The researchers examined the high school K-12 CS Framework subconcepts as well as the high school benchmarks from the STL. The contents from each field were analyzed separately, and then those analyses were compared to reveal emerging similarities or differences. The researchers who performed the analyses had expertise in T&E teacher preparation and experience with writing T&E education curriculum. The researchers started by creating a chart with each of the K-12 CS Framework subconcept statements for grades 9-12; they then compared each subconcept with what was deemed to be the closest aligned STL benchmark(s) for grades 9-12. From these analyses emerged themes that reflected the comparative content from both sets of standards (Table 1). Each researcher analyzed the standards separately and then arbitrated the differences until a consensus was reached. To ensure accuracy of the interpretation of the CS framework, one graduate student with expertise in CS and one with expertise in electrical engineering reviewed the analysis and provided feedback that helped corroborate the results.

The researchers also analyzed a number of curricular resources they found throughout their research that claimed to teach CS and T&E education concepts. A content analysis was conducted to examine the literature and research presented on these curricular resources to determine what STL designed world components they covered. The result was a list of resources that demonstrated the use of CS as a tool to teach these designed world components. To corroborate the accuracy of the curricular resource analysis, the researchers had the author(s) of each resource review the description presented in Table 2 and incorporated their feedback.

FINDINGS

To answer the first research question, "To what extent does each of the K-12 CS Framework subconcepts for grades 9-12 align with the STL benchmarks for grades 9-12?" a multiple comparative case study analysis was conducted to compare the subconcept statements of the K-12 CS Framework to the closest aligned grade 9-12 benchmark(s) from the STL. Findings are presented in the analysis column of Table 1 on page 80.

TABLE 1: Comparative Content Analysis of the K-12 CS Framework and the STL

Comparative Content	*CS Subconcepts and STL Benchmarks*	*Analysis*
Interactions Among Technologies	CS: Devices STL: 3H - Relationships Among Technologies and the Connections Between Technology and Other Field	The CS framework was specific to computing devices integrated with other scientific, technological, or social systems, whereas the STL asserted that any type of technological innovation (not just those involving computers) could be applied within and among various technologies or across other fields.
Transfer of Information	CS: Hardware and Software STL: 17M - Information and Communication Technologies	Both emphasize the systems model, but the CS Framework is focused on software and hardware interactions for controlling and processing information while the STL were focused on the transfer of information and applications for the communication of many technologies (not only computer software and hardware).
Solving Problems	CS: Troubleshooting CS: Algorithms STL: 8H - Attributes of Design STL: 2Y – Core Concepts of Technology	Both are focused on using the engineering design process (EDP), but while the STL focused on using all phases of the EDP to create physical models and prototypes, the CS Framework only focused on a few of the EDP phases to produce prototypes of computational artifacts, such as programs, simulations, visualizations, and apps.
The Use of Computational Tools	CS: Program Development CS: Data and Analysis CS: Visualization and Transformation STL: 12P - Use and Maintain Technological Products and Systems	The CS Framework was focused on using computational tools and programs to perform calculations, process data, transform data, and transfer data, whereas the STL is focused on utilizing computers and calculation devices as technological tools to communicate data and inform designs to problems.
Networks	CS: Network Communication and Organization STL: 17O - Information and Communication Technologies	The CS Framework was focused on a more in-depth study of the topology or structure of computer networking systems while the STL broadly discussed how communication systems transfer information, not including the topography of networking systems.
Collection of Data	CS: Collection STL: 12P - Use and Maintain Technological Products and Systems	The CS Framework was concerned with computer and network-automated tools used to collect numerical data and the security of those data collection systems. The STL did not address data collection methods or data security, rather it focused on collection of data to inform engineering design practices, which was not limited to computers and automated tools.

Note. CS = K-12 Computer Science Framework (2016) subconcept; STL = Standards for Technological Literacy benchmark (ITEA/ITEEA, 2000/2002/2007).

Comparative Content	*CS Subconcepts and STL Benchmarks*	*Analysis*
Storage and Retrieval of Data	CS: Storage STL: 17O - Information and Communication Technologies	The CS Framework emphasized the specific processes for organizing data in relation to storing, accessing, and archiving information using computer and network systems whereas the STL focused on the broader view of how information is transferred through a communication system.
Representation of Data	CS: Visualization and Transformation STL: 17P - Information and Communication Technologies STL: 3H - Relationships Among Technologies and the Connections Between Technology and Other Fields	The CS Framework was focused specifically on the application of mathematical operations to transform and analyze data to be represented by computer software and programming while the STL emphasized various technologies (electronic and non-electronic) can be used to represent data and apply concepts from various fields (not just mathematical operations) to foster innovation.
Modeling	CS: Inference and Models STL: 11P - Apply the Design Process	CS Framework was focused on using computers to create data models for developing inferences and predictions to test and validate computer model data. The STL was focused on creating and evaluating various types of models throughout all phases of the engineering design process to not only predict but also evaluate design solutions not limited to computer generated or mathematical models.
Mathematical Applications	CS: Algorithms CS: Visualization and Transformation STL: 3J - Relationships Among Technologies and the Connections Between Technology and Other Fields	The CS Framework focused specifically on using computational systems and programs to perform calculations while the STL emphasized the application of both mathematical and scientific concepts to aid in engineering design decisions and advance various technologies (not limited to programming, software, and computers).
Structuring of Data	CS: Variables STL: 17Q - Information and Communication Technologies	The CS Framework emphasized programming knowledge and data structures as a means for improving programming and program efficiency, whereas the STL focused on visual, auditory, and tactile methods to effectively communicate data.
Determining Tradeoffs	CS: Control STL: 4I - The Cultural, Social, Economic, and Political Effects of Technology	The CS Framework focused on considering the tradeoffs specifically related to choice of programming language for control structures, however the STL focused on the broader global, environmental, cultural, safety, societal, and economical tradeoffs associated with various technologies beyond programming.

Note. CS = K-12 Computer Science Framework (2016) subconcept; STL = Standards for Technological Literacy benchmark (ITEA/ITEEA, 2000/2002/2007).

TABLE 1: Comparative Content Analysis of the K-12 CS Framework and the STL (Continued)

Comparative Content	*CS Subconcepts and STL Benchmarks*	*Analysis*
Systems Approach	CS: Modularity STL: 2Y – The Core Concepts of Technology	The CS Framework focused on systems design using programming language for software applications, module relationships, and program management while the STL focused on systems thinking related to natural and manmade control systems related to many technologies, beyond software applications and programming.
Societal Access to Technology	CS: Culture STL: 4K - The Cultural, Social, Economic, and Political Effects of Technology	The CS Framework focused on the design of computing technologies and artifacts to provide equitable societal access to such technologies while the STL focused on the broader cultural, social, economic, and political effects that various forms of technology have on society.
Greater Societal Impact	CS: Cybersecurity CS: Social Interactions STL: 4I - The Cultural, Social, Economic, and Political Effects of Technology STL: 4K - The Cultural, Social, Economic, and Political Effects of Technology STL: 17N - Information and Communication Technologies	The CS Framework emphasized that computing and network security measures have helped to connect people from different cultures and career fields while considering tradeoffs between accessibility and security. The STL focused on the various uses of many types of communication systems and the decision making process to consider both positive and negative global, environmental, cultural, safety, societal, and economical trade-offs of technologies.
Safety and Ethics	CS: Safety, Law, and Ethics STL: 9L - Engineering Design	The CS Framework focused on legal issues and tradeoffs related to computing, specifically Internet usage, whereas the STL focused on a broader scope of safety and ethical issues that affect society such as safety, reliability, economic considerations, quality control, environmental concerns, manufacturability, maintenance and repair, and ergonomics.

Note. CS = K-12 Computer Science Framework (2016) subconcept; STL = Standards for Technological Literacy benchmark (ITEA/ITEEA, 2000/2002/2007).

To answer the second research question, "To what extent do select curricular resources integrate CS concepts in alignment with the designed world components of the STL?" the researchers conducted a content analysis of courses they discovered during their research that claimed to teach both T&E and CS concepts. The curricular resources presented in Table 2 were ones that the analysis found to demonstrate the best use of CS as a tool for teaching various designed world components (Table 2).

TABLE 2: Curricular Resources that Addressed Components of the STL Designed World Using CS

Curricular Resource	*Description*	*STL Designed World Components*
Precision Farming	The FarmBot is an example of an open-source CNC system operating from Arduino and Raspberry Pi coding that makes precision farming possible (Lentz, 2016). Teachers can work with students to create a track structure (structural and manufacturing technologies) and program (information and communication systems) for more efficient crop growth (agricultural and biotechnology).	A, C, E, I, Ma
Microcomputers and Sensors (e.g., Raspberry Pi)	Love, Tomlinson, and Dunn (2016) provided a wealth of instructional resources for utilizing programming to control various sensors and solve authentic engineering design challenges such as a smart house.	C, E, I, Ma, T
Scientific and Technical Visualization I & II	These standards-based curricula by ITEEA (p. 7) are focused on using complex graphic and visualization tools such as graphics and animation software to illustrate, explain, and present technical, mathematical, and scientific concepts. Ernst and Clark (2007) demonstrated learning gains related to the various designed world components as a result of these curricula.	A, C, I, Ma, Me, T
Game Art and Design	This standards-based curricula by ITEEA (p.7) teaches students about the basics of game theory and strategic thinking to create a working prototype of a board game. In this curricula, students learn basic knowledge and skills that relate to fundamental programming concepts associated with the industry. Lesson topics such as probability and Nash Equilibrium have proven to be important in many fields of learning including biology, computer science, politics, agriculture, and economics. Ernst and Clark (2007) found this curriculum to be very engaging while addressing many technology and science standards.	I
Cyber Security	This unit from ITEEA's Advanced Technological Applications (ATA) curriculum was developed in collaboration with the U.S. Naval Academy and addresses an array of science, technology, engineering, and mathematics (STEM) standards. Current research efforts (NSF, 2015) are examining the learning of cyber security through representational fluency, which is a powerful tool to teach complex concepts in science and mathematics.	I
Advanced Manufacturing	Loveland (2012) demonstrated how learning basic G & M code promotes higher order technology and mathematics thinking. Students must apply advanced math and technological problem solving skills to operate computer numerical control (CNC) lathes, milling machines, and routers. Even if schools do not have these advanced manufacturing machines, students can still simulate the manufacturing process through Computer Aided Manufacturing (CAM) software.	I, Ma
Robotics	There are various robotics curricula available that can be beneficial to student learning, for example, as Berenguel et al. (2015) demonstrated. Those that go beyond kits, and require students to design and construct their own robotic systems apply many STEM skills. Additionally, they integrate programming with engineering design to solve problems related to many of the designed world components.	C, E, I, Ma, T

Note. STL = Standards for Technological Literacy benchmark (ITEA/ITEEA, 2000/2002/2007); A = agricultural and biotechnology; C = construction; E = energy and power; I = information and communication systems; Ma = manufacturing; Me = medical; T = transportation

DISCUSSION

Even though the content analyses revealed similarities and differences among subconcepts and benchmarks, and the standards addressed by certain curricular resources, a few limitations should be acknowledged. The benchmarks in Table 1 were those the researchers selected as the best aligned based on their analysis of the STL. It is also important to note that the researchers did not have access to information about all CS curricula, for example, the recently released Project Lead the Way (PLTW) CS pathway. The analysis presented in Table 2 did not examine the content of specific lessons and units within the curricula, only descriptions and previous research findings related to those curricula were analyzed.

From the comparative content analysis presented in Table 1, it is clear that there were differences in how technology was viewed in both the K-12 CS Framework and the STL. The CS Framework was more narrow in scope regarding technology, focusing primarily on an in-depth study of computers, electronic devices, programming, and computational thinking; in comparison, the STL had used a broader perspective of the various technologies across all industries that affect the world (medical, agricultural and biotechnology, energy and power, information and communication, transportation, manufacturing, and construction technologies). Although the STL acknowledged that electronic technologies such as computers are important, they also indicated it is not the only technology that students must understand how to analyze, design, and troubleshoot. This difference in technological content presented a challenge for analyzing two of the CS subconcepts (cyber security and data collection) that did not fully align with a STL benchmark. Cyber security was included in the Greater Societal Impact category because it had a similar focus. Also, as mentioned in the analysis column, there was no specific STL benchmark that fully aligned with the CS subconcept of data collection. This benchmark issue highlighted that both the CS Framework and the STL had different strengths for different purposes, and they were not fully aligned between each subconcept and benchmark.

Regarding the design processes, the CS Framework emphasized the importance of the design process and troubleshooting, but it did not provide the specific procedures of engineering design, which are core components of T&E education. However, according to the Framework, researching, evaluating, troubleshooting, and implementing potential solutions were discussed. Examples that the framework provided of complex problem solving strategies included: computer-focused issues, such as resolving connectivity problems, adjusting system configurations and settings, ensuring hardware and software compatibility, transferring data, and identifying the effects of lingering bugs. In contrast, the STL focused more on the practices of design processes and engineering design, such as defining the problem, brainstorming, researching and idea generation, criteria identification and constraint specification, possibility exploration, approach selection, design proposal developments, model or prototype, making and testing, and the evaluation of design using specifications, redefinition, creation, communicating processes and results. The STL also emphasized the broader applications of engineering design to develop solutions and functional physical prototypes in order to answer technological problems beyond specific electronic issues.

Furthermore, the CS Framework and STL may differ in their alignment to other content areas. Only in the *Devices* subconcept statement did the CS Framework mention a connection to science practices, citing integration of computing devices with biological systems. However, mathematics connections such as algorithms, variables, data visualization and transformation, and computational modeling were embedded throughout the framework. In contrast, the STL provided examples of the relationships between mathematics, science, and other content areas to inform technological innovation. For example, Standard 5 described specific scientific examples regarding the effects of technologies on the environment, and Standard 16 cited explicit connections between technologies, energy, and power concepts, such as conservation of energy and thermodynamics. The STL also advocated for T&E educators to integrate content from other areas in order to provide a more holistic experience to learning science, technology, engineering, and mathematics (STEM) (p. 6). The findings described above may be the reason that most states classified CS classes as a mathematics requirement rather than a T&E education graduation requirement.

The second research question revealed that though the CS Framework and the STL may have had different foci, some curricular resources demonstrated the possibility to use CS as a teaching tool for components of the STL designed world as suggested in the literature (Ernst & Clark, 2007, 2009; Wright, Rich, & Leatham, 2012). Using this approach would align educators with MSDE technology education Standard 5 which dealt with the application of computational thinking skills and CS as tools to develop solutions to engineering problems. Each resource in Table 2 covered multiple designed world standards. This content analysis demonstrated that when planned properly, CS concepts can be integrated in T&E education courses as a tool for teaching about various components of the designed world and creating engineering design solutions while also developing students' computational thinking skills. These findings provide a hopeful outlook for integrating CS and T&E education, while still promoting technological and engineering literacy for all students.

CONCLUSIONS

From the analyses it became evident that there were differences between the K-12 CS Framework and STL, specifically the narrow versus broad views of technology. Despite these differences the content analysis revealed there are successful curricular resources that have utilized CS as a tool to teach multiple components of the designed world portion of the STL and CS concepts. Given these examples, T&E educators should view CS as a tool to engage students and teach T&E content and practices while integrating CS concepts in an authentic engineering context. Integrating CS in T&E does not come without reservations though. As indicated in the review of literature, some policy makers and administrators may confuse CS with T&E education, despite differences among the definitions, the subconcepts, and the benchmarks. It is critical that T&E educators communicate these differences and demonstrate ways that T&E uses CS to solve engineering problems beyond simply electronics, information, and communication technologies. Applications of CS in an authentic engineering design context can highlight both the similarities and differences between CS and T&E education, and may help in maintaining a more comprehensive technological and engineering focus that can introduce students to numerous career and college options, beyond those focused solely on computers and electronics.

Implications and Recommendations

A number of implications and recommendations for researchers and practitioners can be drawn from this study. It must be noted that this research only examined the standards and curricular resources from a surface level; therefore, to better understand how specific CS courses can be implemented nationwide (e.g., Advanced Placement CS, PLTW CS pathway) further research is needed to examine to what extent the objectives, units, lessons, and other instructional resources align with the STL. Analyzing courses at this level may provide a deeper understanding of how CS is being applied to meet the STL and help all students achieve technological and engineering literacy. Moreover, because this study determined that CS can be used as a tool to teach T&E concepts, further research is warranted to examine how CS can be integrated with the designed world components of the STL. Wright et al. (2012) suggested that CS could be included within Standard 17 because programming is a form of communication technology. However, as a result of the findings, it is recommended that T&E teachers work to develop rigorous STEM curricula in collaboration with CS, science, and mathematics educators to serve as a bridge between CS and STEM education. In addition, the researchers of this article recommend that programs for T&E teacher preparation strive to integrate CS concepts within engineering design coursework and link CS applications to the learning of communications and electronics in T&E courses.

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