



Cyber-supported Professional Learning Experiences that Build Technology and Engineering Educators' Practice

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ABSTRACT

Educational changes due to school reform and the introduction of new national standards create a need for professional learning experiences for STEM (Science, Technology, Engineering, and Mathematics) educators that are results-driven, easily accessible, and aligned with identified best practices (National Research Council, 2009; National Staff Development Council, 2001). This need, specifically addressing technology and engineering educators, generated the development and delivery of the *Transforming Teaching through Implementing Inquiry* (T2I2) project. Within the T2I2 development stage, learning objects were created to introduce, reinforce, and broaden technology and engineering educators' conceptual content and pedagogical content knowledge to inform and impact their personal teaching practice. To deliver this instruction, a cyber infrastructure was created to support content development, assessment, community building, and cyber-coaching.

This field study followed the methodology established within T2I2's two-year pilot study (Ernst, Segedin, Clark, & DeLuca, 2014), selecting participants from the identified five-state region (IL, KY, OH, NC, and VA) and requiring these participants to complete T2I2 learning objects and accompanying written and video artifacts. Submitted artifacts were analyzed using the non-parametric Wilcoxon-signed-ranks Test, providing evidence that suggested that the field study teachers demonstrated proficient abilities to contribute to a learning community; manage, monitor, and adjust learning environments, and increase their self-assessment. The combined pilot and field test studies provide evidence to support expanding the development and use of the T2I2 model for science educators for a more interdisciplinary approach to STEM professional learning experiences.

keywords: teacher learning, technology and engineering education, web-based professional development

INTRODUCTION

In this era of school reform and new national standards, professional development for educators is a key factor in building teacher confidence and competences (Dede, Ketelhut, Whitehouse, Breit, & McCloskey, 2009). National STEM education initiatives cite the need and importance of professional learning opportunities for Science, Technology, Engineering, and Mathematics (STEM) educators, but the instructional support offered to these educators varies in quality and effectiveness (National Research Council [NRC], 2009). Professional learning experiences for technology and engineering teachers are often found to be deficient and less robust than professional development for teachers in other STEM disciplines (DuBois, Farmer, Gomez, Messner, & Silva, 2009; Li, Ernst, & Williams, 2015; National Academy of Engineering & NRC, 2009). The lack of effective professional development for technology and engineering educators is further accentuated by a shortage of licensed and certified teachers for this discipline (National Board for Professional Teaching Standards [NBPTS], personal communication, October 2012). As states adopt the *Next Generation Science Standards* (NGSS), there will be increased demands for professional development for STEM educators to address changes in content and pedagogy that integrate science content with engineering practices and promote inquiry- and design-based teaching and learning (NRC, 2015).

A lack of effective professional development for some and increased needs to shift instruction for all, require the development of and easy access to results-driven, job-embedded professional learning experiences (National Staff Development Council [NSDC], 2001). Professional development that changes teacher practice must build a community of learners and be flexible, practical, and focused on content and strategies that can be immediately implemented within classroom settings (Li et al., 2014; Garet, Porter, Desimone, Birman, & Yoon, 2001; NSDC, 2001; Schlang, 2006;

Weiss & Pasley, 2006). Traditional models of professional development can be costly, time consuming, and often an added burden to teachers' already over-stretched commitments (Dede et al., 2009). Today's educators need professional learning experiences that can merge with existing expectations, incorporate resources that may not be readily accessible, and offer a supportive learning community that provides real-time, continuous, classroom-based support. Professional development provided through an online setting provides this framework for learning and, through asynchronous online discussions, a platform for self-reflection, collaboration, networking, and shared resources (Almendarez-Cadena, 2014; Dede et al., 2009; Zepeda, 2015).

The need for quality and easily accessible professional learning opportunities for technology and engineering educators was the impetus behind the development and delivery of the *Transforming Teaching through Implementing Inquiry* (T2I2) project. T2I2's first goal in addressing this need was to develop learning experiences that reinforced and broadened technology and engineering educators' conceptual understanding, teaching practices, and pedagogical content knowledge. Specific content and practices, identified from *the National Board for Professional Teaching Standards (NBPTS) for Early Adolescence through Young Adulthood (EAYA) Career and Technical Educators*, framed the T2I2 professional learning experiences for secondary technology and engineering educators (Pearson, 2012). The T2I2 structured and practice-driven experiences, known as Learning Objects, encouraged and modeled ways for technology and engineering educators to improve their classroom instruction, participate in professional activities, and increase student learning.

An equally important goal for the T2I2 project was to develop a cyber infrastructure to support the delivery of the newly developed web-based resources and materials. Within this system, documents and teacher artifacts were easily shared. All stakeholders benefited from the system architecture that allowed for easy authoring, publishing, assessment, community building, self-reflection and cyber coaching. Achieving both goals was critical to the success of the T2I2 project.

The instructional design of the T2I2 Learning Objects, paired with the web-based learning environment, resulted in the implementation and delivery of professional development that changed teacher practice (Segedin, Ernst, & Clark, 2013). The T2I2 research supports the premise that effective instructional design and an efficient and effective technical infrastructure can substantially impact the success and acceptance of online learning (Cheawjindakarn, Suwannattachote & Theeraroungchaisri, 2012).

RESEARCH HYPOTHESES

A two-year field study within the T2I2 project followed a two-year pilot study. The scope and results of the pilot study are described within the article, *Flexible and Job-Embedded Professional Development for In-Service Technology, Design, and Engineering Educators* (Ernst, Clark, & Bowers, 2017). The pilot study was formative in design resulting in revisions and improvements to content within some Learning Objects, self-assessment tools and user features within the cyber infrastructure. The two-year summative field study, informed by the pilot study, provided the setting to verify the effectiveness of both the design materials and delivery infrastructure. Five investigational hypotheses framed both the pilot and field study.

- Research Hypothesis 1: H_0 - A teacher's ability to *manage* learning environments was deemed proficient following the use of the T2I2 professional development materials.
- Research Hypothesis 2: H_0 - A teacher's ability to *monitor* learning environments was deemed proficient following the use of the T2I2 professional development materials.
- Research Hypothesis 3: H_0 - A teacher's ability to *adjust* learning environments was deemed proficient following the use of the T2I2 professional development materials.
- Research Hypothesis 4: H_0 - 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: H_0 - A teacher's ability to *increase self-assessment* was deemed proficient following the use of the T2I2 professional development materials.

Field study teachers paralleled the work of the pilot study teachers. Both groups completed T2I2 professional development modules and responded to the same performance assessments that required the completion of written and video artifacts. The performance assessments and artifacts mirrored the evidence required of teachers applying for National Board *Certification for (EAYA CTE)* and provided insight into the field study teachers' abilities to manage, monitor, and adjust their learning environments; develop reflective self-assessment strategies; and increase contributions to the broader learning community (Pearson, 2012).

STUDY PARTICIPANTS AND METHODOLOGY

The researchers refined and enhanced the learning environment and instructional design of the T2I2 project based upon user feedback and analytic data from the pilot study. Following the protocols within the methodology of the pilot study, middle and high school teachers for two field study groups were recruited from the project's five-state region (Illinois, Kentucky, Ohio, North Carolina, and Virginia). As part of the requirements for participation, none of these teachers held Technology Education National Board certification.

The first field study group was composed of five middle and eight high school teachers (grades 6 - 12). Similar to the pilot group, this field study group agreed to: (1) complete all 18 Learning Objects within the four T2I2 curricular units and (2) to submit written and video artifacts following the completion of each unit.

Six participants, one middle and five high school teachers, were involved in the second field study and agreed to a streamlined task. They were asked to: (1) complete only eight of the 18 Learning Objects within two T2I2 curricular units; and then (2) submit the corresponding written and reflective artifacts. This group's work targeted two units that had major revisions based upon formative feedback from teachers within both the pilot and first field study groups.

The T2I2 Learning Objects addressed topics identified for *EAYA CTE National Board Certification* and were originally developed by a team of technology and engineering

Nationally Board Certified teachers, technology and engineering teacher educators, and veteran in-service technology and engineering K-12 educators. Following a uniform design, each Learning Object included (1) a research-informed section addressing each topic's "Impact on Learning"; (2) step-by-step suggestions for implementation in the "Procedures in the Classroom" section and; (3) strategies to check for successful implementation within the "Determine Success" section.

A summative five-question post-assessment quiz was included in each Learning Object to check for the teachers' baseline understanding. Upon the completion of the Learning Objects within each unit, teachers' abilities to apply newly learned practices were demonstrated through written and/or video artifacts. These artifacts provided evidence that addressed the research hypotheses for both the pilot and field studies. All work within T2I2 was asynchronous once participants completed an introductory webinar. This webinar familiarized teachers to the T2I2 website, resources, deadlines, and project goals. Monthly virtual office hours and frequent emails from the researchers offered encouragement and assistance to the field study groups. Each field study followed the academic year, beginning in September and ending by May.

Data collection and analysis for the field study followed the pilot study's methodology. Data was combined from both field study groups, resulting in a sample of 19 educators, and it was analyzed using quantitative research methods. The submitted written and video artifacts were scored by a National Board Certified teacher using a four-point scoring system and modified rubric. Results from this assessment, statistically analyzed using non-parametric procedures, provided data that addressed the five research hypotheses. Teachers' user data, related to the summative post-assessments, and teacher access data, analyzing the time spent on each unit, provided feedback regarding the learning environment.

The initial research approach for the T2I2 project suggested a treatment and control study. Guidance from the sponsoring entity, however, resulted in modifying the original approach and proceeding with the described directional studies for both the pilot and field studies.

INSTRUMENTATION

Following the pilot study's protocol, criterion-referenced metrics of the NBPTS were used to assess and measure the field study teachers' written and video artifacts, providing feedback as to the teachers' abilities to conduct self-assessment, contribute to a learning community, and improve their instruction by managing, monitoring, and adjusting a learning environment. These artifacts reflected teaching practices related to the specific content and pedagogy introduced to the field study group through the T2I2 Learning Objects.

Each of the 18 Learning Objects addressed a particular topic. Learning Objects were grouped into four units based upon common themes and NBPTS assessment criteria. The teacher artifacts were completed and submitted upon the completion of each of the units. Participants within the first field study group were expected to complete all units. This work is organized within Table 1.

TABLE 1: First field study group's artifacts aligned with unit, learning objects, and hypotheses

Artifacts	Unit	Learning Objects	Research Hypotheses
Entry 2.1: Video Capture	Demonstration Lesson	Designing Standards Based STEM; Lab and Class Management; STEM Curricula	Research Hypothesis 1: H_0 - A teacher's ability to <i>manage</i> learning environments was deemed proficient following the use of the T2I2 professional development materials.
Entry 2.3: Written Commentary	Demonstration Lesson	Designing Standards Based STEM; Lab and Class Management; STEM Curricula	Research Hypothesis 4: H_0 - A teacher's ability to contribute to the learning community was deemed proficient following the use of the T2I2 professional development materials.
Entry 3.1: Video Capture & Entry 3.3: Written Commentary	Fostering Teamwork	Best Practices; Classroom Quality; Enhancing Classroom Creativity; Implementing Learning Activities; Multiculturalism in the Classroom; Working with Special Populations	Research Hypothesis 2: H_0 - A teacher's ability to <i>monitor</i> learning environments was deemed proficient following the use of the T2I2 professional development materials.
Entry 1.4: Written Commentary	Assessment of Student Learning	Action Research; Adapting Instruction; Data Analysis; Formative Evaluation Techniques; Initial Student Evaluation	Research Hypothesis 3: H_0 - A teacher's ability to <i>adjust</i> learning environments was deemed proficient following the use of the T2I2 professional development materials.
Entry 4.1: Description and Analysis	Documented Accomplishments	Professional Organizations School and Community; Student Organizations	Research Hypothesis 5: H_0 - A teacher's ability to increase self-assessment was deemed proficient following the use of the T2I2 professional development materials.

Teachers in the second field study group completed only two of the four units, depicted in Table 2. Both tables show the pairing of Learning Objects with artifacts required for each entry and indicate how this evidence matches the research hypotheses.

For statistical analysis, the scoring instances (*n*) varied depending upon the entry, due to the fact that there was a supplemental field study for two of the units. As seen within Table 1, the artifacts submitted upon the completion of all Learning Objects within the Demonstration Lesson Unit provided evidence to address the first and fourth research hypotheses. The artifacts provided for this entry addressed the NBPTS criterion metrics pertaining to explanation and demonstration of progression steps, interaction with students as they perform demonstrated skills, and monitoring performance while providing feedback and addressing student questions.

Completion of the Fostering Teamwork Unit and subsequent written and video entries provided

data to address the second research hypothesis. This entry aligns with the NBPTS criterion metrics pertaining to explanation of the specific application in which students are engaged, support of student teamwork and student communication skills, monitoring performance while providing feedback and addressing students' questions.

As seen with Tables 1 and 2, the artifacts submitted upon the completion of all Learning Objects within the Assessment of Student Learning Unit provided evidence regarding teachers' abilities addressed within the third research hypothesis. This entry incorporated NBPTS criterion metrics pertaining to knowledge of students in designing assessments, relation of assessments to course learning goals, problem-solving in assessment design, assessment related to workplace practice and career exploration, and assessment in shaping teaching practices for the purpose of adjusting instruction.

TABLE 2: Second field study group's artifacts aligned with unit, learning objects, and hypotheses

Artifacts	Unit	Learning Objects	Research Hypotheses
Entry 1.4: Written Commentary	Assessment of Student Learning	Action Research; Adapting Instruction; Data Analysis; Formative Evaluation Techniques Initial Student Evaluation	Research Hypothesis 3: H_0 - A teacher's ability to <i>adjust</i> learning environments was deemed proficient following the use of the T2I2 professional development materials.
Entry 4.1: Description and Analysis	Documented Accomplishments	Professional Organizations School and Community; Student Organizations	Research Hypothesis 5: H_0 - A teacher's ability to increase self-assessment was deemed proficient following the use of the T2I2 professional development materials.

The fifth research hypothesis was addressed through the assessment of the artifact submitted once both field study groups completed all Learning Objects within the Documented Accomplishments Unit. This entry incorporated NBPTS criterion metrics pertaining to how the teacher had strengthened practice through professional development, shared expertise with others, including within both the education and the community settings, engagement of parents and other adults in communication, and improvement strategies.

All submitted artifacts were reviewed by the same National Board certified assessor using a modified four-point rubric. Participants' abilities were assessed on a continuum ranging from (4) clear, consistent, and convincing evidence to (1) little or no evidence. The level of teacher performance expected for each research hypothesis was (3), proficient. Based on artifact

assessment throughout the pilot and field studies, improvements were made to the T2I2 System Architecture to assure ease of use for researchers, developers, assessors, and teacher participants.

The project infrastructure provided an internal site which allowed for creating and packaging Professional Development Learning Objects, delivering and sharing documents and edited improvements, and evaluating teacher learning, all within a dedicated project website. Figure 1 depicts the T2I2 System Architecture. The project website gave writers, contributors, and participating teachers access to the site. All resources were cloud-based allowing for authoring, publishing, delivering assessment, community building and cyber coaching. Modifications to the cyber infrastructure streamlined the teacher interface and increased the frequency of cyber coaching, with little changes to the base System Architecture.

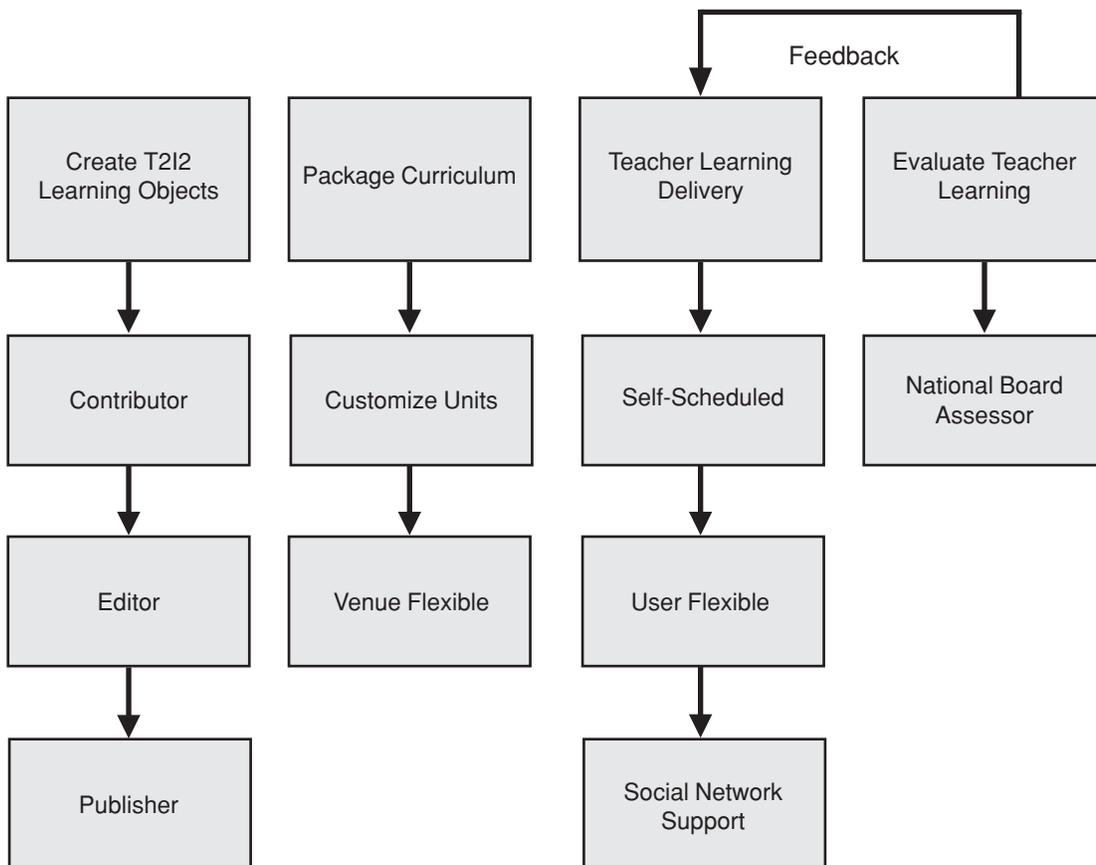


Figure 1. T2I2 System Architecture

DATA AND ANALYSIS OF FINDINGS

All data was analyzed following the same quantitative research methods employed for the pilot study data. Teachers' artifacts from both field study groups were reviewed and assessed. The non-parametric Wilcoxon-signed-ranks Test, a test of hypothetical value, was used to analyze the participants' assessment scores. This analysis provided evidence to address the five research hypotheses that targeted the teachers' abilities to contribute to learning communities; monitor, manage, and adjust learning environments; and increase self-assessment.

As stated previously, an assessment score of 3 indicated a teacher's abilities as "proficient," according to the NBPTS scoring rubric. With this in mind, a median ≥ 3 was the specified parameter for this field study. Table 3 displays the results of the Wilcoxon-signed-rank Test of hypothesis for the five directional research hypotheses. Data from the two combined years reflects the participation of 19 educators.

Analysis of the data compared the Wilcoxon-signed-ranks Test to the related critical value associated with the sample size of the data generated by the participants. The sample size was less than 50, indicating no need for normal approximation with the continuity correction. The reported p -value is exact with a critical alpha value set at 0.05 for this study (Noymer, 2008). As noted in Table 3, the number of instances varied based upon each outcome variable's number of constructs.

The research hypotheses were all directional identified by the notation $H_1: \Theta > 3$. Based upon the analysis of each set of data, the researchers failed to reject each positive directional hypothesis. The data suggests that the field study teachers' participation in the T2I2 professional learning experiences supported their ability to contribute to the learning community; manage, monitor, and adjust the learning environment; and increase their self-assessment.

The researchers were also interested in gathering information about the T2I2 web-based learning environment through the collection and analysis of teachers' user and access data. Comparisons of the pilot and field study teacher user data, which includes quiz scores and teacher trials, can be found in Table 4. Field study participants'

mean quiz scores were somewhat lower than those of the pilot group and their average number of attempts for the quizzes were also lower. This suggests that the teachers were using the quizzes as quick self-check formative assessment tools, as was intended by the researchers.

Teacher access data considered the average time teachers spent on each unit. A comparison of both the pilot and field study groups' results can be seen in Table 5. As the user interface was enhanced based upon pilot teacher feedback, teachers devoted more time to each unit. The data suggests that the platform supported and encouraged participants' authentic use of the provided instructional materials.

Implications

This summative assessment reinforced the pilot study findings that the T2I2 professional development supported participating educators' abilities to manage, monitor, and adjust their learning environments; increased their ability for self-assessment, and increased their contributions to the learning community. Although the schema of the study targeted technology and engineering educators, the topics of the T2I2 Learning Object lend themselves to each of the STEM disciplines. Notable commonalities among the STEM practices support the development of interdisciplinary T2I2 teacher learning materials. To move the project in this direction, a parallel portfolio of science T2I2 Learning Objects are currently under development. The science T2I2 learning experiences are framed by the *Next Generation Science Standards* (NGSS) and will support educators to develop design-based teaching practices. The prototype science Learning Objects will be delivered utilizing the T2I2 web-based architecture and utilized with both pre-service and in-service science educators.

The asynchronous, easily accessible, web-based resources provided flexible and job-embedded professional development for the participating in-service teachers. The design of the T2I2 resources allowed for self-paced learning utilizing a platform that promoted networking and collaboration. Successes within this project should inform future professional development opportunities and leverage lessons learned from both curricular and infrastructure design.

TABLE 3: Wilcoxon-signed-rank test of hypotheses

Research Hypothesis	<i>n</i> = scoring instances possible	<i>n</i> for test	Median Est.	Wilcoxon Stat.	p-value	Method
RH1	19	13	3	30	0.4122	Normal Approximation
RH2	19	13	3	56	0.2141	Normal Approximation
RH3	19	19	3	15	0.9254	Normal Approximation
RH4	19	13	3	3	0.932	Normal Approximation
RH5	19	19	3	12	0.8364	Normal Approximation

TABLE 4: Pilot and field study teacher user data

Units	Mean Quiz Scores		Average Number of Attempts for the Quiz	
	Pilot Group	Field Study Group	Pilot Group	Field Study Group
Assessment of Student Learning	94.50	88.21	4.50	2.25
Demonstration Lesson	100.00	93.85	3.83	1.75
Fostering Teamwork	98.46	92.31	3.15	1.72
Documented Accomplishments	97.78	79	3.22	5

TABLE 5: Pilot and field study teacher access data

Units	Average Time Spent on Unit (minutes)	
	Pilot Group	Field Study Group
Assessment of Student Learning	3.38	24.19
Demonstration Lesson	2.84	20.67
Fostering Teamwork	5.99	16.72
Documented Accomplishments	2.94	17

CONCLUSIONS

The pilot and field study data supports continued use of the T2I2 flexible professional development resources and infrastructure.

This platform could be a tool to deliver online asynchronous professional learning to all STEM educators. The Learning Objects, while initially developed to address the professional development needs of technology and engineering educators, frame cross-STEM discipline best practices. The commonalities among STEM disciplines and similar professional development logically leads to developing interdisciplinary T2I2 Learning Objects that model the integration of STEM content and practice.

The T2I2 system architecture and cyber infrastructure provides a tested platform and tool for online asynchronous professional learning experiences. This system has proven to be flexible and easily accessible for content developers, researchers, course facilitators, and participants. The platform and shared learning experiences developed a powerful community of technology and engineering educators. This community of learners would be strengthened by the inclusion of science and mathematics educators to truly develop an integrative STEM community of learners.

The authors recommend developing and implementing pre-assessment tools to set a baseline for the T2I2 learning prior to teacher participation within the units. Identifying teachers' initial levels of understanding could inform modifications and the development of future Learning Objects.

This summative assessment confirms the value of the T2I2 learning materials, resources and delivery system. Teachers' professional development requires teacher agency, giving teachers more control over their learning (Mehta, 2016). Unfortunately, unlike the T2I2 resources, the bulk of online professional development opportunities are activity and content focused, not classroom-practice based. The unique professional development needs to prepare STEM educators to build and maintain effective integrated learning environments can be addressed and supported by the T2I2 resources and platform.

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