Developing Preservice Teachers' Technology-Integrated Design: Comparing a Problem-Centered Approach in Face-to-Face and Flipped Courses

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Abstract

Researchers have noted the critical need for developing teachers as designers, especially as it relates to designing purposeful instruction with technology. This study applied a problem-centered approach based on the First Principles of Instruction. The course's goal was to develop preservice teachers' application of TPACK when designing technology-integrated lessons. Using an embedded, quasi-experimental design to compare TPACK-application outcomes between face-to-face and flipped course implementations, preservice teachers' growth was shown to be statistically significant in both the face-to-face and flipped course sections but not statistically different between sections. Additionally, a descriptive phenomenological analyses of preservice teachers' experiences with the problem-centered principle provided additional explanations of these quantitative outcomes and offered insights for future problem-centered design.

Introduction

The terms instruction and teaching have been defined similarly by leaders in teacher education (TED) and instructional design and technology (IDT) (Elen, 2013). IDT leaders have defined instruction as "anything that is done purposefully to facilitate learning (Reigeluth & Carr-Chellman, 2009, p. 6)" while TED leaders have defined teaching as "the deliberate activity of increasing the probability that students will develop robust skill in and knowledge of the subject under study and coordinated within larger education aims (Ball & Forzani, 2009, p. 503)." Given the similar intents of these terms in their respective disciplines (i.e. facilitating learning and increasing students' skill and knowledge) and their comparable methods (anything purposeful and deliberate activity), there has been great interest in developing teachers design thinking (Harris & Hofer, 2009; Koehler & Mishra, 2005). More recent research projects further exemplify the synergy as researchers have been interested in improving technology enhanced learning environments by engaging teachers' in participatory design (Cober, Tan, Slotta, So, & Könings, 2015) and have also been examining how teachers can enhance their teaching by using instructional design processes for planning, designing activities, and selecting media (Carr-Chellman, 2016).

Countering the development for teachers as designers are questions of necessity and purpose. Should and why do teachers need to be designers? One may argue that given most teachers' time constraints, potentially limited expertise in instructional design, and likely few incentives for designing, engaging in design is not an advantageous endeavor (Kirschner, 2015). This argument is built upon the costs outweighing the benefits; the cost of teachers doing the work, the cost of developing their design thinking, and the cost of incentivizing these efforts. However, these concerns may be countered simply by the fact that teachers already are acting as designers (McKenney, Kali, Markauskaite, & Voogt, 2015). They are designers due to necessity and expectation. Institutional structures often need teachers to design and expect them to customize cookie cutter resources to meet the needs of their learners, their objectives, and their environment. Teachers also create and modify digital resources as an epiphenomenon of emergent technology adoptions by school districts. Especially for commercial digital tools not specifically developed for educational environments, teachers need to design for purposeful integration of the technology (Laurillard, 2012; Svihla, Reeve, Sagy, & Kali, 2015). Additionally, the push for deeper student learning has cast a fresh vision for the role of teachers; a vision that expects them to design powerful learning experiences (Martinez, McGrath, & Foster, 2016). The need and expectations for teachers to act as designers, however, does not negate the costs Kirschner listed (2015), but developing teachers' design practices and thinking may increase the benefits, potentially decrease the cost, and thereby constitute a valuable area of research.

Purpose

This study seeks to examine a problem-centered approach to developing preservice teachers' design of technology-integrated lessons and resources. Further, this study will compare the impacts of the problem-centered approach when used in comparable face-to-face (F2F) and flipped course sections. Both course sections were designed according to the First Principles of Instruction (FPI), and both course's learning outcomes were based upon the technological, pedagogical, content, knowledge (TPACK) framework (Koehler & Mishra, 2009; Merrill, 2002). While the broader mixed methods study also examined preservice teachers' perceptions of their TPACK and learning experiences related to the entire FPI model, the next sections focus on explaining how participants interacted with the problem-centered principle of instruction as a means of informing the TPACK application outcomes. The research questions are the following:

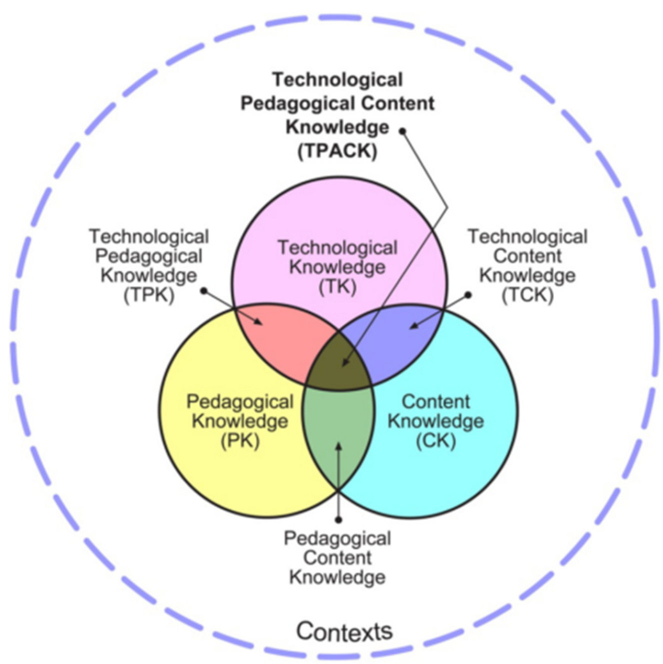
- How do preservice teachers' application of TPACK to technology-integrated lessons compare between flipped and F2F sections of a course designed according to the FPI?
- How do the preservice experiences with FPI's problem-centered principle explain their application of TPACK?

Perspectives

TPACK

The technological, pedagogical, content knowledge (TPACK) framework has significantly impacted technology-integrated design and preservice teacher development. As of 2014, over six hundred articles had been published based on TPACK, and over one hundred forty instruments had been devised to measure its constructs (Koehler, Mishra, Kereluik, Shin, & Graham, 2014). Scholars have applied the TPACK framework to reimagining practice in K-12 and higher education (Chai, Koh, & Tsai, 2013) and to reforming methods for developing preservice teachers (Lee & Kim, 2014). Prior to TPACK, similar frameworks for technology integration knowledge had been discussed (Angeli, Valanides, & Christodoulou, 2016). First introduced as TPCK, Mishra and Koehler (2008) changed TPCK to TPACK to emphasize the Total PACKage of knowledge needed for teachers to effectively design curriculum and instruction with technology.

Figure 1
TPACK Framework



Note. Reprinted from "What is Technological Pedagogical Content Knowledge", by Koehler, M., & Mishra, P., 2009, *Contemporary Issues in Technology and Teacher Education*, 9(1), p. 63.

Extending Shulman's PCK framework from three to seven domains of knowledge, TPACK is composed of three overlapping circles that represent three distinct domains (TK, PK, and CK). As illustrated by Figure 1, four hybrid domains (TPK, TCK, PCK, and TPACK) are formed from the overlapping circles. Technological knowledge (TK) refers to the knowledge of how to use software, hardware, and associated technologies. Pedagogical knowledge (PK) encompasses the knowledge of learning theories, instructional methods, and assessment (Chai et al., 2013). Content knowledge (CK) is the knowledge one has of a subject matter. The hybrid domains, consequently, transform isolated knowledge areas to create new forms of knowledge. As one example, technological content knowledge (TCK), is the knowledge of how to leverage technologies to research and create content within a subject area but does not consider knowledge for teaching. TPACK application, the course's goal in this study, is the ability to select and integrate various technologies that facilitate instructional methods within a specific content area.

First Principles of Instruction

A problem-centered approach, based on the First Principles of Instruction (FPI), framed the design and implementation of this course. Merrill (2002) contends that applying FPI's problem-centered principles of activation, demonstration, application, and integration will improve instruction's efficiency, effectiveness, and engagement. The assumptions are that learning will be promoted when learner's prior knowledge is activated, or they are given opportunities to build this knowledge with new experiences. Learning will be promoted when new knowledge is demonstrated to the learners, and when learners apply this knowledge to varied problems and integrate it within their everyday experiences. All these phases are more effective when situated and connected within authentic and complex problems. Although the course in this study applied all components of the FPI, this paper focuses on the problem-centered principle, its corollaries, and learners' related experiences and learning outcomes.

In this study, the problem-centered principle engaged preservice teachers in solving an authentic and relevant problem through the iterative design of increasingly complex, technology-integrated, lesson plans and digital artifacts. The design problem, a technology-integrated lesson with supporting digital resources, was divided into five distinct phases. The number of phases was based partly on contextual factors such as the number of class meetings, but it was also related to components of a conventional lesson in childhood and early childhood education. The design phases were (1) analyzing the context, (2) selecting and aligning content and technology standards, (3) crafting learning objectives, (4) designing learning activities, and (5) creating assessments.

Per the FPI's *show task* and *problem progression* corollaries, each instructional module focused on a technology tool and a specific phase or component skill of the whole problem. The show task corollary posits that learners should be shown what problem or task they will be able to complete as a result of the instruction. Therefore, following instruction on the module's new component skill, an entire problem or instructional scenario was presented to the students. For the problem progression corollary, the design problem shifted to a different context in each module, and its complexity increased as preservice teachers applied additional component skills. The increased complexity of subsequent problems and the provision of multiple problems intended to progressively improve learners' skills. Although they began with fewer and simpler tasks within the problem, they gradually engaged more components of the design problem until they were assigned the entire problem.

Since the initial component skill taught was assessment, students were only required to plan an assessment for the first design problem; all other components were provided. Learners then designed an assessment for each subsequent design problem. The second component skill, writing effective learning objectives, was provided in the initial design problem but required of students for the second design problem and beyond. This implementation of the problem progression corollary intended for students to develop mastery of isolated component skills situated within varied and authentic design problems. This proposed to scaffold them for their final design problem, when they would be expected to design a technology-integrated lesson and supporting digital resources for their field placement.

Methods

This study compared the impact of two FPI-based courses on preservice teachers' application of TPACK when designing technology-integrated lessons within a problem-centered environment. To examine this impact, the quantitative data analysis focused on comparing the two conditions (F2F and flipped) on the TPACK outcome variables. Further, the study also explored preservice teacher learning experiences. The qualitative analysis of their reflection journals and the interview transcripts sought to better understand how they interacted with the content in each course version and how they perceived the FPI elements impacted their learning experiences.

During the spring 2017 and fall 2017 semesters, participants were recruited from four sections of a required technology integration course in their teacher preparation program. All participants were either elementary or early childhood majors with a focus on inclusive and special education. There were 32 participants total. Twenty participants completed the F2F course in the spring, and 12 completed the flipped course in the fall.

Participants completed pre- and post- technology-integrated lesson designs using a specified template. Two raters individually applied the TPACK-based technology integration assessment rubric to each lesson (TIAR; Harris, Grandgenett, & Hofer, 2010). The TIAR consists of four domains, and scores can range from four to sixteen. Researchers met weekly to discuss scoring and reached consensus on lesson scores that differed by greater than two points. Finally, the primary researcher calculated gain scores from the differences between the pre- and post- scores and computed an ANOVA of gain scores following an exploratory analysis.

As for the qualitative data, eight course assignments for each participant were analyzed, resulting in approximately 240 written artifacts. The researcher also interviewed four participants, three from the F2F course (Andrew, Aadan and Angie) and one from the flipped course (Brooke). Interviews ranged from 27 to 42 minutes. All interviews were recorded, imported into MAXQDA alongside participants' reflections, and transcribed verbatim. A descriptive phenomenological approach to qualitative data was then applied to this analysis (Cilesiz, 2011).

Phenomenological research attempts to represent the general nature of the phenomena by exploring it from the various perspectives of those who have experienced the phenomena (Matua & Van Der Wal, 2015). Thus, this study sought to represent the phenomena of experiencing a technology integration course intended for preservice teachers that has been designed according to the problem-centered principle of the FPI. The descriptive phenomenological method was selected for its alignment with the research questions focused on exploring participants' experiences with course elements in both the F2F and flipped course versions. Further, a phenomenological approach has been applied to similar studies in educational technology to explore preservice and in-service teachers learning experiences and their TPACK development (Clark & Boyer, 2015, 2016; Lin, Groom, & Lin, 2013).

In phenomenology, general themes or the essence of an experience are represented as a textural-structural synthesis. The essence represented by this study does not intend to be a universal truth for experiences in technology-integrated courses or experiences with a problem-centered principle. Rather, as Moustakas wrote, "The fundamental textural-structural synthesis represents the essences at a particular time and place from the vantage point of an individual researcher following an exhaustive imaginative and reflective study of the phenomenon (Moustakas, 1994, pp. 101–102)." As a researcher continues to study a phenomenon, an infinite number of experiences may be discovered (Husserl, 1931). The goal of the phenomenological analysis reported in the following sections was to best describe the general lived experiences of the participants in these problem-centered technology integration courses and the essential aspects of the experiences that related to their TPACK application.

Results

FPI's Impact on TPACK Application

While the ANOVA results showed no practical or significant differences between groups, an examination of the confidence intervals offered information about the potential statistical significance of each treatment group's mean gain score. The 95% confidence intervals for this analysis did not include zero for either group. The intervals for each group ranged as follows: F2F group ranged from 2.61 to 5.59 and flipped group ranged from 2.30 to 6.70. These data show that while the two groups' gains were not significantly different, both groups exhibited a significant increase in their application of TPACK to technology integration lessons as the mean gain score is statistically different from zero.

To explore the statistically significant gains in TPACK application further, participants' gains on the TIAR subscales were analyzed. As the TIAR subscales' data did not meet the assumptions of normality for parametric tests, a Wilcoxon Signed Ranks test was applied. Table 1 displays the resulting pre- and post- medians, effect size, and degree of significance. All four domains of TPACK application as measured by the TIAR were statistically significant for both groups. These data indicate support for FPI's potential to promote learning and indicate that the FPI may promote learning equally well in F2F and blended environments. Next, the descriptive phenomenological analyses of participants' experiences with the problem-centered principle will be discussed and related to these quantitative outcomes.

Experiences with the FPI as Explanations for Growth in TPACK Application

As displayed in Table 1, preservice teachers exhibited statistically significant growth in the application of TPACK to technology integrated lesson designs. Many shared that experiences with elements of the problem-centered principle positively influenced their learning, helped them apply knowledge in the course and provided an authentic context for their learning. Brenda clearly connected her problem-centered course experiences with learning how to integrate technology when she wrote, “Each week I feel I am becoming more and more comfortable with creating lessons with my design team, while incorporating the new types of technology we are learning each week and the ISTE standards. I feel that when the time comes around and I have to plan a lesson for my second grade students this semester, I will have so many new technology options that I can incorporate into my lesson.”

Brenda identified the repeated opportunities for practice, her increased comfort with design and knowledge of technologies, and her confidence that these knowledge and skills would be useful. In terms of TPACK-application, Brenda’s statement aligned closely with elements of the TIAR. Preservice teachers exhibited consistent growth across all TIAR criteria with medians increasing one point. Preservice teachers’ experiences with the

Table 1
Wilcoxon Signed Ranks Tests of Pre- and Post-TIAR Scores

Criteria	*Group*	*n*	*Mdn (Pre)*	*Mdn (Post)*	*Z*	*Sig. (2-tailed)*	*Effect Size r*
Curriculum Goals and Technologies	F2F	20	2.00	3.00	2.86	.004	0.64
	Flipped	12	2.50	3.50	1.79	.074	0.52
	Flipped[a]	11	2.50	3.50	2.41	.016	0.73
Instructional Strategies and Technologies	F2F	20	2.00	3.25	3.47	.001	0.78
	Flipped	12	2.00	4.00	2.97	.003	0.86
	Flipped[a]	11	2.00	4.00	2.97	.003	0.90
Technology Selection(s)	F2F	20	2.00	3.00	3.03	.002	0.68
	Flipped	12	2.00	3.00	2.03	.043	0.59
	Flipped[a]	11	2.00	3.00	2.68	.007	0.81
"Fit"	F2F	20	2.00	3.00	3.43	.001	0.77
	Flipped	12	2.00	3.00	2.56	.010	0.74
	Flipped[a]	11	2.00	3.00	2.95	.003	0.89

[a]Outlier removed from this group based on a sensitivity analysis results.

FPI-elements in the courses may offer explanations for the growth in these criteria and lay the groundwork for considering future design implications. The integrated findings discussed next will focus on relating participants’ experiences with two criteria from the TIAR, (1) Curriculum Goals and Technologies and (2) Technology Selection(s).

Curriculum Goals and Technologies

Emphasizing the alignment between technology selection and curricular goals, this area of TPACK application was noted as an area of concern during activation phase of instruction and early application phases. During an interview with Aadan, he reflected on his experiences with a one-to-one chromebook initiative, “Um I think technology can be a fantastic tool depending on how it's used.” He continued to describe how he often did not sense there was an alignment between technology and curricular goals when he was a student and found the tools distracting. Avery also noted times when technology seemed to be used for the sake of technology and not in service of content and learning when she wrote, “I would’ve rather done things my own way, but usually when technology was involved we were required to do things so specifically and include so many components (follow so many steps). Furthermore, the types of technology I used were very confusing to me at times and I feel that they were not helpful to my learning. I would’ve been better off without the technology and just doing things the old school way.” While some preservice teachers recalled learning important skills with technology, its’ integration in their K-12 education was frequently seen as superfluous to curricular goals.

In spite of these critical perspectives, preservice teachers at the beginning of the course still remained open to the possibilities as Bridget wrote, “The more technology a teacher can incorporate into the lesson the better. This will make [it] feel like a normal part of everyday life.” Bridget’s rationale for incorporating technology and her peers’ observations of technology integration attempts in their K-12 classrooms offer possible factors for the limited alignment between curriculum goals and technologies on the pre-course lesson designs. In preservice teachers’ prior technological experiences, content was often relegated, ignored, or misaligned with the digital tools’ affordances. As Bridget argues for more technology in the classroom, she does not support her position by relating it to learning and instruction. Her premise assumes that teachers should be concerned with technology becoming normative and that resulting instruction will improve. This perception of technology’s role does not account for content nor consider the role of pedagogy as technology becomes the end goal.

Preservice teachers’ iterative lesson designs during the application phase of instruction may also explain the positive shift in their attention to the alignment of technology with content goals. As Arianna noted, “I would definitely say the repeated practices we complete in this class are productive to us as future educators. As it may be redundant and tedious for some, it still is eliciting great and continuous practice of effective ways to consider and implement technology into the classroom.” She and Angie both highlighted the benefits of this continuous practice. Participants’ experiences with the problem progression corollary were described as benefitting their ability to isolate and focus on key design elements. They were able to break down problems and build up their confidence.

One of these key design elements, or what Merrill (2012) referred to as a subtask, was referenced in Bridget’s reflection on her group’s technology integrated lesson design near the end of the semester. Bridget wrote, “I think that it would be important to make sure that our objectives are closely aligned with the technology that we incorporated. I want the technology included to extend and build on the lesson, not be completely irrelevant or come across as busy work. I hope that as we finalize our lesson, we can nail down forms of technology that fit our objectives.” The continuous practice elicited by the problem progression corollary during the application phase of instruction provided a space to reconsider technology’s relationship to curricular goals within a lesson design. Bridget shifts from “the more technology…the better” to writing of the importance of alignment and fit between learning objectives and technology. Whereas considerations of learning and content were absent from her earliest reflections, she now wants the technology to “extend” and “build” and to be relevant.

Further connecting the increase on this TIAR criterion with participants’ opportunities for practice and problem progression is yet another of Bridget’s reflections. She wrote, “I think that starting with most of the information filled in made me feel more successful in my abilities to plan a lesson that met both Common Core State Standards and ISTE standards.” In this statement she identifies technology and content standards, recognizes the need for lessons to address them, and relates the problem progression corollary to her sense of success and confidence. Brooke’s experiences also support this connection as she wrote, “By using this process I believe that it has benefited our groups understanding of what the most important components that go into a lesson are.” While she believed technology to be an important element to consider from the beginning, she wrote that should be considered alongside learning objectives and assessments. This iterative design process informed by the problem-centered principle and its corollaries was regarded as beneficial by the preservice teachers and may have contributed to their statistically significant increase in alignment of curricular goals and technologies.

Technology Selection(s)

The Technology Selection(s) criterion focused on the compatibility of selected technologies in the preservice teachers’ lesson design given their instructional strategies and curriculum goals. The previously discussed criterion evaluated alignment, but Technology Selection(s) evaluated the appropriateness of the selected technologies. While the median of participants’ technology selections in the pre-lesson designs corresponded with marginally appropriate technology selections, the median for their post-lesson technology selections was at the appropriate but not yet exemplary level. While they did not achieve the highest possible level of technology selection measured by the TIAR, both groups’ growth was statistically significant.

When preservice teachers discussed learning about different forms of technology in this problem-centered environment, they described their experiences learning various digital technologies as a process: introduction to a technological tool (Activation and Demonstration), practice using the tool (Application), and evaluating its potential for a future lesson implementation (Integration). The activation phase introduced preservice teachers to new digital tools and structured experiences for them to build new knowledge about and with these tools. In an early reflection, Andrew acknowledged that prior to the course, he considered himself “tech savvy”. He then listed the many technologies he had already learned in the semester. Similarly, Aadan observed that course experiences exposed him to a range of technologies. Audrey and Alyssa tied these introductory experiences to preservice teachers’ capacity for appropriate technology selections when they wrote that technology integration seemed more achievable after learning about new digital tools. An expanded repertoire of tools, Audrey also wrote, made technology selections more complicated. “It [is] difficult picking and choosing what technology to use (and potentially how to get the best use out of it) for a specific lesson/topic.” Yet, exposure to new tools was just the beginning of the process of learning about new forms of technology.

Based on the FPI’s demonstration and application principles, preservice teachers observed modeling of procedures for using new tools. Along with this modeling, preservice teachers practiced using the tool with a partner or their design group. The following quote demonstrates the transition along this process. “For instance, I didn’t know that Google had so many different applications such as Google Slides, and through the two hours that I was in class I found out how to work the website through instruction and activities (April).” While April concedes a lack of knowledge of Google’s applications, she then acknowledges the benefit of working through instruction and activities in class to develop procedural knowledge. Constructing knowledge of the digital tool’s affordances through the construction of a meaningful artifact, “a Google Slides webpage”, was perceived by participants as critical for future technology integration decisions.

Summarizing her experience with the process, Angie wrote, “I think now it is really impossible to plan a lesson without technology…it’s more about finding and using the RIGHT technology, not just finding any technology.” The TIAR makes the same assumptions as Angie; technology will be selected for the lesson. Angie concludes that technology selections will occur, and teachers must not settle for any technology. Through these processes and as indicated by the TIAR data, preservice teachers selected more appropriate technologies for their instructional scenarios at the end of the course, and participants’ experiences helped them learn the “ins and outs (Avery)” of several new tools as a means for improving their selections.

Implications, Limitations, and Conclusion

Several recent studies have applied the FPI to flipped courses. Some, as this study has done, compared the learning of F2F and flipped course designs. On the surface, Lo, Lie, and Hew’s (2018) results appear to contradict this study. In three of four disciplines studied, they reported that the flipped treatment group outperformed the F2F group. Critical to these results, though, was that instruction in the three F2F groups was primarily lecture-based. In the one flipped to F2F comparison that exhibited no differences in outcomes, the instructor stated that he embedded hands-on activities within the F2F course. Instead of countering the results of this study, these results rather seem to have a similar conclusion. The learning outcomes may be a result of the design of the learning environment. When designs included high leverage instructional practices such as hands-on learning espoused by the problem-centered principle, F2F and flipped approaches may prove equally effective.

Preservice teachers’ experiences with the problem progression, task level, and problem progression corollaries and the robust TPACK-application outcomes further support the need to apply them as intended by the FPI. This is not to say that incorporating the FPI as described by Merrill is a simple process. Studies of the FPI application vary drastically in their application of the problem-centered principle, and a recent study of a flipped course based on the FPI even observed the absence of problem-centered activities during the physical class meeting (Lo et al., 2018). The essence of participants’ experiences in this study, however, indicate the importance of the problem-centered principle, its embedded corollaries, and proper implementation.

A limitation to the results in this study was the variation of participants’ experiences in the field, particularly the mentor teacher’s TPACK, and how these contributed to the results. Nelson (2017) found that preservice teachers were impacted by the frequency and quality of their mentor teacher’s integration of technology. Technological competency was not considered as mentor teachers were selected, therefore, this variable was not measured. Knowing this could potentially impact preservice teachers’ implementation of the lessons factored into the decision to isolate planning as an outcome. First order barriers such as access and mentor teachers’ attitudes toward technology were evident in preservice teachers’ reflections and could not be controlled. The TIAR was purposefully applied to measure TPACK application as it was intentionally constructed neutral of a constructivist orientation and student-centered uses of technology. Its main focus was the alignment of components within a technology-integrated plan for purposeful integration and not evaluating the plan from a theoretical perspective. Applying the TIAR was intended to reduce the impact a mentor teacher might have on the score, as it was believed preservice teachers could score a maximum possible score even with first-order barriers present in the placement context.

The knowledge and skills for designing digital resources and technology-integrated lessons is often of practical significance for teachers. Emerging technologies regularly require teachers to design their own resources and activities for technology to be integrated purposefully (Laurillard, 2012). Exploring design practices for preservice teachers represents a synergistic agenda for teacher educators, teachers, and design researchers (Svihla et al., 2015), and a problem-centered approach based on the FPI appears to be a promising method for structuring the development of these practices.

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