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Facilitating Curiosity: Secondary STEM Education Majors Experiences in a Discovery Learning Center

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ABSTRACT

This study documented twenty secondary STEM teachers' experiences as assistant curiosity facilitators in a Discovery Learning Center (DLC) during and after a summer camp for elementary age students. Data collection spanned four years and included participation at the DLC prior to entering their master's level initial licensure program and into their first two induction years as teachers in high needs school districts. Data from surveys, self-reflections and focus group interviews indicated mixed perceptions related to whether the DLC experiences could influence teaching in formal classroom experiences. Some teachers perceived the summer camps as "playtime" and did not think that learning occurred. Others acknowledged the benefits of informal activity and considered engagement level as an important factor in formal learning environments.

Keywords: Activity Theory, Creativity, Formal Learning Environments, Informal Learning Environments, Preservice Teachers, Secondary STEM Teachers

INTRODUCTION

Secondary Science, Technology, Engineering, and Mathematics (STEM) education majors enter traditional teacher preparation programs with preparation mostly in their content area courses. For those preservice teachers that enter initial licensure programs at the masters' level, they typically have completed undergraduate degrees in the area they are planning to teach. However, for them personally, there may be gaps in their experiences as learners at younger ages. The time between their experiences as middle school students is seven or more years. The obvious advantage of these preservice teachers is their strength in content knowledge. Experiences in collegiate level courses deepen and strengthen their subject-matter knowledge using traditional lecture style methods (Felder, 2021). The potential limitations are their lack of skills in current pedagogical practices and experiences with reform oriented or novel curriculum materials.

STEM centers have grown in popularity around the US and the rest of the world and come in the form of buildings intended specifically for learners of all ages or they could be designated spaces equipped with materials to promote active learning of STEM concepts. These spaces offer hands-on experiences in lab settings and physical spaces for a variety of choices for the public. Many of these centers have the word "discovery" in them for the purpose of providing a space for informal learning and inquiry. One considerable difference between these STEM centers and formal classrooms is the lack of formal assessments of learning which could challenge preservice teachers' views about whether students benefit academically from these experiences.

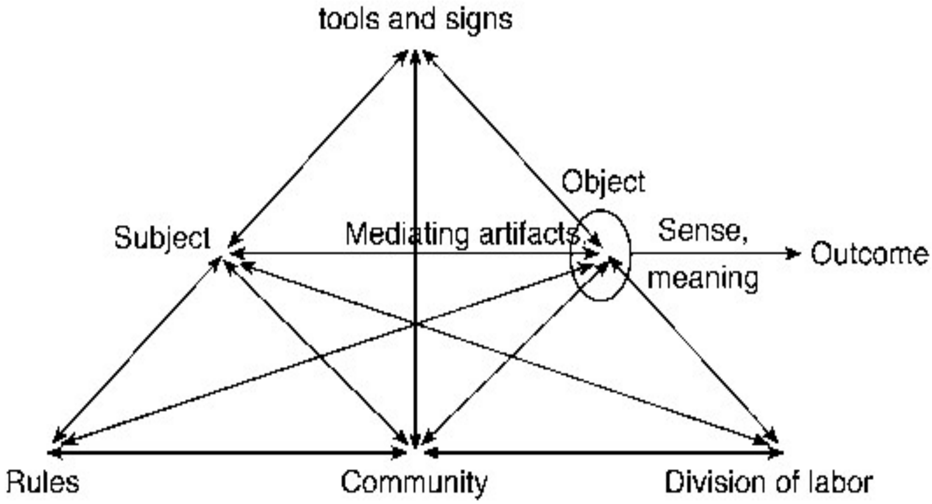
The purpose of this article is to describe secondary preservice teachers' (PSTs) experiences as learners and as assistant facilitators at a STEM discovery learning center summer camp for elementary-age students. Twenty secondary STEM preservice teachers participated in a discovery learning center (DLC) prior to their Master of Arts in Teaching (MAT) licensure program at a university in the southern part of the United States. This experience aimed to involve these preservice teachers in activities that elementary age students completed as part of a week-long summer camp. Their role as an assistant to the Curiosity Facilitator at a STEM DLC was an opportunity for them to reimagine learning within an informal environment.

LITERATURE REVIEW

Activity Theory

Activity theory (AT) is a framework based on the idea that "doing precedes thinking, goals, images, cognitive models, intentions, and abstract notions like definition and determinant", which develop as a result of practical engagement (Engeström, 2001). In Figure 1, Engestrom (1987) depicts the structure of the human activity system in which components such as rules, tools and signs, and community are mediating artifacts in sense making and outcomes. In the case of preservice secondary STEM majors experiencing and facilitating lessons at a discovery learning center (DLC), all corners of the triangle are distinctly different than formal learning environments. While there are some basic rules for safety and social purposes, DLCs have many fewer boundaries such as individual desks, walls separating learners, and isolated learning experiences. Rather than emphasis on rules, division of labor and visual learning, DLCs emphasize tactile learning and open exploration.

Figure 1
The Structure of a Human Activity System (Engestrom, 1987, p. 78)



This structure promotes inquiry and creativity. Sriraman (2009) studied the research habits of mathematicians and found that social interaction, imagery, heuristics, intuition, and proof are common characteristics mathematical creativity (p. 13). Similar qualities are identified with respect to the work of scientists. Hadzigeorgiou, et al., (2012) described characteristics such as imagination, social settings, finding and solving problems, etc. as important components of creativity in science education. Discovery learning centers are a type of learning environment that potentially allows for the type of creativity advocated for by STEM educators (Lindeman, 2020).

Informal vs Formal Learning Environments

Hussim et al., (2024) described several characteristics of informal learning including inquiry-based, project-based, design-based, cooperative learning, student-centered, and hands-on (p. 5). Informal Learning Environments or ILEs such as STEM discovery centers differ from formal school environments in several important areas. Formal Learning Environments or FLEs have different structures, expectations, and roles for participants. FLEs, in particular, involve rules for in-class behaviors, roles of students and teachers, and evaluation systems that are part of the bigger system of the school and district requirements.

Standardized testing system requirements, as part of FLEs, often dictate actions of administrators, teachers, and students (Au, 2022). Learning is specifically measured by assessments aligned with standards documents by content area and subjects based on preset guidelines. ILEs do not typically have standardized evaluation systems or formal assessments that would provide others with a record of individual student learning or achievement. However, studies have found that an emphasis on experiential learning in STEM content areas did not lead to lower scores on standardized tests compared to traditional instructional methods (Scogin, et al., 2017; Craig & Marshall, 2019).

The experiences of the participants are central to the structure of ILEs. Most discovery learning centers, museums, etc, are, by design, free exploration centers. Participants of all ages move freely among exhibits and stations to examine based on the interest level of the individual and group interests. Within the summer camp experiences, there is more structure, with facilitators and certain constraints, but with opportunities to create and explore within reasonable restrictions for the safety of all involved. Learning is unbound for each individual and allows for the opportunity to not participate at all if there is lack of interest in the group activity. Alternative options are available to students to choose something or observe others.

Example ILEs

Informal STEM learning environments outside of formal classroom settings vary in structure. Some are separate locations from schools (ie, museums, discovery centers, etc) (Morris, et al., 2024; Shaby, et al., 2025). Others may be located in formal school settings but without the constraints of curricular and assessment expectations (e.g. Russell, & Schneiderheinze, 2005; Lang et al., 2018,). These ILEs may also take the form of STEM clubs and STEM fair preparation (Xia et al., 2024). As with human activity systems, the framing of research of learning in ILEs is socio cultural learning (Lave & Wenger, 1991). Schauble et al., (1997) proposed an integrated framework to study learning in ILEs such as children's museums that included the environments themselves, meaning making, and motivational factors (p. 4).

STEM clubs within formal school structures, but outside of formal classroom instruction, could also be considered ILE's in that participation is typically voluntary and products are not evaluated as part of formal assessment systems. For example, Lang et al., (2018) involved preservice teachers in a "Makerspaces" student-led club during lunch time. These "pop-up", technologically advanced spaces, were positive additions to the buildings in terms of promoting interest in STEM related projects (p. 54).

The differences between ILEs and FLEs are what is most surprising for STEM majors compared to their most recent experiences as students at the collegiate level. This is especially the case in terms of their perceptions of "what counts" as learning. Much of their recent experience is based on test scores, grades, graduation, etc. To observe in an ILE situation not tied to formal evaluation systems encourages them to consider learning in a substantially different context than what they have just experienced themselves.

The STEM discovery learning center (DLC) in this study is set in a suburban area of a southeastern state with a population of about 600,000 people. The building itself is approximately 35,000 square feet. A large area of the DLC is devoted to self-directed stations and activities related to nature and weather, building structures, and many other STEM related exploration opportunities. There are areas for climbing and physical activity as well as laboratories for self-guided and guided experiments. There are classrooms for professional development and summer camps. There is also a significant outreach to schools in the area similar to the Makerspaces concept to bring the ideas of the DLC to the schools. This DLC has substantial hours open to the public and is meant for all ages.

The summer camps are typically geared towards students from Kindergarten through sixth grade and are taught by STEM educators. STEM camp lessons are hands-on and designed to engage children. Examples include, "designing your own squishmellow", "blubber glove owl pellets", "ozobot coding bracelets", etc. PSTs served as assistants to the curiosity facilitators at the DLC during the summer and prior to the beginning of the MAT program.

Secondary Preservice Preparation

Preservice programs to prepare secondary STEM teachers are focused on pedagogical content knowledge through methods courses, school-based internships, and other learner centered approaches (Berisha & Vula, 2021; Bosica et al., 2021; Harris & De Bruin, 2018; Jeskova et al., 2022; Menon & Ngugi, 2022). Initial licensure master's programs may be secondary preservice teachers' first experiences focused on teaching their content areas of expertise rather than as learners of collegiate level subjects. This shift in emphasis is sometimes dramatic with the realization that middle and high school students learning is likely different from their own. For example, Bosica et al., (2021) compared traditional approaches to teaching methods focused on problem-based learning (PBL) and found that preservice teachers were more likely to change their views of teaching STEM after the PBL course.

Student centered and PBL approaches are consistent with activity learning theory in that emphasis is placed on learning by doing (Engeström & Sannino, 2021; Gyasi, et al., 2021). Application of activity theory to secondary preservice STEM teacher preparation suggests that these future teachers should experience teaching inquiry methods in order to become effective with these methods in their own future classrooms (Macleod et al., 2020; Wieselmann et al., 2021). Experiences in a DLC summer camp in the role of facilitation prior to the preservice program and induction year have the potential to add an additional dimension to their thinking and lesson planning in their future experiences.

RESEARCH METHOD

Qualitative methods grounded in phenomenological inquiry were used to analyze and triangulate data for common themes (Dangal & Joshi, 2020; Aguas, 2022). Specifically, observations were used to analyze engagement levels among preservice teachers as they assisted teachers at the summer camps. Written reflections were coded based on perceptions about what the children at the camp were doing with respect to labs and hands-on activities and whether those activities were perceived to be learning experiences. Focus group interviews provided opportunities for the preservice teachers to reflect on the relevance of the DLC experiences to their classroom teaching practices. Finally, lesson plans were evaluated to identify elements similar to lab activities from ILE experiences.

Participants

The participants were 13 science and seven mathematics preservice secondary teachers enrolled in an 11-month MAT program. Table 1 shows the specific majors and years of participation. The required DLC experience included participation in a summer camp for children ages five to eleven. The lead teachers were called "curiosity facilitators" and preservice teachers were assigned to assist with the summer camp. Cohort One preservice teachers-assisted for six hours for four days prior to the start of MAT classes. Due to changes in the structure of the MAT program, Cohorts Two and Three preservice teachers participated in two-four afternoon summer camps prior to or at the beginning of the MAT. They also spent an afternoon in free exploration of the DLC prior to their roles as assistant curiosity facilitators.

Table 1
Preservice Teachers by Cohort and Major

Cohort	Mathematics	Science
2021-22	Leah	Theo, Bea, Miranda, Bonnie, Bob, Shay
2022-23	Melanie, Jeff, Betsy	Stan, Katari, Landon
2023-24	Abby, Brooklyn, Rachel	Yeni, Katherine, Zach, Lacy

Data sources included observations of the summer camp by the author of this article, individual written reflections by each preservice teacher and focus group interviews with each cohort. Open coding was used to identify themes based on content, cohort, and individual and groups reflections that emerged from the PSTs experiences at the summer camp (Glaser & Holton, 2023). The timeline of data collection began during the summer when PSTs participated in the DLC summer STEM camps, continued into their internship year as part of their MAT program, and their first four years of teaching in a high needs school district. Table 2 summarizes the data collection period. The project related to data collection is currently in year five of a seven year project.

Table 2

Timeline and Sources for Data Collection

Event	Data Sources
Summer DLC experience	Field notes collected by researcher, reflections by PSTs
Year-long Internship	Lesson Plans; Focus Group Interviews
Years 1-4 Teaching in high need school districts (Induction Years)	Surveys, Zoom meetings twice a year

The research questions addressed by this study were:

- How did Secondary PSTs respond to children's participation in a STEM camp at a discovery learning center?
- What, if any, impact, did these experiences have on their experiences as interns and novice teachers in FLE's?

RESULTS

The themes that emerged from the data sources were as follows. Theme 1: Elementary students' participation in summer camps was not considered a learning experience by many of the PSTs since they were not assessed through formal testing or written products. Theme 2: Applicability of STEM camp experiences to FLEs varied among PSTs. Theme 3: Creativity aspects of activities from ILEs were reflected in lesson plans written and implemented in FLEs. Themes 1 and 2 reflect answers to Research Question 1 (How did Secondary PSTs respond to children's participation in a STEM camp at a discovery learning center?) Theme 3 reflects data in support of Research Question 2 (What, if any, impact did these experiences have on their experiences as interns and novice teachers in FLE's?).

Theme 1: Summer STEM Camp as a Learning Experience

The responses to the summer camp experience varied by cohort. Cohort 1 (2021-22) PSTs did not experience the discovery learning center as participants prior to their roles as assistants to the curiosity facilitators. They also were not given choices on their summer camp assignments.

Table 3

Example Responses To Questions about Discovery Learning Center

Preservice Teachers	Cohort	Written Reflections
Theo	1	To be honest, it felt much more like babysitting the nature of camp is not the same as a classroom dedicated to learning.
Shay	1	I think the main purpose of the summer camps are to help children have a fun environment to be at during the summer. I did not feel the camps were educational focused.
Miranda	1	I think they do a good job of keeping children interested but at times I think the abundance of everything there may be distracting from learning.
Bea	1	I did not consider the DLC to be an authentic learning environment for the campers.
Betsy	2	Not all information needs to be formally lectured to be understood. Letting students understand new concepts through hands-on activities or in group casual discussions lets them understand it in a new perspective.
Jeff	2	It taught children to cooperate with others which has unlimited potential in a school setting with group projects, labs, studying, and more.
Katari	2	When it comes to science informal play allows students to do things and question what is happening or what would happen.
Yeni	3	The campers did not have to submit assignments but participated in the labs and many of them had products at the end.
Zachary	3	Some students played instead of completing the labs but most students stayed engaged throughout the camp.

Cohort 2 and 3 PSTs spent a half day at the DLC as visitors prior to working with summer campers. Table 3 shows sample responses from written reflections and focus group interviews. Most of the Cohort 1 PSTs perceived summer camp experiences as playtime or a place for children to be entertained while parents worked. In contrast Cohort 2 and 3 PSTS reflected on the camp experiences in terms of formal classroom ideas such as STEM concepts, classroom management ideas, and aspects of their content related to the real world.

As indicated by the responses, Cohort 1 PSTs did not perceive the summer camps to be learning experiences for the children participating. Their reflections focused on aspects of students' behaviors rather than the STEM activities they were involved with during the summer camp. In relation to activity theory, the role of assisting with summer camp activities without experiencing the activities as learners influenced PST's perceptions of whether learning occurred for children participating in STEM activities. In contrast to those comments, PSTs from Cohorts 2 and 3 focused on content and activities and connected their observations to FLEs. For example, Betsy from Cohort 2 noted that "…hands-on activites..and group learning…" can facilitate understanding.

Theme 2: Applicability to Formal Learning Environments (FLEs)

The PSTs acknowledged that some of the activities from the STEM DLC could apply to classroom experiences. For example, Leah and Bob suggested that the circuit experiment could be replicated within a classroom setting. Stan commented that, "he would use the toy creation activities" as part of his science instruction. Several of the PSTs concluded that STEM DLCs were not learning opportunities for the campers. For example, Miranda, in response to applicability to FLEs stated, "Campers do not have to gain anything from their day. They can go home and forget all about what they saw and learned that day, but regular students will need to understand the material they learned". In contrast, Betsy gave the following reflections about applicability to FLEs:

> Not all information needs to be formally lectured to be understood. Letting students understand new concepts through hands-on activities or in group casual discussions lets them understand it in a new perspective. Lots of math can be modeled since math is used to understand the world around us. Letting students see the geometry or physics applications of the class information can make them more excited to learn, inspire deeper questions, and result in a more problem-solving community. (Betsy, Summer 2022)

Following the summer experiences as assistants to the curiosity facilitators, the PSTs from each cohort began their year-long field experience. Most of their lessons and teaching experiences reflected more traditional lesson plans aligned with their mentor teachers. For example, Melanie from Cohort 2 taught a systems of equations lesson to 11^{th} grade students and focused the lesson on a procedure of substitution that they had learned prior and planned to show the method of linear combinations for the lesson. In reflecting on the success of the lesson, Melanie shared the following thoughts:

> I know these are smart kids, they have just become too reliant on their calculator. So, they cannot find the lease common multiple between two numbers without plugging in multiple "trial" numbers. However, once they know what to multiply it by, most of the errors I saw were numerical errors. They understood the basic step-by-step structure of elimination. (Melanie, Fall 2022)

Over 50% of the lessons reviewed in both math and science reflected traditional methods they observed in their mentor teachers' classrooms. Betsy, in contrast, taught a lesson on the Similar Triangle Continuation with Side-Splitter and Three Parallel Lines Theorems. She began her lesson by sharing information about her background in civil engineering and referenced buildings in Washington DC with unique street designs. In her reflections on the lesson, Betsy made the following comments:

> The students seemed really intrigued with trying to guess what my first picture was of the Capital building ceiling in D.C. They seemed surprised and had questions about my time in D.C. later, but all paid great attention and were silent in the beginning of the lesson when I was talking about it. I think talking about my unique experience and my interests of D.C. and road design because of civil engineering made them want to pay more attention. I showed them on the map where I lived and how I would walk to the Congressional buildings for work. This map showed them the unique street designs that happened to use transversals through parallel lines, which allowed for use of similar triangle that they had been working on previously. I gave them some time to try the problem before letting them know that we would be learning how to solve it with a new theorem later. (Betsy, Fall 2022)

Betsy's last statement demonstrates that she was willing to let her students explore and work with problems from real-life situations prior to giving formal

Table 4
Lesson Examples Perceived to Motivate Student Learning

Induction Year Teacher Name	Content Area	Lesson
Betsy	Robotics	Students had to calculate angles and write programs for their robot.
Shay	Biology	Students used sources to provide evidence for their claims as they work towards completing a Mock IRR report.
Bonnie	Physical Science	Students had to design their own way to figure out which one had more mass (diet vs classic coke).
Yeni	Biology	They had to go find a "nucleus" around the classroom and copy down the DNA sequence and transcribe it into mRNA.
Jeff	Engineering	They used catapults they created to get their own data and determine if their catapult was precise but not accurate, accurate but not precise, etc. It really helped that they made the catapults beforehand because they were invested in the results.
Zack	Physical Science	To model sound and light waves, we used our bodies to model particle collisions for both types of waves.
Leah	AP Calculus	My students worked on a lesson about finding the derivative of e^x and ln(x). They made connections between the graph of each function and its derivative informally by looking at tangent lines with toothpicks, then made tables where comparing various values of the derivative to the value of the function computed numerically with calculators, then were able to notice the patterns and write equations for the derivatives. Students worked in random groups of 3 at whiteboards around the room, with one student writing at a time.
Brooklyn	Algebra 2	I took a Desmos activity and made it into my own lesson in order to teach students function notation. It was a pizzeria menu simulation.

Katari	Biology	I had the students participate in an activity in which they got to observe osmosis. They then got to come up with an experiment to see what would move through the dialysis tubing and how semipermeable membranes work.
Abby	AP Statistics	Students created their own sample distributions by doing 3 different activities: Rolling a dice, seeing how close to a target they can throw an object, seeing how close to 5 seconds they can stop their stopwatch. Students then learned how to differentiate between the different shapes of distributions as well as how the mean and median relate to each other in skewed vs symmetric data.
Katherine	Physical Science	This last week was our school's Multicultural Week so our lessons that week focused on traditional dances in the Pacific Islands. Students made a position vs time graph of their dances and calculated their average speed during each section. The physical moving and measurement really helped solidify how distance and displacement is calculated for the students.
Bea	Seventh Grade Science	In 7th grade students were working on F=MA and were building a structure to protect a Pringle chip from a filled water bottle. Then they tested their design with different size water bottles. Students were given many instructions, just to use one piece of card stock and a long strand of tape to build their design and test it. Students got so creative!

instruction. Melanie's reflections indicated a focus on procedures and decontextualized situations reflecting of less emphasis on exploratory aspects of learning the content. In contrast, Betsy's reflections focused on the contextualized situation and how she utilized it to motivate students' learning of the mathematics content.

Theme 3: Creativity in Lesson Planning in Formal Learning Experiences

During their induction years of teaching, the PSTs completed a survey and described a lesson which they perceived was effective in terms of student learning. Twelve of the 20 lessons reported contained elements of human activity and creativity. Table 4 summarizes the 12 examples.

The survey also asked the Induction Teachers how often (daily, weekly, monthly), they were able to teach lessons similar to the example they described and all 12 responded "weekly". The 40% of teachers who did not describe activity-oriented lessons used phrases such as "I provided the power points, I gave notes, etc." indicating a teaching directed lesson. In contrast, 11 of the 12 lessons described in Table 4 made specific references to what students would be doing during this lesson.

DISCUSSION AND CONCLUSIONS

There were not clear and consistent patterns across all 20 STEM secondary teachers in this study in terms of impact of their experiences at the DLC and their teaching preferences. For example, Theo, an eighth-grade science teacher, perceived the ILE to be more about babysitting than a FLE, reported on a more teacher-directed lesson. On the other hand, Bea, also a science teacher, reflected on the ILE camp as not related to learning like Theo but reported that the Pringle chip lesson was similar to lessons she implemented on a daily basis as a seventh-grade teacher in her own classroom.

Two of the teachers in this study, Jeff and Betsy, had undergraduate degrees in computer science and engineering, and entered the MAT program to become mathematics teachers. Their responses from pre-MAT to MAT and induction years were more consistent with application and inquiry views of teaching. They noted the importance of group work and hands-on activities in their experiences at the DLC STEM camp and also reported on the significance of those types of lessons in their induction year teaching experiences.

The research reported by Sevinc & Lesh (2022) provided evidence that preservice teachers increased in their understanding of how to develop mathematically and contextually rich problems over the course of a semester-long methods course by engaging with contextually rich and realistic problem situations. However, they also suggested that additional research is needed to show long term residual effects on their classroom practice beyond their preservice program. The results of this study are similar in that as PSTs, there was less evidence of creativity and student-centered lessons than in their induction years. Data will continue to be collected for these 20 teachers through their first four years to continue to document the types of lessons they perceive to be meaningful in terms of student learning.

Activity theory provides a lens into examining creativity in teaching and learning STEM subjects. The opportunities to participate in facilitating hands-on activities within an ILE is an experience that may help broaden secondary STEM preservice teachers' perceptions of what "counts as learning". The STEM DLC in this study used no formal methods of assessment such as quizzes, tests, or even performance assessments. As the name implies, the goal for the "Curiosity Facilitators" was to create an environment almost entirely focused on the activities and processes (Kent, 2024). To this degree, ILEs in the summer could be considered the opposite of FLEs in which learning is ultimately defined by student performance on some type of summative measure like a standardized test. Even with advances in technology and AI, standardized tests rarely capture the process of learning in an authentic manner. They are mostly measures of specific knowledge within distinct subject areas (Au, 2022).

The middle and high school years are when students begin to refine their thinking about their future career paths. In order to increase the number of STEM majors at the collegiate level, it is important for secondary STEM teachers to engage students in activities similar to the path of professionals in these fields. Experiences facilitating activities in ILEs can provide confidence to PSTs to consider how similar activities can be used in classrooms and potentially increase motivation of more students to consider STEM careers in their future.

IMPLICATIONS

This study focused on 20 STEM preservice teachers prior to their entrance into their year-long internship and through their first four years of teaching in their own classrooms. Therefore, the ability to generalize to other similar programs is limited. However, more experience with ILEs may be desirable than fewer when it comes to whether similar activities would be attempted with students in FLEs. There are many restraints to risk taking in preservice programs as well as during induction years of teaching. Lack of resources, mentoring, and/or administrative support are potential roadblocks to creativity in lesson planning.

Additional research is needed to further address hinderances to student-centered lesson planning and implementation. For example, Betsy perceived hands-on activities to be integral to student learning of mathematics. As a PST, she was able to integrate her real-world experiences into her lessons and engage students in hands-on activities. However, in her first induction year of teaching, she became a seventh-grade mathematics teacher in a rural school. She was required to follow a prescribed math curriculum and lacked administrative support to try innovative teaching methods with her students. Even though she attempted to initiate a "math talent show" during her first year of teaching, she became discouraged by the lack of support she received and left the school district after one year and became a high school engineering and robotics teacher in a more suburban area. Her experiences are, more often than not, the rule rather than the exception. It is essential for future teachers to participate in a variety of teaching experiences across a variety of learning environments to increase their likelihood of incorporating these practices in their own classroom.

Activity theory applications to secondary STEM teacher preparation show promise for incorporating creative ideas gained in ILE settings to formal classroom instruction. Opportunities for preservice and inservice teachers to participate in STEM activities as their own future learners would experience demonstrate the potential for systemic improvements to teaching and learning at the middle and high school levels. Future research should continue to examine the impacts of these experiences over an extended period of time to determine the long-term effectiveness of activity theory in STEM teaching and learning.

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