

K–8 Pre-Service Teachers' Evaluation of Existing Geometry Activities That Utilise a Technological Resource

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Prior research has highlighted the importance of integrating technology into mathematics education, though preservice teachers often do not feel prepared to integrate technology into their classroom upon degree completion. This qualitative, descriptive study sought to examine kindergarten through eighth-grade preservice teachers' ($N = 44$) evaluation of existing geometry activities that utilise a technological resource. Specifically, the researchers examined the impact that the technological resource utilised in the activity would have on instruction, aspects of the activity that preservice teachers either liked or disliked, and preservice teachers' rationale as to why they would choose to either use or not use the activity in their future K–8 mathematics classrooms. To guide the methodology of this study, the researchers utilised the Passive, Interactive, and Creative—Replacement, Amplification, and Transformation (PICRAT) model. Data were collected from responses to an open-ended prompt as part of a mathematics methods course and analysed with both *a priori* (i.e., PICRAT) and emergent coding. Findings from the *a priori* coding showed that the activities evaluated by preservice teachers most frequently utilised a technological resource (often a mathematical game) in a way that aligned with the interactive, amplification level of the PICRAT model. Emergent coding revealed that preservice teachers most frequently liked the content of the activity, disliked topics related to the pedagogical implications of implementing the activity and founded their rationale for future use on pedagogical considerations related to implementation. Implications of the findings are discussed as well as recommendations for future research.

Keywords • mathematics teacher education research • pre-service teacher • technology • geometry • PICRAT model

Introduction

A theoretical approach to mathematics education that can be observed throughout the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) is the concrete, representational, abstract (CRA) sequence based on Bruner and Kenney's (1965) stages of representation: enactive, iconic, and symbolic. When informed by the CRA sequence, mathematics instruction includes both teachers' presentation of concepts and students' exploration of concepts through a sequence that utilises: (a) concrete models, such as base-ten blocks or fraction tiles; (b) representational models, such as drawings or virtual models; and (c) abstract models, such as mathematical symbols and numbers. The use of the CRA sequence has been found to be especially beneficial in developing students' conceptual understanding of various mathematics concepts (Flores et al., 2020; Flores et al., 2014; Flores & Milton, 2020; Milton et al., 2019). Appropriate concrete models, however, may not always be accessible or practical. In these cases, the use of representational models, including virtual models, is likely crucial for the development of students' conceptual understanding of mathematics concepts.

Research has shown that numerous applications of educational technology in the kindergarten through eighth grade (K–8) mathematics classroom have been beneficial to several aspects related to students' mathematics outcomes. Two of the most-frequently researched technological resources in relation to mathematics education are virtual manipulatives and mathematical games. Research has



shown that the use of such resources have been beneficial to students' outcomes in mathematics, such as their conceptual understanding (Reimer & Moyer, 2005; Suh & Moyer, 2007), achievement on assessments (Brezovszky et al., 2019; Kiger et al., 2012), attitudes toward mathematics (Lee & Chen, 2015; Sen et al., 2017), and confidence (Yuan et al., 2010). Specifically in the context of geometry, recent studies have shown that dynamic geometry environments such as GeoGebra or Geometer's Sketchpad support students' geometric reasoning, visualisation, and mathematical communication (Bach et al., 2024; Kusumah et al., 2020; Pittalis & Drijvers, 2023). Research has further suggested that technology-infused geometry environments may help students examine invariant geometric relationships through exploration and manipulation rather than observation alone (Baccaglini-Frank, 2019; Bach et al., 2024; Leung et al., 2013). Geometry provides a particularly appropriate context for examining technology integration because many geometric concepts involve visualisation, spatial reasoning, transformation, and manipulation of representations. More so, CRA-aligned geometry instruction may utilise technological resources, such as virtual manipulatives or dynamic geometry environments, during the representational stage. Consequently, geometry serves as a useful context for examining how PSTs evaluate technology-infused mathematics activities.

Given the current relevance of technology integration, the research-based benefits of technology use in K–8 mathematics, and the potential to align geometry instruction with the CRA sequence by utilising technological resources, it is crucial that K–8 preservice teachers (PSTs) are prepared to integrate technology into their future mathematics classrooms. Nonetheless, research has reported PSTs often feeling unprepared to integrate technology into the classroom upon entering the field as an in-service teacher (Piedra Moreno, 2024; Tondeur et al., 2012). Prior studies have reported findings related to this feeling of unpreparedness, such as a lack of technology skills (Teo, 2009), negative attitudes toward technology integration, and a lack of confidence in their ability to meaningfully integrate technology (Crompton, 2015; Piedra Moreno, 2024). When deciding how to integrate technology into the classroom, teachers logically have two options: (a) locate an existing activity that utilises a technological resource and conduct an evaluation of the activity or (b) create a new activity that utilises a technological resource. Few research studies, however, have examined technology integration through a perspective that honours this distinction. Thus, research that examines the process of how PSTs plan to integrate technology while noting the distinction between evaluating and creating a technology-infused activity may be beneficial to our understanding of K–8 PSTs' abilities to integrate technology into mathematics.

In their analysis of in-service secondary mathematics teachers, McCullough et al. (2018) examined factors that influenced teachers' integration of technology into mathematics lessons. They reported aspects of technological resources that teachers liked and disliked, highlighted teachers' rationale for utilising specific resources, and summarised teachers' experiences using technology to teach secondary mathematics. A thorough review of the literature revealed no studies were found to have a similar approach applied to K–8 PSTs. Therefore, the approach utilised in McCullough and colleagues' study informed the research design in this examination of K–8 PSTs.

The intent of this study was to examine K–8 PSTs' evaluation of existing geometry activities that utilise a technological resource. Specifically, the researchers were interested in the impact that the technological resource could have on instruction, the specific aspects of the activity that PSTs either liked or disliked, and PSTs' rationale as to why they would choose to either use or not use an activity in their future K–8 mathematics classrooms. Thus, the research questions in this study included the following:

1. *In existing geometry activities that utilise a technological resource evaluated by K–8 PSTs, how would the resource impact mathematics instruction?*
2. *What do K–8 preservice teachers like about existing geometry activities that utilise a technological resource?*
3. *What do K–8 preservice teachers dislike about existing geometry activities that utilise a technological resource?*



4. Which characteristics of existing geometry activities that utilise a technological resource inform K–8 PSTs' interest in implementing the activity in their future classrooms?

Theoretical Framework

The guiding theoretical lens of this study was Kimmons et al.'s (2020) Passive, Interactive, and Creative—Replacement, Amplification, and Transformation (PICRAT) model, which allowed the researchers to examine the impact of technology integration regarding both students' relationship to technology and teachers' pedagogical practices. Organised as a hierarchical matrix (Figure 1), the PICRAT model is comprised of nine distinct levels that classify technology's impact on instruction in respect to the perspective of both students and teachers.

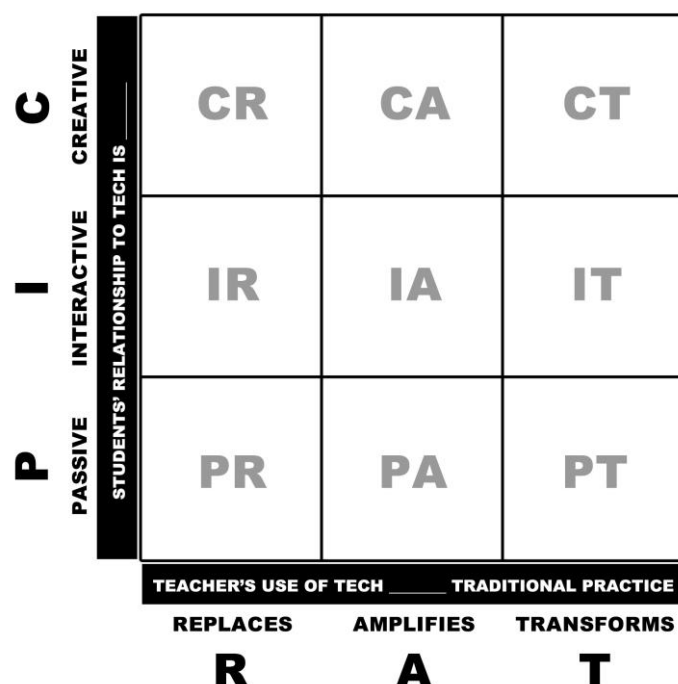


Figure 1. The hierarchical PICRAT matrix (Kimmons et al., 2020, p. 189). [CC BY 3.0]

The PIC portion of the PICRAT model describes how students use a technological resource during instruction. In the first level—passive learning—students use technology to receive content passively, such as reading notes on a PowerPoint, listening to an audiobook, or watching a YouTube video. Kimmons and colleagues (2020) noted that while passive modes of learning are essential, they are insufficient on their own to support effective learning. The second level of PIC is interactive learning, in which students use technology to explore, experiment, collaborate, and engage in other active behaviours—such as playing games or manipulating dynamic models. While interactive learning promotes lasting, meaningful learning (Kennewell et al., 2008), the learning that occurs in such activities is largely structured by the technology rather than by the student. The final PIC level—creative learning—transcends this limitation by allowing students to use technology to create learning artifacts, such as writing computer code or constructing virtual figures with dynamic mathematics software. Instances of creative learning best promote lasting, meaningful learning as students apply concepts and skills to create artifacts to solve problems (Papert & Harel, 1991). Kimmons and colleagues noted that focusing on students' use of technology may prevent the erroneous practice of assigning educational value to the technology itself (e.g., "GeoGebra is a high-quality resource, so any activity in which

students use GeoGebra is a high-quality activity”). By reflecting on the PIC portion of the PICRAT model, teachers are forced to examine more closely how students may use technology during instructional activities and consider the pedagogical benefits of the use of technology.

For the second portion of the PICRAT model, Kimmons et al. (2020) adopted the RAT model proposed by Hughes et al. (2006), which describes how the use of technology impacts teachers’ practices. The first level is replacement, in which technology is used to replace a previous practice (e.g., using an interactive whiteboard instead of a chalkboard) without any functional improvement. Kimmons and colleagues noted that while replacement is not necessarily poor practice, it does not provide substantial benefits to students’ learning outcomes. At the second RAT level—amplification—technology use enables some degree of enhancement to students’ learning practices or outcomes (e.g., using review features of a word processor for efficient feedback or using digital devices to gather data for analysis). While amplification improves teachers’ practice, Kimmons and colleagues stated that it does not drastically change pedagogy. The final RAT level is transformation, in which the use of technology enables implementation of a previously inconceivable or impractical pedagogical practice (e.g., using a virtual simulation to analyse data). Integrating technology at the transformation level allows teachers to implement underutilised pedagogical practices and provide students with unique learning experiences. To aid in the process of determining the RAT level with which a particular use of technology aligns, Kimmons et al. supplemented their descriptions with the flowchart shown in Figure 2.

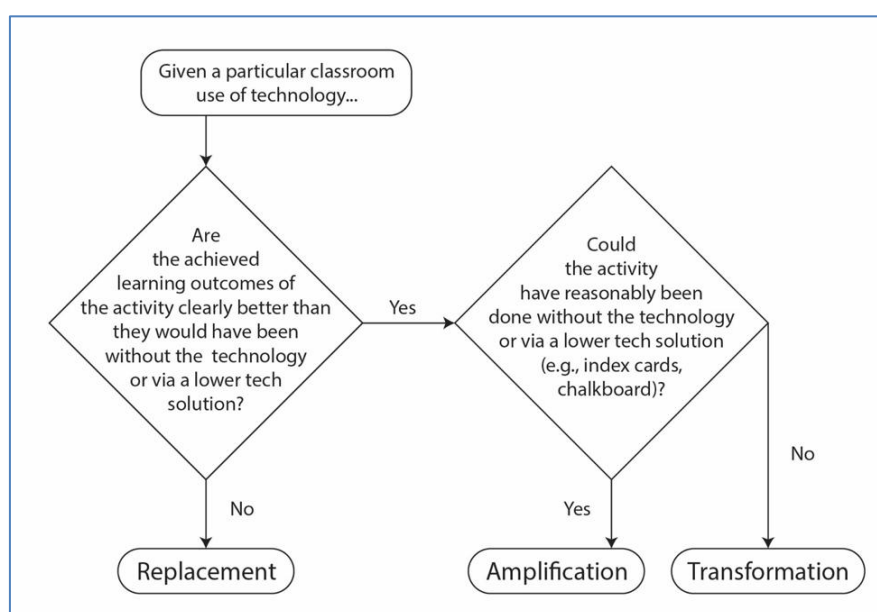


Figure 2. Flowchart for the RAT portion of the PICRAT model (Kimmons et al., 2020, p. 189).
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In this study, the PICRAT model guided the data collection, data analysis, and interpretation of the findings. Regarding data collection, the prompts utilised were designed in a way that would provide information in relation to both students’ and teachers’ use of technology. The data analysis was heavily impacted by the PICRAT model as it was employed as an *a priori* codebook. Additionally, the interpretation of the findings was conducted through the lens of the PICRAT model by relating the findings to the distinctions identified in the model. At the same time, the researchers recognise that technology integration requires more than technological knowledge alone. Technological Pedagogical Content Knowledge (TPACK) emphasises the interaction of technological, pedagogical, and content knowledge in teachers’ instructional decision-making (Koehler & Mishra, 2009). PSTs’ ability to

evaluate existing technology-infused mathematics activities may provide evidence regarding how they draw upon these domains of knowledge when making instructional judgments. Moreover, although PICRAT was used as the analytical framework in this study, PSTs' evaluations may also reflect aspects of developing TPACK.

Methodology

A social constructivist, qualitative paradigm was utilised in this study to seek understanding regarding K–8 PSTs' evaluation of geometry activities that utilise a technological resource. In social constructivism, understanding of the world is sought by relying on the views of participants (Creswell & Poth, 2017). Through the lens of social constructivism, a descriptive approach was applied to examine how PSTs make sense of geometry activities that utilise a technological resource. Thus, this study collected and analysed K–8 PSTs' responses to describe the culture of PSTs' evaluation of geometry activities that utilise a technological resource.

Researcher Positionality

A social constructivist perspective recognises the co-construction of reality that occurs between researchers and research participants (Creswell & Poth, 2017). Due to this recognition, the researchers must situate themselves in relation to the context of a study to increase transparency. At the time of this research, the first author was a doctoral candidate studying mathematics education and an instructor of K–8 Math Methods. He has a strong interest in researching PSTs' experiences with educational technology and their abilities to integrate technology into their future mathematics classrooms. The second author is an associate professor of mathematics education and is an instructor of K–8 Math Methods as well. She has taught both undergraduate and graduate mathematics education courses at the research site for over ten years. Since the researchers are instructors of K–8 Math Methods, they recognise the potential for power and/or status differentials between themselves and the participants of this study. These differentials may have had an impact on PSTs' willingness to participate in this study and/or their responses to the prompts utilised for data collection. The researchers were aware of this potential and were conscious of their personal biases, beliefs, and experiences with PSTs when recruiting participants, collecting data, analysing data, and interpreting the findings.

Context, Population, and Sample

This study was conducted at a large postsecondary institution in the Northwest region of the United States and approved by its Institutional Review Board. Participants ($N = 44$) of this study were recruited from an undergraduate mathematics methods course (i.e., K–8 Math Methods). One section of the course during both semesters of 2021 were utilised for recruitment. All participants were enrolled in the course and were working toward a bachelor's degree in elementary education with licensure to teach grades K–8. Participants were in either their penultimate or final year of the teacher education program, and many were expected to complete their student teaching experience in the semester following the mathematics methods course. Thus, the population of this study was PSTs who were undergraduate students at the research site, enrolled in their third or fourth year of an elementary education program, and enrolled in K–8 Math Methods.

In two subsequent iterations of the K–8 Math Methods course, participants engaged in a two-day lesson (two 75-minute periods) on K–8 geometry during the fifteenth week of each semester. In the lesson relevant to this study, PSTs explored theories, pedagogical considerations, and mathematics content relevant to K–8 geometry. Based on the K–8 geometry topics presented by Van de Walle et al. (2018), PSTs completed a two-day lesson addressing van Hiele's model (1984), the CRA sequence (Bruner & Kenney, 1965), K–8 geometry content, and technology-infused geometry instruction.



Data Collection

Data were collected immediately following the two-day lesson on K–8 geometry. Notably, data collection occurred in April and November of 2021 during the COVID-19 pandemic. The creation of the prompt used for data collection was informed by both the PICRAT model and McCullough et al.'s (2018) examination of factors that influenced secondary mathematics teachers' integration of technology into mathematics. To examine K–8 PSTs' evaluation of geometry activities that utilise a technological resource, PSTs were asked to respond to the following prompt:

Locate an existing geometric thinking and/or geometric concepts activity that utilises a technological resource (e.g., GeoGebra) and respond to the following prompts: What do you like about the activity? What do you dislike about the activity? Why would you choose to either use or not use this activity in your future classroom?

PSTs had the flexibility to select any existing geometry activity that utilised a technological resource, though GeoGebra was provided as an example. No restrictions were placed on grade level, type of resource, publisher, platform, or PICRAT level. PSTs submitted their responses to this prompt to the researchers via a learning management system. Responses were initially downloaded as individual files and later organised into a spreadsheet. When organising the data into the spreadsheet, PSTs' names were removed and replaced with identification numbers to maintain anonymity and ensure confidentiality.

Data Analysis

Separate analyses were conducted in relation to each research question. To address the first research question, the researchers utilised the PICRAT model as an *a priori* codebook. Each PST's response was coded as passive, interactive, or creative (PIC), and replacement, amplification, or transformation (RAT) by each of the researchers. In cases where the use of technology could potentially be coded as multiple levels, the researchers selected the level that aligned with the most prominent use of technology in the activity. The researchers compared their initial coding, discussed and made changes that were deemed necessary, and assessed the interrater reliability (IRR). To provide a description of the activities evaluated by PSTs and address the second, third, and fourth research questions, the researchers utilised emergent coding following the theme-identifying strategy of repetition. As described by Ryan and Bernard (2003), repetition identifies themes based on the frequency at which a topic occurs and reoccurs in participants' responses. In alignment with Creswell and Poth's (2017) recommendations for emergent coding, the researchers established a coding platform in a spreadsheet and developed cooperatively a list of preliminary codes in relation to each research question. Next, each researcher applied independently the preliminary codebooks to each PSTs' response. The researchers then compared their coding, made changes that were deemed necessary following discussion, and assessed the IRR of their coding. Following the recommendation of Creswell and Poth, the researchers represented IRR as percent agreement, that is, the percentage of codes that were the same for both researchers.

Methods of Achieving Validity

While the concept of qualitative validity is debated, Creswell and Poth (2017) described how various methods can be employed to increase several constructs related to the validity of a study. To increase the dependability, we presented rich descriptions of our research procedures to ensure that others can follow and critique our decisions. The confirmability of our findings was increased by including detailed descriptions of the data (i.e., verbatim responses from PSTs) and thoroughly discussing the data analysis procedures utilised in this study. Our complete description of the site, population, and sample clearly established the appropriate transferability of the findings. We sought to increase this study's authenticity by positioning ourselves in relation to the context in which this study occurred. Lastly, the reliability of our findings was increased by utilising multiple coders, assessing the IRR, and



employing peer debriefing throughout the writing process. More so, an audit trail was established by documenting of all coding decisions, emergent codebook revisions, and consensus discussions.

Results

Of the 53 PSTs recruited for this study, 22 from each iteration of the course in subsequent semesters ($N = 44$, 83.0%) consented for their responses to be analysed for research purposes. Of this sample that agreed to participate in this study, all but three PSTs had adequately responded to the prompt utilised for data collection. The missing data occurred in the portion of the prompt that asked, “What do you dislike about the activity?” Since these three PSTs had responded adequately to the other portions of the prompt, they were only excluded from the analysis for the third research question. An analysis based on demographic factors (e.g., gender, race/ethnicity, year in program, undergraduate major, etc.) was not possible due to the characteristics of the sample recruited (i.e., mostly White females).

After the researchers coded the data individually, the IRR of both the *a priori* and emergent coding was calculated to ensure Creswell and Poth’s (2017) recommended minimum IRR of 80% was achieved. When using the PICRAT model as an *a priori* codebook, the researchers attained an acceptable IRR of 81.8%. Emergent coding achieved acceptable IRRs of 80.5%–95.5% across analyses with a mean weighted IRR of 89.6%.

To provide a more detailed description of the activities evaluated by PSTs, the researchers used emergent coding to examine the types of technological resources that the activities utilised. The analysis found that three different types of resources were utilised in the activities evaluated by PSTs, as seen in Table 1. Most PSTs ($n = 30$, 68.2.%) chose to evaluate an activity that utilised a mathematical game while others evaluated an activity that utilised a virtual manipulative ($n = 13$, 29.5%) or a virtual demonstration of a mathematics concept ($n = 3$, 6.8%). Likely due to the lesson’s focus on geometric shapes and properties, many PSTs evaluated an activity that utilised a mathematical game in which students were asked to sort and classify various geometric shapes based on their appearance, such as the game shown in Figure 3.

Table 1

Type of Technological Resource Utilised in Activities Evaluated by PSTs

Resource Type	<i>n</i>	Examples
Mathematical game	30	Sorting geometric shapes (https://www.geogebra.org/m/wHnByPks#material/bgY4rBep) Identifying geometric shapes (https://mrnussbaum.com/shape-factory-online-game) Identifying types of triangles (https://www.splashlearn.com/s/math-games/identify-types-of-triangles)
Virtual manipulative	13	Interactive tangram puzzle (https://www.geogebra.org/m/zrGERP88) Dynamic geometry environment (https://www.geogebra.org/m/tzdtevu7) Interactive proof environment (https://canfigureit.com/)
Virtual demonstration	3	Informal proofs of properties of triangles (https://www.geogebra.org/m/JVc49sEa) Definitions of points, lines, and planes (https://www.geogebra.org/m/z2FSQCSv#material/KV8xXxLF) Constructing the Twitter logo with circles of varying radii and color (https://www.geogebra.org/m/TtXNqBv6)





Figure 3. GeoGebra game for sorting objects (GeoGebra Team German & GeoGebra Translation Team German, 2022). [CC BY-NC]

Impact of Technological Resources on Mathematics Instruction

To address the first research question, PSTs' responses were coded in alignment with the *a priori* codebook of the PICRAT model. Each researcher coded each response as either passive, interactive, or creative (PIC) and either replacement, amplification, or transformation (RAT). Codes were based on both the affordances of the technological resources utilised in the activities as well as PSTs' descriptions of how the activity could be implemented into the K–8 mathematics classroom. Additionally, each PST's response was coded as a single level of the PICRAT model. Frequencies and examples of PSTs' responses that aligned with each observed PICRAT level are shown in Table 2. Notably, no activities evaluated by PSTs utilised technology in a way that aligned with the PT (passive, transformation); IT (interactive, transformation); or CR (creative, replacement) levels of the PICRAT model.

Table 2
Activities Through the Lens of the PICRAT Model

PICRAT Level	<i>n</i>	Examples
PR	1	Reading definitions of points, lines, and planes (https://www.geogebra.org/m/z2FSQCSv#material/KV8xXxLF)
PA	6	Completing a non-interactive quiz that provides instant feedback (https://www.mathgames.com/skill/1.5-count-edges-vertices-and-faces)
IR	5	Composing/decomposing shapes with an interactive tangram puzzle (https://www.geogebra.org/m/zrGERP88)
IA	29	Playing interactive games that provide instant feedback (https://www.geogebra.org/m/wHnByPks or https://www.geogebra.org/m/DNC5JUDD)
CA	2	Creating shapes in a dynamic geometry environment (https://www.geogebra.org/m/tzdtevu7)
CT	1	Creating proofs in an interactive geometry proof environment (https://canfigureit.com/)

Nearly two-thirds ($n = 29$, 65.9%) of the activities evaluated by PSTs utilised technology in alignment with the IA (interactive, amplification) level of the PICRAT model. Activities coded as IA most commonly included the use of games in which students could drag geometric shapes into various categories (e.g., circles, triangles, squares, rectangles, prisms, pyramids, etc.) and also included games where students would be asked to classify three-dimensional shapes based on the properties of their two-dimensional nets. These technological resources were coded as interactive because students would need to interact with the resource (e.g., drag or rotate geometric shapes or nets) to study the mathematics content. The rationale for coding these resources as amplification was frequently associated with the resource's ability to provide instant feedback to individual students. This capability would likely improve students' learning outcomes but would not likely have a significant impact on a teacher's pedagogical practice since the activities could reasonably be implemented without technology. Five PSTs (11.4%) evaluated activities that utilised technology in alignment with the IR (interactive, replacement) level of the PICRAT model. Activities coded as IR included the use of virtual manipulatives in which students could drag two-dimensional shapes to engage in composition and decomposition (e.g., tangram puzzles). These interactive technological resources were coded as replacement since they did not include any form of feedback to students, so students' learning outcomes would likely not differ greatly had the same activity been implemented without the use of technology.

Seven of the activities evaluated by PSTs utilised technology in a way that promoted passive learning, with six (13.6%) aligning with the PA (passive, amplification) level and one (2.3%) aligning with the PR (passive, replacement) level of the PICRAT model. In these activities, students would not interact with the technological resources in a meaningful way or use the resources to create mathematical representations. Rather, students would engage primarily in passive learning, such as reading or observing. Activities coded as PA included the use of games in which students would be quizzed on the properties of geometric shapes or composition of nets, videos of informal proofs of properties of triangles, and a slider-controlled demonstration of the construction of a logo. These activities were coded as amplification because they either incorporated instant feedback, efficiently presented informal proofs, or modelled complex mathematical representations, all of which would potentially improve students' learning outcomes. The activity coded as PR was a virtual list of definitions of points, lines, and planes. This activity was coded as replacement because the information could realistically be presented without digital technology (i.e., written on a whiteboard) while maintaining students' learning outcomes.

Only three PSTs evaluated an activity that utilised technology in a way that enabled students' creative learning, with two (4.5%) aligning with the CA (creative, amplification) level and one (2.3%) aligning with the CT (creative, transformation) level of the PICRAT model. In these activities, students would use the technological resources to create geometric shapes or geometry proofs. Activities coded as CA utilised a dynamic geometry environment (i.e., GeoGebra), in which students could create and examine various two-dimensional shapes. These were coded as amplification due to the potentially beneficial impact of increased efficiency on students' learning outcomes and the fact that the activity could reasonably be implemented using a lower-technology solution (e.g., whiteboard, geoboard, etc.).

The activity coded as CT was an interactive geometry proof environment in which students could manipulate geometric shapes and construct proofs of various theorems. In the proof environment, students would manipulate geometric relationships dynamically while immediately testing conjectures against formal proof structures. Rather than constructing paper-and-pencil proofs after static observations, students could iteratively create, revise, and validate proof statements in response to dynamic feedback. Such interactions alter both the role of the learner and the instructional decisions of the teacher, making the activity difficult to reproduce in a non-digital setting.



Liked Aspects of Activities

The second research question was investigated by examining PSTs' responses to the portion of the prompt that asked, "What do you like about the activity?" Emergent coding identified seven themes, which were organised into three primary categories: (a) content, (b) technological design, and (c) pedagogy. Content themes included the quality of mathematics content, the use of relevant contexts, and the variety of content included in the activity. Technological design themes included the technology's ease of use and the interactive nature of the technology. Pedagogy themes included the activity's provision of immediate feedback and its capability to scaffold instruction. Frequencies and examples of PSTs' responses that informed each theme observed are shown in Table 3. Since each PST's response could potentially be coded as multiple themes, the sum of the frequencies in Table 3 is greater than the sample size.

Table 3
What PSTs Liked About the Activities

Theme	<i>n</i>	PSTs' Responses
Content		
Mathematics content	17	• [The activity] requires students to focus on the properties of each of the shapes as well as what classes the shape fall into • I really like this activity because it helps connect 2D shapes to 3D shapes • I like that this resources gets students to think not only about the 3D shape of a figure, but also what the net of a 3D shape may look like
Variety	10	• [The activity] gives you an array of different shapes that are different sizes • [Students] can practice comparing many different shapes including circles, squares, quadrilaterals, etc. • I like that the shapes students are asked to classify are in different orientations and sizes
Relevant context	9	• The activity uses everyday objects so students feel like what they are learning is relevant • This activity has excellent real-world application since students are sorting common objects that they will see in their everyday lives • I like that [the activity] gives students real-world photos and items instead of just drawing out of a textbook
Design		
Ease of use	8	• I like this activity because it is very simple and easy to use • I like that this website is very easy to navigate—it has clear instructions and also has pictures to help guide the students • I really like how easy the program was to use—the points are very clear, the directions were easy, and the goal of the activity was concise and specific
Interactive	6	• [The activity] allows students to physically move a shape into its proper category • The activity provides a ruler that students can use to measure both length and right angles
Pedagogy		
Feedback	7	• The activity gives automatic feedback • This resources tells students if they are right or wrong • [The activity] will show a green check when students get the correct answer
Scaffolding	7	• I like that this activity has a series of activities to work through—this allows for scaffolding, for students to build upon their knowledge, and work their way toward understanding more difficult concepts as they go along • This [activity] provides easier to increasingly difficult sorting [of shapes] • I like that [the activity] progressively gets harder



Of the three primary categories, the largest proportion of PSTs discussed topics related to the content of the activity when reporting aspects of the activity that they liked. Within this category, the most frequently discussed theme was the quality of mathematics content, which was mentioned by 17 PSTs (38.6%). Specifically, PSTs liked activities that would allow students to compare various two- and/or three-dimensional shapes based on their properties (e.g., parallel sides, right angles, etc.). PSTs also liked when activities included a wide variety of shapes for students to examine ($n = 10$, 22.7%) and when activities utilised a context that was relevant to students ($n = 9$, 20.5%), such as using a coin instead of a circle or a fish tank instead of a rectangular prism.

Several PSTs noted that they liked specific design aspects of the technological resource utilised in the activity. Eight PSTs (18.2%) liked the ease of use of the technological resources—often citing the inclusion of clear instructions and well-functioning mechanics. Additionally, six PSTs (13.6%) mentioned that they liked the interactive design of the technological resource. Examples highlighted by PSTs included resources in which students could drag shapes into categories, reposition shapes to practice composition and decomposition, or drag a virtual ruler to measure the side lengths of shapes.

Lastly, PSTs also liked the pedagogical implications of implementing the activity. Several PSTs ($n = 7$, 15.9%) noted the benefits of activities in which instant feedback was included. In the activities evaluated by PSTs, the feedback generally identified solutions as either correct or incorrect but rarely included further explanation of the rationale for correctness or incorrectness. Additionally, 15.9% of PSTs ($n = 7$) highlighted the activity's potential to be used to scaffold mathematics instruction. PSTs suggested that scaffolding would be possible when implementing activities because of the order in which their components were presented, with initial tasks being easier to complete and subsequent tasks increasing in levels of challenge and difficulty.

Disliked Aspects of Activities

The third research question was investigated by examining PSTs' responses to the portion of the prompt that asked, "What do you dislike about the activity?" Emergent coding identified six themes, which were organised into three primary categories: (a) content, (b) technological design, and (c) pedagogy. Content themes included a misleading representation of mathematics concepts and the limited assortment of content included in the activity. The only technological design theme was structural aspects of the technology that restricted students' use in some way. Pedagogy themes included the lack of immediate feedback and the activity having a limited application in the classroom. The final theme identified was PSTs reporting that there was nothing that they disliked about the activity. Additionally, it is worth noting that the sample size of this specific analysis was $n = 41$, as three PSTs did not provide a response to this portion of the prompt utilised for data collection. Frequencies and examples of PSTs' responses that informed each observed theme are shown in Table 4. Since each PST's response could potentially be coded as multiple themes, the sum of the frequencies in Table 4 is greater than the sample size.

Table 4
What PSTs Disliked About the Activities

Theme	<i>n</i>	PSTs' Responses
Pedagogy		
Limited application	16	- One thing is dislike about this activity is that there is no room for extension—it is pretty basic and does not give a lot of room for students to grow [The activity] could only be useful for a certain age level - This activity can become boring for students since it is repetitive
Inadequate feedback	4	- I dislike that there is no way for students to check their work after they have classified all of the shapes [The activity] does not tell [students] why answers are wrong or how to think differently - I do not like that [the activity] does not tell [students] the correct answer
Content		
Limited content	11	- I wish this activity had more templates for students to try and fit smaller shapes into - I wish there was an option to change the shape...to see more than just the parallelogram - There is no way to...add any additional geometric solids for students to sort
Misleading mathematics	3	- This activity does not emphasise the different between 2D and 3D shapes...the [2D] poster and [3D] dice are designated as the same [shape] - The students can only classify squares as squares—I would make it so students could classify the square as both a square and a rectangle
Design		
Restrictive structure	13	[The activity] does not allow for the [3D] shapes to be rotated...this would be helpful for a student who struggles to visualise the whole shape - What I do not like about this activity is that it will not let [students] drag a shape into the [incorrect] side - I do not like that this activity does not include images of the triangles
Nothing		
	4	- I do not have anything I dislike about this activity - I actually like everything about this activity

When discussing aspects that they disliked about the activities, PSTs most frequently discussed topics related to the pedagogical implications of implementing the activity in a classroom. Many PSTs ($n = 16$, 39.0%) mentioned disliking that the activity they evaluated because they felt that the activity would only be applicable in a limited number of settings. For example, PSTs stated that activity: (a) was repetitive and would quickly become boring to students, (b) would not provide students with a challenge, (c) could only be used with young or struggling students, or (d) did not provide opportunities to scaffold instruction for students who would benefit from extension activities. Additionally, some PSTs ($n = 4$, 9.8%) disliked that the activity selected did not provide students with adequate feedback as to whether their solutions were correct or incorrect.

Additionally, PSTs discussed aspects related to the content of the activity when highlighting what they disliked about the activity. Several PSTs ($n = 11$, 26.8%) disliked that the activity included a limited amount of content—generally referring to the variety of shapes that were present in the activity. A small group of PSTs ($n = 3$, 7.3%) disliked that the mathematics content included in the activity was



somewhat misleading. In these cases, PSTs were speaking of an activity that would ask students to sort both two- and three-dimensional shapes, such as the GeoGebra game previously shown in Figure 3. Despite this, the categories into which shapes could be sorted were labelled with the names of two-dimensional shapes. Thus, to reach the “correct” solution in this activity, students would have to place some three-dimensional shapes into categories labelled as two-dimensional shapes (e.g., placing a picture of a pyramid into the category for triangles).

Specific design aspects of the technological resource utilised in the activity were disliked by several PSTs ($n = 13$, 31.2%). The only theme that aligned with this category was PSTs reporting that the structure of the resource was somewhat restrictive. Generally, PSTs who discussed this topic suggested additional features that could be added to the technological resource to make the activity more valuable to students’ learning. Some improvements that PSTs suggested included: (a) the ability to rotate three-dimensional shapes, (b) the ability to decompose three-dimensional shapes into nets, (c) the ability to move shapes into incorrect categories, and (d) the inclusion of additional resources (e.g., virtual ruler, coordinate grid, or images of shapes).

Lastly, a small group of PSTs ($n = 4$, 9.8%) noted that there were no aspects or characteristics of the activity that they disliked. This group only included PSTs who provided a response to, “What do you dislike about the activity?” Thus, this group does not include the three PSTs who did not provide a response to this portion of the prompt, as they were excluded from the analysis of this research question.

Rationale for Future Use of Activities

The fourth research question was investigated by examining PSTs’ responses to the portion of the prompt that asked, “Why would you choose to either use or not use this activity in your future classroom?” Emergent coding identified six themes, which were organised into three primary categories: (a) content, (b) technological design, and (c) pedagogy. The only content theme was the activity’s inclusion of valuable mathematics content. The only technological design theme was the engaging nature of the technology utilised in the activity. Pedagogy themes included the activity’s potential to be used to either introduce, practice, or review content. The final theme identified was PSTs’ lack of specification as to why they either would or would not use the activity in their future classroom. Additionally, most PSTs (93.2%) reported that they would use the activity in their future classroom (e.g., “I would definitely use this resource” or “I would use these activities”). Two PSTs reported that they would maybe use the activity in the future (e.g., “I am not 100% sure if I would use this [activity] in the classroom or not”) while just one PST did not plan to use the activity (e.g., “I would probably not use [the activity]”).

Most PSTs based their rationale for future use of the activity they evaluated on various topics related to the pedagogical implications of implementing the activity. In responses that aligned with the pedagogy category, PSTs discussed various purposes of implementing the activity. Most reported that they would use the activity to either introduce ($n = 12$, 27.3%) or review ($n = 10$, 22.7%) content, but several also suggested that the activity could be implemented to allow students to practice newly learned content or as a supplemental activity ($n = 9$, 20.5%). In addition, it is worth noting that the two PSTs who reported they would maybe use the activities evaluated in the future based their rationale on the potential to use the activity to either review content or have students practice content.

One quarter of PSTs ($n = 11$, 25.0%) stated that their decision to either use or not use the activity in their future classroom was based on the activity’s inclusion of valuable mathematics content. PSTs reported that these activities would likely help students improve their understanding of: (a) the properties of different shapes, (b) the relationships between the properties of shapes, (c) the connection between two- and three-dimensional shapes, and (d) the application of shape to “real-world” phenomena. The one PST who stated they would not use the activity evaluated in their future classroom indicated that a lack of valuable mathematics content informed the decision, as the PST “could find or create something that is more rigorous for the students.” Frequencies and examples of PSTs’ responses



that informed each observed theme are shown in Table 5. Since each PST's response could potentially be coded as multiple themes, the sum of the frequencies in Table 5 is greater than the sample size.

Table 5
PSTs' Rationale for Future Use of Activities

Theme	<i>n</i>	PSTs' Responses
Pedagogy		
Introduce content	12	- I could use this to introduce properties of parallelograms - I would...use [the activity] as an introduction tool to help student identify different 3D shapes around the classroom - I would use this [activity] in my classroom to introduce the topic of using properties to identify a shape
Review content	10	- I would use this activity in my classroom as a quick, whole-class refresher before starting a lesson - I would use this resource...as a review...of 3D shapes - I would most likely use this resource...before a quiz for students to refresh their memories
Practice content	9	[The activity] is good practice because it gives immediate feedback - I think this activity provides students with a good opportunity to practice classifying different sizes and orientations of shapes - I would use this [activity] for specific students who may need extra practice
Content		
Valuable mathematics content	11	- Because this activity and all of its components are so thorough, it will allow students to build a solid understanding of the concept of geometric nets - This is a great visual to show how the sides and angles can be the same and different - I like that [the activity] has real-life examples—I think it is important to connect math to real life
Design		
Engaging	6	- I like that...it could be a really engaging [activity] for younger students [The activity] can get students interested in concepts of geometry by including something that they...enjoy - I would use this [activity] in my future classroom because it is a fun, interactive way for students to strengthen their mathematical thinking
Not Specified		
	9	I would absolutely use this in my classroom

Few PSTs ($n = 6$, 13.6%) discussed technological design features when presenting their rationale as to why they would use the activity in their future classrooms. In these responses, PSTs generally discussed concepts related to engagement, such as students likely enjoying the technological resource or having fun while working with interactive, virtual models. Additionally, several PSTs ($n = 9$, 20.5%) did not specify their rationale as to why they would choose to use or not use the activity in the future classroom. In these cases, PSTs generally stated that they would use the activity in the future but did not provide specific characteristics of the activity that informed their interest in future implementation.



Discussion

Most PSTs reported that they would like to implement the activity they evaluated in their future classrooms. Nevertheless, PSTs' tendency to select an activity that utilised technology in a way that aligned with the IA level of the PICRAT model suggests that additional training in technology integration may be needed in order for PSTs to be prepared to more meaningfully integrate technology (e.g., integration that aligns with the CA, IT, or CT levels of the PICRAT model). Additionally, this study contributes to the research field by assessing the reliability of using the PICRAT model as an *a priori* codebook and providing an example of utilising the PICRAT model as a theoretical framework.

The PICRAT Model

While the authors obtained an acceptable IRR for the PICRAT model, they did experience some challenges in coding activities as a single PICRAT level. The design of the PICRAT model implies mutual exclusivity between the levels. Nevertheless, the authors argue that the distinctions between levels are not as binary as suggested—particularly when examining the use of technology over an extended time. For example, some activities evaluated by PSTs in this study used the same technological resource in a way that aligned with different levels of the PICRAT model at different points in time during the activity (i.e., using GeoGebra to first present information [i.e., passive learning] and then allowing students to use GeoGebra to manipulative and experiment with different shapes [i.e., interactive learning]). A potential method for increasing the utility of the PICRAT model could be to assess technology's impact on instruction over time rather than as a single, summative snapshot. More so, quantitative analyses might consider weighted observations over time (e.g., 5 minutes of PR and 15 minutes of IA) to obtain a more precise representation of how technology is being used in the classroom.

Impact of Technological Resources on Mathematics Instruction

The findings of the *a priori* coding in alignment with the PICRAT model regarding the first research question found that the activities evaluated by PSTs most frequently aligned with the IA level of the PICRAT model (65.9%). One possible explanation of this finding is that IA activities may simply be overrepresented within publicly available geometry repositories. Many online resources are designed for practice and feedback and therefore naturally align with IA uses of technology. Consequently, the dominance of IA activities may reflect both PSTs' preferences and the broader digital resource ecosystem available to teachers. Another possibility is that PSTs may gravitate toward IA uses because they resemble familiar instructional practices while still leveraging technology's efficiency and engagement benefits. More transformative technologies often require greater pedagogical expertise and confidence.

Notably, very few PSTs (6.8%) evaluated activities that utilised technology in alignment with high-impact levels of the PICRAT model (e.g., CA, IT, and CT). These findings align with those of prior research, as Meyerink and Luo (2025) found that K–8 PSTs' proposed uses of technology in mathematics most frequently aligned with the IA level of the PICRAT model with few instances aligned with high-impact levels. Similarly, K–8 in-service mathematics teachers classified their own technology-infused activities as amplification when evaluating activities in relation to the RAT portion of the PICRAT model (Thomas & Edson, 2019). While mathematical games were utilised in many of the evaluated activities, several activities utilised virtual manipulatives such as geoboards, pattern blocks, or tangrams—aligning with the findings of Moyer-Packenham et al. (2008).

Overall, these findings are encouraging as most PSTs evaluated and considered the future use of an activity that utilised technological resources in a way that fostered students' interactive learning and amplified teachers' instruction. At the same time, findings also suggest that additional training may need to be integrated into teacher education programs to promote uses of technology that align with the high-impact levels of the PICRAT model. Recommendations from the literature for technology



integration training that may promote PSTs' high-impact uses of technology include: (a) explicit modelling of high-impact practices by teacher educators (Foulger et al., 2017), (b) experience using the PICRAT model (Kimmons et al., 2020), or opportunities to use technology in K–8 classrooms (Graham et al., 2004). It is unclear whether teacher educators can or should expect PSTs to attain the high-impact levels of the PICRAT model when selecting and evaluating activities that utilise a technological resource. For example, when utilising the Framework for Teaching (Danielson, 2007), teacher educators do not expect PSTs to attain the distinguished/advanced level since it is assumed that years of experience are needed to reach this level. Rather, the expectation is that PSTs attain either basic or proficient levels for each element of effective teaching. Similarly, it is possible that high-impact uses of technology are mostly unattainable by PSTs and are instead a product of years of technology-infused teaching experience, though more research is needed on this topic.

Liked Aspects of Activities

The themes identified during the emergent coding of the second research question showed that most PSTs liked various aspects related to the content of the activity, such as the quality of mathematics content, the relevance of the context, or the variety of shapes included. By comparison, fewer PSTs discussed aspects related to either the design of the technological resource utilised in the activity or the pedagogical implications of implementing the activity, which is what in-service secondary mathematics teachers tended to discuss (McCullough, 2018). An explanation for the imbalance among these three categories is unclear. After a thorough review of the literature, no studies were located that examined how K–8 PSTs determine what they value about existing geometry activities that utilise technological resources. One potential explanation for this finding is that evaluating the value of the content of an activity may be easier than evaluating either characteristics of a technological resource or the pedagogical implications of implementing the activity. Another potential explanation might be that PSTs simply tend to focus on the content of an activity when conducting an evaluation. Regardless, further research on this topic is needed to provide additional understanding of how PSTs determine which aspects of an activity they think might be beneficial to mathematics instruction.

Disliked Aspects of Activities

The themes discovered during the analysis of the third research question found that PSTs most frequently disliked aspects of the activity related to the pedagogical implications of implementing the activity—often noting that the activity would only be applicable in a limited number of settings. Interestingly, pedagogy-related topics surfaced more frequently when PSTs identified limitations rather than strengths. One possible explanation of this finding is that pedagogical shortcomings may be more salient to PSTs during evaluation when compared to pedagogical affordances. Additionally, several PSTs disliked aspects related to the content of the activity and the design of the technological resource utilised in the activity. Like the analysis regarding aspects of activities that PSTs liked, no studies were found in the literature in which the process of how K–8 PSTs determine what they dislike about existing geometry activities that utilise a technological resource was examined. Thus, the rationale for why the largest proportion of PSTs disliked aspects related to pedagogical implications remains unclear. Nevertheless, PSTs' tendency to dislike aspects of an activity aligns with prior research that highlighted PSTs' lack of confidence in their ability to integrate technology (Crompton, 2015). PSTs with limited classroom experience may focus heavily on implementation concerns because they have not yet developed confidence in adapting and/or implementing technology-infused activities. Consequently, it is possible that potential instructional difficulties become more visible than potential pedagogical opportunities.



Rationale for Future Use of Activities

Findings regarding the fourth research question showed that most PSTs ($n = 41$, 93.2%) would use the geometry activity they evaluated in their future classrooms, and they most frequently cited various pedagogical implications as the rationale informing their interest. Specifically, PSTs often based their interest in future use of the activity on the potential to use the activity to either introduce content, review content, or allow students to practice newly learned content. Several discussed the value of the mathematics content in the activity when discussing their interest in future use while a small group mentioned design aspects of the technological resource. PSTs' optimistic views toward utilising technology-infused activities in the future aligns with prior research showing that the majority of K–8 PSTs anticipated integrating technology into the mathematics classroom relatively frequently, such as weekly, several times per week, or daily (Meyerink & Luo, 2025). Similarly, these findings somewhat align with those of McCullough et al. (2018), as in-service secondary mathematics teachers tended to base their selection of technological resources on the technology's: (a) ease of use, (b) ability to support instruction, and (c) inclusion of interactive features. The reasons why particular characteristics influence K–8 PSTs' interest in implementing an activity that utilise technological resources, however, remain underexplored in the literature.

Limitations

Limitations related to external validity include the sampling technique, research design, and context. The study recruited a convenience sample of PSTs from a single postsecondary institution, utilised a cross-sectional design, and focused exclusively on geometry. Consequently, the findings may not be generalisable to other samples, to the same population at different points in time, or other areas of mathematics.

The use of classroom artifacts also introduced the potential of contamination, which may affect internal validity. PSTs, however, were instructed to respond independently to the prompt used for data collection, and the researchers found no evidence of contamination (e.g., collaboration between PSTs) was discovered by the researchers. Finally, data were collected across two semesters that differed in instructional format because of institutional responses to the COVID-19 pandemic. Although no notable differences emerged between the cohorts, the possibility that instructional format influenced PSTs' responses cannot be ruled out.

Implications of Findings and Future Research

The findings of this study are promising, as most PSTs evaluated and considered the future use of an activity that utilised a technological resource in a way that aligned with the IA level of the PICRAT model. As echoed by the creators of the PICRAT model (Kimmons et al., 2020), interactive activities encourage lasting and meaningful learning (Kennewell et al., 2008) and using technology to amplify instruction can increase efficiency in teaching and learning or improve productivity (Hughes et al., 2006). Despite this, few PSTs evaluated and considered the future use of technology-infused activities that align with high-impact levels of the PICRAT model (e.g., CA, IT, and CT), which suggests that more ought to be done to best prepare K–8 PSTs to integrate meaningfully technology into mathematics (Piedra Moreno, 2024; Tondeur et al., 2012). For example, teacher educators could explicitly model and make visible different pedagogical uses of technology to make the levels of implementation (e.g., creative and/or transformative uses) explicit in their instruction. There is also the potential to integrate course activities in which PSTs utilise the PICRAT model to either evaluate technology-infused activities or redesign activities to align with a higher level. Lastly, while this study focused on PSTs' evaluation of geometry activities that utilise a technological research, future studies could examine other strands of mathematics (e.g., fraction concepts, algebraic thinking, statistics), integrate perspectives from in-service teachers to allow for comparison, or utilise a longitudinal design to explore participants' technology use tendencies over time.



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Ethical approval

Ethical approval for the research was granted by the Institutional Review Board at Montana State University, which was the employer of both authors at the time of this study. Informed consent was given by all participants for their data to be published.

Competing interests

The authors declare there are no competing interests.

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