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Preservice Special Education Teachers Using Making for Academic Interventions: An Exploratory Multiple Case Study

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Teaching through collaborative making has found its way into K12 schools and colleges of education, but minimal research exists on making for learning in special education settings. Even less research is available focusing on preservice special education teachers using making as a pedagogical tool for academic interventions. This multiple case study explored five preservice special education teachers' perceptions, conceptions, acting knowledge, and efficacy when teaching students with disabilities through making. Results indicated that participants' beliefs about teaching through making evolved, and they reported a deepened understanding of effective teaching methods for students with disabilities.

The maker movement is influencing curriculum and pedagogy in K12+ schools worldwide. In the United States, many schools now have their own dedicated maker space, enacting maker activities for instruction and enrichment (Jones, 2021) and project-based learning connected to the core curriculum (Nichols, 2020). Little empirical research attention has been given to the possible impact of the maker movement on special education contexts (Buehler et al., 2016). The few studies and publications available focus on inclusive settings where learners with disabilities are high-functioning (Giusti & Bombieri, 2020; Sormunen et al., 2020).

No studies were identified focusing on preservice special education teachers and the maker movement nor on preservice special education teachers' enactment of making for learning. To fill this gap in the research literature, the present study investigated the ways preservice special education teacher candidates use making as a pedagogical strategy to increase student learning during an academic intervention for students with severe disabilities. The objective of this study was to explore future special education teachers' conceptions and perceptions of using making as a means of teaching students with disabilities supported by various technological tools.

Theoretical Framework

This project was driven by a theoretical framework couched in constructionist theories of learning and teaching (Papert & Harel, 1991), which center on the idea of students learning through engaging in hands-on, project-based learning. Underpinning constructionist theories in our inquiry was the understanding that, for effective teaching in current contexts, teachers must have a working knowledge of technology, pedagogy, and content (TPACK) to teach digital-age learners (Mishra & Koehler, 2006). That is, constructionist pedagogies intersect with current technologies to support student learning, allowing teachers to monitor and adjust to the unique needs of students with disabilities.

Constructionism is underpinned by constructivist learning pedagogical theories, with a specific focus on learning through creating or building concrete objects (Ackerman, 1996, 2001). Constructivist pedagogy was formally articulated as a defined movement in the late 19th and early 20th centuries (Null, 2004). Constructivist pedagogies include foundational practices, such as (a) students as active participants in the curriculum who learn by doing; (b) the inclusion of social skills; (c) teachers as facilitators; (d) curriculum influenced by student interest; (e) curriculum that is personalized and differentiated; (f) a focus on critical thinking and problem solving; and (g) assessment that is authentic and formative (Brooks & Brooks, 1999).

The theoretical connections between constructivism and constructionism situate our beliefs about teaching and learning and drive our research (Ackerman, 2001). Just as constructionism is the pedagogical driver of our theoretical framework, we believe that TPACK contributes to the successful actions of teachers during the instructional process. The TPACK framework developed by Mishra and Koehler (2006) defines seven separate types of knowledge teachers must enact when teaching in a technology-rich environment. These seven subsets of knowledge are Content Knowledge (CK), Pedagogical Knowledge (PK), Technology Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological and Pedagogical Knowledge (TPK), Technology and Content Knowledge (TCK), Technological, Pedagogical and Content Knowledge (TPACK). Each set of knowledge can be isolated and observed as a separate construct (Schmid et al., 2021), but the most effective practice is when they are fully emergent in TPACK.

Expanding on the theory of constructionism and teacher knowledge as defined in TPACK, we also employed strategies of the Makification framework (Cohen et al., 2017). These strategies add to our theoretical framework by supporting an analysis of what happens when preservice teachers intentionally incorporate maker-focused pedagogical decision-making. Our study was dedicated to intentionally incorporating making for learning when teaching students with disabilities.

Making for learning, as perceived in this study, combines the analytic strategies of special education instruction (Spooner et al., 2012) and the student-centered, making for learning strategies of the Makification framework (Cohen et al., 2017). The resulting interactions allow preservice teachers to deeply engage K12 special needs students in personalized, rigorous academic development as the candidates concurrently developed their knowledge of and experience with student-centered teaching methods (Bevan, 2017; Clapp et al., 2017).

Literature Review

This section will briefly describe relevant research related to our study. We considered special education teaching strategies, making for learning, and the implementation of making in a special education context. Much of the current research on making and special education focuses on the products of digital designs such as 3D printed or laser cut objects, or the research describes tools that can be used as assistive technology for students with disabilities (Buehler et al., 2016). Some research on making and special education has focused on traditional inclusion classrooms implementing project-based learning and making where learners with disabilities are high functioning (Giusti & Bombieri, 2020; Sormunen et al., 2020). All these contexts contribute to and extend our knowledge base in using technology to support students with special needs. We view this content as important in the pedagogical development of preservice teachers who intend to teach students with severe disabilities. However, additional research on the use of technology to support students with severe disabilities is also critical to preservice teacher development for special education contexts, and this is a gap in the research.

Students with severe disabilities are often not placed in inclusive settings (Agran et al., 2020), which impacts their engagement, activities, and social and academic progress. The learning experiences students with severe disabilities receive in noninclusive settings often lack engagement and may not lead to learning (Gee et al., 2020; Sauer & Jorgensen, 2016).

Special education teaching strategies for students with severe disabilities tend to rely on teacher-directed activities based on Individual Education Plans (IEP) dependent on disciplinary-based standards. Teachers identify a finite academic or life skills task and design an activity for the learner that uses analytic instruction, question and response, and wait time for finite student response (Spooner et al., 2012). We propose that breaking from the traditional teaching mold to incorporate making for learning with special education students may offer new opportunities to support student learning through constructivist approaches (including making) and can provide teachers with a variety of progressive tools to engage students with varying disabilities (as asserted by Meissner et al., 2017).

Making

Making is the process of creating physical objects and requires students to explore new ideas and academic areas. This student-driven exploratory practice is not emphasized in traditional preservice teacher education (Gee et al., 2020). Special education teachers play a pivotal role in supporting student development. Teachers can be supported in thinking beyond traditional or didactic approaches in working with students with special needs by taking an active role in determining appropriate organization, structure, and processes during a non-linear learning process (Lee & So, 2015) — such as those approaches aligned with making.

Making for learning is founded on the intentionality and knowledge of teachers (Corbat & Quinn, 2018) as they develop an analytic plan for academic learning, based on what the student needs to know and what the student wants to make (Martin, 2015). The teacher develops minilessons, tasks, and questioning strategies throughout the making process to increase academic understanding and integrate content when and where appropriate. This approach allows students to develop knowledge and skills to complete the project successfully.

Much research on making has examined the physical spaces in which making pedagogy occurs, along with the actions that occur in that space (Blackley et al., 2017; Blackley et al., 2018; Gomez, 2019; Paganelli et al., 2017). Gomez described makerspaces as ill-defined places where constructionist learning (Papert & Harel, 1991) can occur, learner identity can develop, and communities of practice can flourish. The theory underlying this study is founded not in the space where making happens but in the practice of teaching with a maker mindset (Cohen et al., 2018b).

Learning occurs throughout the making process (Clapp et al., 2017). "Learning by doing" entails asking a question, finding or developing resources and information, and completing a set of interdisciplinary tasks to develop a product that answers the question (Blumenfeld et al., 1991). These are many of the same components as Project Based Learning (PBL). PBL is an integrative perspective engaging students in investigation and is a student-centered approach to teaching.

Using making as a medium for learning posits a teacher alongside the learner as a coconstructor of both things and knowledge. Cohen et al. (2017) coined the term "Makification" as a framework for how teachers incorporate the making of things for teaching and learning in school settings. Their framework pulls from Papert's (1980) explanation of constructionism and adds aspects of PBL, art education, and engineering education processes to propose a purposeful integrated approach to teaching academics through making in school-based contexts (Cohen et al., 2017).

Teachers and teacher educators have been investigating how making can lead to classroom learning (Harlow & Hansen, 2018; Wardrip & Brahms, 2016). Cohen et al. (2018a,b) reported that teachers often have misconceptions about the connections and possibilities of making and teaching. They evaluated reflections of teachers and preservice teachers who engaged in a maker workshop and found that participants struggled to connect discipline-specific content to making. Teachers often conceived of making solely as using technology to design, build, modify, or repurpose material objects to create a product that can be used, interacted with, or demonstrated (Cohen et al., 2018b; Martin, 2015). While the inclusion of digital technology may be part of the learning activity, it is not a requirement in maker spaces. However, in enacting making, teachers can choose to rely on more hands-on materials sans digital technology in some instances.

The movement to include maker activities in educational contexts has stimulated the need to reimagine education (Peppler & Bender, 2013), especially for students with special needs. (Meissner et al., 2017). Sator and Bullock (2017) observed two preservice teachers who voluntarily engaged in making and reflecting on their making. They concluded that making can allow teacher candidates to wrestle with and communicate their views on teaching and learning. Although the participants in the Sator and Bullock study did not teach through making, they reflected on the possibilities of incorporating teaching and making.

Although making does not necessarily involve digital technology, teachers choosing to integrate digital tools need specialized knowledge. Teachers' efforts to design learning activities for discipline-specific contexts must be supported by a fluid knowledge of tools or technologies, both digital and nondigital, to facilitate authentic learning (Angeli et al., 2016; Figg et al., 2018).

Methodology

The purpose of this research was to explore five preservice teachers' perceptions, actions, and learning about teaching as they implemented maker pedagogies with a student with disabilities. We hoped to learn how integrating a making-for-learning field experience impacted preservice special education teachers' development. The exploratory multiple case study design was deemed appropriate for this research investigation, where the researcher acts as an objective observer of a real-life event and collects data that are then used to explore participants' response to the studied phenomena — in this case, preservice teachers' understanding and enactment of teaching content through making when teaching students with special needs (Noor, 2008; Yin 2003). The emphasis is on process and meaning-making based on the participants' voices and is best measured using qualitative measures (Lincoln & Denzin, 1994). Multiple sources of evidence were collected, including self-reported teacher efficacy scores, lesson plans, semistructured interviews through focus groups, and video reflections. The use of multiple case studies allows for individual case analysis as well as cross-case analysis (Yin, 2003). This study was guided by the following research questions.

1. How do special education preservice teachers conceptualize teaching through making**?**

2. How do preservice special education teachers' perceptions of making for learning shift over time when enacting a making for learning intervention with students with multiple disabilities?

3. What struggles and barriers occur when preservice teachers enact a making for learning intervention for students with multiple disabilities?

4. How does the experience of facilitating a making for learning experience for students with disabilities impact preservice teachers' efficacy?

Participants

Five teacher education candidates participated in this exploratory multiple case study. The preservice teacher participants (PSTs) were all traditional college students seeking a K12 special education degree and certification through an accredited university in the midsouth United States. Four females and one male participated. All of the participants were Caucasian, and all of their names have been changed to protect their identities. Gordon, the lone male participant, and Theresa were enrolled in the first semester of their senior year. Erika, Kinsey, and Karli were all in the second semester of their junior year as shown in Table 1.

Table 1
Participant Demographics

Identifier	Gender	Ethnicity	Year in Program
Erika	Female	White	3
Kinsey	Female	White	3
Karli	Female	White	4
Theresa	Female	White	3
Gordon	Male	White	4

The PSTs' teacher education program emphasizes technology integration with instruction. In addition to a stand-alone technology course, all courses are required to integrate technology throughout the program. The preservice teacher participants had completed courses on instructional technology, foundations of diverse learners, curriculum and assessment planning, educational programming for middle and secondary students with mild disabilities, current issues and trends in special education, and educational programming for students with significant disabilities. Before this experience, the participants had integrated field experiences where they observed in-service teachers and facilitated short observed lessons.

Intervention

Professional Development

The PSTs participated in a 6-hour professional development experience aligned to recommendations from both Burke's (2013) experiential professional development model and the holistic professional development model presented by Lee et al. (2020). Professional development for inclusive maker instruction supports teachers in designing instruction for a wide range of diverse learners, including students with exceptionalities, by designing curriculum to address learner variability, activity design, and fluency in making (Lee et al.). Our professional development was designed to address these areas by allowing collaborative creation time to increase maker fluency, introducing making learning models, and engaging in collective dialogue around designing maker learning experiences for individuals with disabilities. It is important to note that the professional development experience occurred before the PSTs had any information about their student partners, so the context was broad and holistic.

The synchronous professional development occurred in three 2-hour sessions on consecutive Fridays early in the semester before the participants went to any field placement. Each session consisted of a dedicated time for constructive dialogue (Prestridge, 2010) about assigned readings, time for participants to openly create using digital tools, and a time for group discussion about incorporating making for learning. These 6 hours were designed to add to participants' previous experiences in an undergraduate technology integration class, where they first experienced making for learning. Their previous experience included dedicated learning about classroom applications for making, including digital design through Tinkercad (https://www.tinkercad.com), AR/VR through multiple iPad applications, and nondigital making using various classroom items. Extending their learning by capitalizing on previous experiences allowed students to increase their fluency as makers (Burke, 2013; Lee et al., 2020).

During the professional development training, participants studied the book, *Maker-Centered Learning* (Clapp et al. 2017), learned about constructionist learning theory (Papert & Harel, 1991), and participated as makers by digitally designing objects using Tinkercad. The digital design process included participating in the tutorials provided by the design program and creating digital models of their choosing using the program. Three of the students used Tinkercad to create a building exterior. Two students created multiple items and investigated the draw and extraction tools, but did not complete one particular model. One participant used the tools in Tinkercad to create multiple cookie cutters. The participants utilized this time to increase their fluency using the digital platform but did not submit their digital creations.

Sessions included Socratic dialogue structures surrounding the reading, focusing on defining making for learning and brainstorming how making could be enacted with students with diagnosed severe learning disabilities. In this process, the preservice teachers collectively participated in a student-centered learning experience through creation, where the teacher acts as a facilitator while the students' interests drive the learning (Burke, 2013). The participants were motivated by an interest in student-centered teaching of students with special needs, including questioning strategies and scaffolding for varied cognitive and physical disabilities.

We implemented this professional development model to support the participants' interests and motivation as change-makers in the classroom (Garet et al., 2001). The experience, although brief, allowed the participants to develop an initial understanding of making for learning, consider strategies for implementing making with learners with disabilities, and increase their digital design fluency using Tinkercad. They were then positioned to engage with students in the field to extend their knowledge into application and reflection.

Preparing for Making for Learning

After the professional development, each preservice teacher participant was assigned a partner high school student, as shown in Table 2. The preservice teacher participants were supported by three faculty members who served as coaches and observers throughout the project. The faculty used an embedded coaching model focused on Lee et al.'s (2020) community of practice. The faculty coaches facilitated group discussions, provided support and resources for lesson planning, including examples of accommodations and modifications, and were present in the school environment to provide support and troubleshooting alongside the preservice teacher.

Along with the faculty coaches, the preservice teacher analyzed their partner student's IEP. The partner high school students' IEP goals and academic modifications and accommodations were made available by the partner school with permission in alignment with the approved IRB and established protocol. Co-analysis of the IEP allowed the participants and coaches to collaborate and connect ideas developed during the professional development to the planning process. While together, the preservice teachers decided, based on their partner's academic profile and IEP goals, that it would be appropriate to use making for learning pedagogies as a way to meet mathematics goals.

Table 2
Student With Disability (SWD) Partner Profiles

Preservice Teacher	SWD	Ethnicity	Year	Gender	Identified Disability
Erika	1	W	11	F	Intellectual disability
Kinsey	2	W	10	M	Intellectual disability
Karli	3	W	12	F	Autism, Intellectual disability
Theresa	4	W	12	M	Down syndrome
Gordon	5	W	12	F	Multiple disabilities, hearing impaired

After reviewing the IEP, each preservice teacher developed a short mathematics assessment based on their partner students' IEP goals. They administered their assessment during the first in-person meeting with their partner student. The preservice teacher participants also assessed each student's interests in making through an interest inventory. Each assessment was unique and focused on the student's math goals, as shown on the IEP. The administration of these assessments was observed by the coaches and the classroom teachers from the partner school.

The preservice teacher participants developed a 6-week intervention plan to reach their partners' short-term mathematics learning goals. Their intervention plans included a projected timeline and lesson plans. The intervention plans focused on teaching math concepts through codesign and comaking objects of interest to the learner. The preservice teachers enacted the intervention for 90 minutes, once a week each week, for the duration of the 6-week project. After each session, the preservice teacher participants recorded a video reflection focused on their experience in the session and their decision-making using the following questions to guide their reflection:

1. How did you incorporate making for learning with your student today?
2. What did you learn about your student?
3. What did you or your student struggle with?
4. What successes did you find?
5. What would you do differently/the same?
6. What adjustments did you make during your lesson?

Participants also engaged in two semistructured focus group interviews that were recorded. One semistructured focus group interview session was recorded 4 weeks into the project, and the final semistructured focus group interview session was recorded after the project was completed.

Data Analysis

Data were collected and analyzed from the PSTs' video reflections and responses to semistructured focus group interview sessions. Each data source explored the participants' perceptions, conceptions, and understandings of making for learning in the context of teaching students with disabilities. All of the reflections were recorded, transcribed, and transferred to NVivo (https://lumivero.com/products/nvivo/) for coding and analysis. All transcripts were evaluated and coded by three researchers using joint probability agreement. The intercoder reliability was established via a percentage of agreement at .97.

The first stage in the coding process allowed the researchers to establish initial codes using the constant comparative analysis with descriptive and simultaneous coding (Saldaña, 2015). In a constant comparative analysis, the researcher can compare the data from the study with emergent codes in an iterative process. According to Onwuegbuzie et al. (2009), three major stages characterize constant comparative analysis: (a) open coding, (b) grouping into categories, and (c) selective coding. Leech and Onwuegbuzie (2008) noted that constant comparative analysis is appropriate for the analysis of focus group data.

Initial coding indicated that the participants' responses focused on their plans to support students in meeting their goals and the alignment of their practice to making for learning. Initial findings also aligned with the findings of Cohen et al. (2018b), indicating that the preservice teachers linked making to a digital tool. In this case, that tool was Tinkercad.

After initial coding in the first data analysis stage, the researchers engaged in the second stage of qualitative coding based on a selected induction coding method. The researchers selected and employed an adjusted frame analysis model (Goffman, 1974) to further assess and understand the influence of the intervention on PSTs' perceptions of themselves, their partner students, and their understanding of making to support the learning of students with disabilities. Frame analysis draws from a social science methodology to analyze how participants understand and respond to a presented or experienced situation (Goffman, 1974) and allows for the examination of how individuals construct meaning.

Using the frame analysis approach, various themes and subthemes emerged, allowing the researchers to evaluate the frequency and impact of particular patterns of participant responses, as shown in Table 3, revealing both individual and collective understanding of maker pedagogies extrapolated from participants' lived experiences (Goffman, 1974; Saldaña, 2015).

Table 3
Categories and Codes

Code Label	**Description**
Conflict	Conflicts or obstacles experienced by the participant which prevent him/her from achieving the objective
STA	Student academic conflict
STB	Student behavioral conflict
STD	Student disability conflict
TCH	Teacher conflict related to lack of knowledge or lack of initiative
INI	Initiative, efficacy, resourcefulness
- PCK	Pedagogical content knowledge
- TCK	Technological content knowledge
- TPACK	Technological, pedagogical, and content knowledge
- TPK	Technological pedagogical knowledge
Context	Description of specifics related to the classroom environment and knowledge of student
MMUS	Maker Misunderstanding
NMP	Non-Maker Pedagogy
Objective	Participants' objectives in forms of action verbs
Responses	Responses (attitudes, emotions, conceptions) to the conflict or objective including emotional reflection
Strategy	Participant strategies to deal with conflicts or to achieve objectives.
- ACA-S	Action was taken by student learners to meet the objective(s).
- ACA-T	Teacher-centered strategies to support student academic learning
- BEH-S	Student-centered behavioral strategy/choice in response to the conflict
- BEH-T	Teacher-centered behavioral/Motivational-strategies that support behavioral responses to conflicts.
- MKR-S	Student actions in the making process
- MKR-T	Teacher-centered strategies for teaching and maker pedagogy

Using Goffman's (1974) allowance for how individuals construct meaning, we drew from our theoretical framework when analyzing data in the second coding round. We examined narrative data presented in the participants' reflections to illuminate their knowledge in relation to the TPACK Framework and the seven distinct knowledge elements presented by Mishra and Koehler (2006). The frequencies are reported in Table 4.

Table 4
Frequencies of Coded Data

	Primary Category %	First Level Codes %	Second Level Codes %
Conflict	29.39		
STA		14.12	
STB		9.04	
STD		9.04	
TCH		67.80	
- INI			22.03
- PCK			40.68
- TCK			0.00
- TPACK			5.08
- TPK			32.20
Context	12.11		
Maker Misunderstanding	3.32		
Non-Maker Pedagogy	0.78		
Objective	3.32		
Responses	13.87		
Strategy	37.21		
- ACA-S		2.59	
- ACA-T		39.38	
- BEH-S		5.18	
- BEH-T		44.04	
- MKR-S		1.55	
- MKR-T		7.25	

Additionally, each participant's self-perceived efficacy was evaluated through a pre and post administration of the Student Teacher Efficacy Scale for Teaching Students with Disabilities (Zhang et al., 2018). This allowed each participant's qualitative data to be examined relative to their efficacy at the beginning and end of the project, shown in Table 5.

Table 5
Student Teacher Efficacy Scale for Teaching Students With Disabilities

Participant	Pre (Sum)	Post (Sum)	Difference
EK	54	72	18
GO	103	96	-7
KS	79	117	38
KG	66	84	18
TH	93	98	5

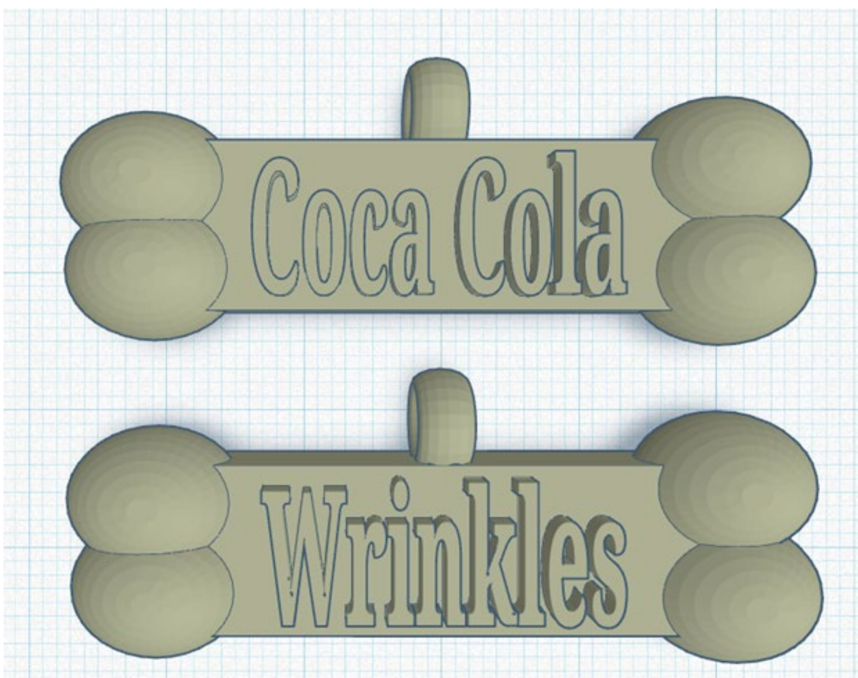
Case Reports

The cases that follow describe the participants and report individual findings from the qualitative analysis. The discussion will focus on findings across cases for additional insight.

Erika

At the time of the study, Erika was a 3rd-year preservice teacher seeking a K-12 special education license. Erika's partner student was a 17-year-old female with an intellectual disability. After analyzing the partner student's IEP, Erika developed an intervention focused on recognizing and manipulating geometric figures. Erika conducted an interest inventory with the partner student, and together, they decided to 3D print name tags in the shape of dog bones (see Figure 1) for the student's dogs. With this goal in mind, Erika also performed a diagnostic assessment and summative assessment of the partner student's geometric recognition skills (i.e., identifying faces, vertices, and edges in shapes), and then connecting 2D shapes (e.g., a square) to a corresponding 3D shape (e.g., a cube).

Figure 1
3D Design of Dog Bone Nametags



During the experience, Erika's partner student was absent multiple times. When this happened, Erika would work with a 16-year-old male partner student who was diagnosed with an intellectual disability and struggled with fine motor skills. Erika's video reflections and responses reflected her work with partner students and her struggle to serve both partner students, as the following quote indicates:

> Probably the biggest adjustment was switching students. Instead of working with [Partner Student 1], I had to work with [Partner Student 2]. He kind of had to start over, and I kind of had to improvise and figure out what shapes would be used to create a shark (instead of dog tags) with the 3D printing. [Partner Student 1's] project had been fairly easy to understand and figure out with practice with making the dog bones ....

Erika's efficacy grew due to her experience, as measured by the Student Teacher Efficacy Scale for Teaching Students with Disabilities (Zhang et al., 2018). With the highest level of student efficacy on scale being 120, Erika's initial level of efficacy was 54 and was the lowest among her peers at the outset of the project. After the intervention, she reported a level of efficacy of 72.

Erika's qualitative data focused on strategies to meet the needs of her students, as well as discussion around the conflicts she was experiencing related to her own pedagogical knowledge and ability to design instruction to support her student(s) in meeting academic objectives. Additionally, more than two thirds of her conflicts focused on her own struggles as a new teacher entering the field with limited knowledge, skills, and experiences. Her conflicts centered primarily on her lack of PCK and TPK in designing maker instruction for her students and much less on the initiative.

The data make clear that the strategies she used to resolve conflicts and develop her efficacy in resolving these conflicts were at the forefront of her experience. Specific to Tinkercad, Erika's responses focused on conflicts concerning her skills using Tinkercad with two students who had different interests and disabilities. After working with Partner Student 2, Erika reflected on the experience of having to monitor and adjust, as the following quote emphasizes:

> His struggles seem to be actually forming the shark. I hadn't practiced creating a shark with the 3D printing because I work with [Partner Student 1], I just prepare for what she is wanting to make. I had a difficult time trying to figure out how to create the shark. [Partner Student 2] struggled with that too; we had to figure out what we were going to use for the body, face and all the fins.

Like her peers, Erika's strategies for resolving the conflicts she faced employed teacher-directed solutions as she sought to guide and direct the academic content of the lesson, the partner students' behaviors, and her ability to "make" with her partner students. Significantly, Erika's references using making as a teacher were the highest among her peers, as the following example of Erika reflecting on using making for learning demonstrates:

> I have used Playdoh the whole time with [Partner Student 1] because that is the type of tactile object she needs, but with [Partner Student 2], that didn't work at all. [Partner Student 2]

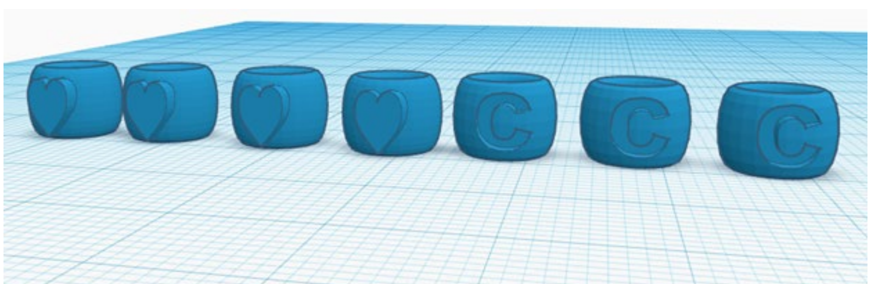
> just needs a whole different means of objects and materials to work with than what [Partner Student 1] needed.

Erika had high self-perceived teacher efficacy and expected struggles with pedagogy and technology. Erika realized that making could be a useful tool for supporting students' academic progression and that making for learning did not have to involve the use of digital technology.

Karli

Karli was also in the second semester of her 3rd year as a preservice teacher. Karli was paired with an 18-year-old female who was diagnosed with autism and had an identified intellectual disability and limited verbal communication skills. Karli analyzed her partner student's IEP and set goals for her partner student to identify the properties of 3D shapes. Her original goal was to help her student create jewelry using Tinkercad as digital design software. Karli worked with her partner student to the point of frustration, and after the 3rd week of intervention, she decided to adjust her plan and use physical making to support her partner student's learning. Karli had already created beads in Tinkercad (see Figure 2), so she printed them and also purchased beads of different shapes that she and her partner student used to create bracelets.

Figure 2
3D Designed Beads



Karli reported that her partner's attitude and communication changed over the course of the intervention. At the beginning of the project, the partner student required paraprofessional support because of her lack of communication. The partner student would only communicate with Karli through the paraprofessional, usually whispering only one or two words. By the end of the 6 weeks, the partner student was smiling and communicating with Karli in full sentences. At the end of the intervention, the partner student could identify two new 3D shapes (cone and prism), as well as recall and communicate the properties of a cube. She also was able to relate a cube to a rectangular prism to recognize that it also had six faces.

Karli's efficacy grew as a result of her experience as measured by the Student Teacher Efficacy Scale for Teaching Students with Disabilities (Zhang et al., 2018). With the highest level of student efficacy on the scale being 120, Karli's initial level of efficacy was 66, and after the intervention, she reported a level of efficacy of 84.

In the qualitative data, Karli referenced conflicts and strategies almost equally. The conflicts tied to her data were more diverse than her peers. Data revealed a preponderance of codes in her responses associated with TCK, PCK, and TPACK. Her references to strategies were teacher directed, similar to her peers; however, she had a higher number of codes tied to student-driven interventions for academic and behavior foci and a few references tied to the teacher's use of making to support student learning. Karli stated, "The vocabulary is being used, the process of making is being used, and it is something that she enjoys doing, so I am excited to see the finished product."

Like Erika, Karli also showed high initiative in addressing the conflicts she encountered. Again, both Erika and Karli realized that making for learning did not require the use of digital technology and that making using physical objects could be a useful tool for supporting students' academic progression. Karli stated in her final video reflection,

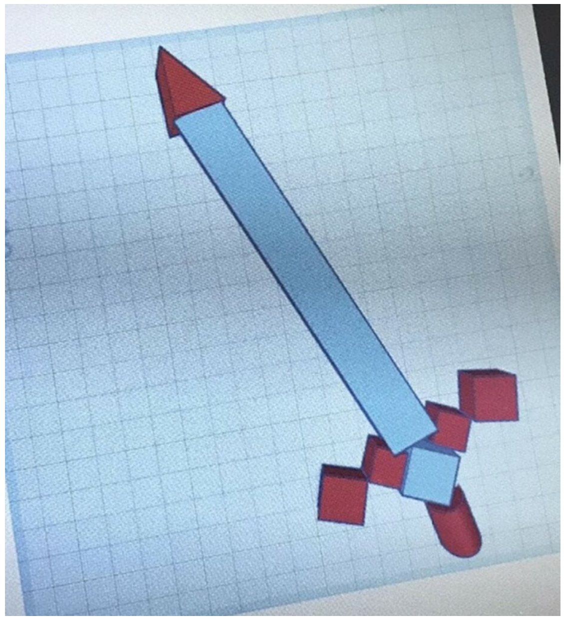
> In my mind, I had thought that the pedagogy of making had to be with Tinkercad or that it had to be with some kind of technology…which wasn't the case at all. There was a lot of making going on (in creating the bracelets), which was really cool. It was a lot of fun to recognize that and to see how my student reacted to it. She had a lot of fun.

Kinsey

Kinsey was in the second semester of her 3rd year as a preservice teacher with the goal to become certified to teach special education K-12. Her partner student was a 17-year-old male with an intellectual disability. Kinsey analyzed her partner student's IEP and conducted an interest inventory, which led to the decision to work toward identifying 3D shapes by designing various Minecraft objects using 3D design through Tinkercad. During the creation, she would support her partner student's learning by examining the geometric properties of the shapes used in the creation process. Throughout the intervention, Kinsey and her partner student created multiple Minecraft-style swords; one example can be seen in Figure 3.

Kinsey's efficacy grew due to her experience as measured by the Student Teacher Efficacy Scale for Teaching Students with Disabilities (Zhang et al., 2018). With the highest level of student efficacy on the scale being 120, Kinsey's initial level of efficacy was 79. After the intervention, she reported a level of efficacy of 117, showing the most gain in the group. Her self-efficacy in teaching students with disabilities grew 38 points throughout this experience.

Figure 3
3D Design Draft of a Minecraft Sword



The qualitative data for Kinsey indicated she experienced fewer conflicts than her peers but generated the same amount of discussion around strategies as her peers. This may have been due to the nature of the assignment with her partner student, or it may indicate a disposition enabling her to move quickly past conflict into finding solutions. Like her peers, her conflicts were primarily centered on her own knowledge and skills in the teaching context, as well as her own sense of efficacy. For example, Kinsey stated in one of her video reflections,

> One of my goals was about edges, vertices, faces. … I think that next week we'll probably keep creating, keep working on it, but I think I'm gonna try to make some sort of flashcards for him. So that he can see the word, and not just hear it. I think that that might help.

Unlike her peers, her responses did not indicate any barriers to technology-based pedagogy, and related data indicated more of an inclination than her peers for empowering the student to drive her own making.

Theresa

Theresa was in her 3rd year as a preservice teacher to become a certified K-12 special education teacher. Theresa's partner student was a 16-year-old male with Down syndrome. Her partner student was nonverbal; his communication largely happened through a digital communicator, which at times did not work. After the initial analysis of the partner student's IEP, Theresa's intervention focused on identifying three-dimensional shapes. Based on her preassessment, she determined that the partner student needed to develop shape recognition and correctly identifying shape names. Theresa found that her partner student successfully matched simple two-dimensional shapes but struggled to match the shape to the name of complex two-dimensional shapes and three-dimensional shapes.

On the postassessment, the partner student successfully matched the 2D shapes and showed an increase in the percentage of names matched to each shape. The partner student was also able to successfully identify most 3D shapes when given an alternate mode of communication. In addition to academic growth and success, the partner student benefited socially and emotionally from the one-on-one interaction. Using the hand-over-hand strategy when using a mouse and computer and increased repetition, the partner student showed growth in independence using Tinkercad. In a video reflection, Theresa stated,

> We were using hand-over-hand, and I think that helped him with understanding the movements of what we were supposed to do and how to drag it. And then he was able to feel what I am doing, and then he's able to repeat that. We had some awesome successes today, he finished two bowling balls, and then we built five bowling pins.

This supported the partner student's motor development and increased his engagement in the design process. At the end of the intervention, Theresa and her partner student used Tinkercad to create a 3D printed set of bowling pins and a bowling ball. (Figure 4).

Figure 4
3D Printed Bowling Ball and Pins

On the Student Teacher Efficacy Scale for Teaching Students with Disabilities (Zhang et al., 2018), Theresa's initial level of efficacy was 93, and after the intervention she reported a level of efficacy of 98. Theresa's efficacy for teaching students with disabilities increased by five points.

Theresa's reflective responses indicated she was stronger than her peers in identifying strategies to address conflicts. Her codes tied to conflict are among the lowest (along with Kinsey). Her responses for the strategy codes are almost double her comments tied to conflict. Within the conflict category, Theresa's codes show that her primary barriers were PCK, INI, and TPK, with some TPACK barriers coded as well. Despite showing strength in her ability to generate strategies when addressing conflict, Theresa's data indicated she still struggled with teacher efficacy. Her strategy codes showed the greatest distribution across the established code options, with a primary focus on behavioral and academic teacher-oriented strategies, followed by maker-based strategies directed by the teacher.

Gordon

Gordon was the only male preservice teacher at the beginning of the final year as a preservice teacher to become a certified K-12 special education teacher. Gordon's partner student was a 17-year-old female student diagnosed with both an intellectual disability and severe hearing impairment. After analyzing the IEP and conducting an interest inventory with the partner student, Gordon decided to use making to support the partner student's learning in mathematics, focused on understanding fractions and identifying and describing geometric shapes. The partner student was particularly interested in chickens, so Gordon decided that their making would focus on creating a 3D rendering (Figure 5) and print of a chicken (Figure 6).

Figure 5
3D Design of a Chicken

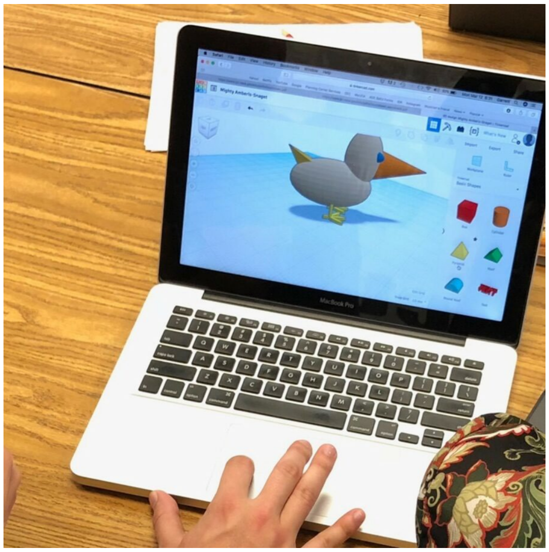
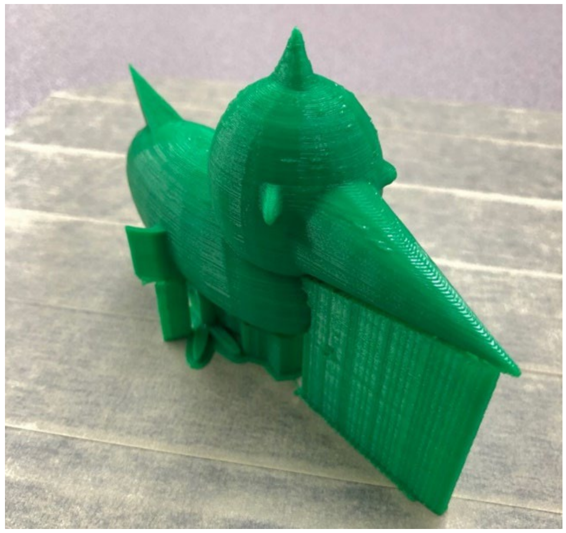


Figure 6
Printed Chicken



In the qualitative data, Gordon's responses were almost equally split between conflict and strategy, indicating a strong ability to generate strategies to address complications in the learning context. However, within the conflict category, Gordon had the highest percentage of codes tied to initiative, indicating some barriers in implementing any strategies to address conflicts. In addition to initiative issues, Gordon's codes indicated struggles with TPK and PCK. In terms of strategies he discussed, Gordon primarily referenced teacher-oriented strategies in behavior and academics and in using maker pedagogies.

Gordon's experience was different from the other PSTs because, in addition to the time spent with his partner student in intervention, he also was placed in the same classroom for one full school day each week as a requirement of the teacher education program. This allowed Gordon to see the students outside the context of the making for learning intervention. This perspective was evident in Gordon's reflections, as he considered how to increase the rigor for his partner student, specifically in relation to the content learned during class (i.e., fractions). For example, Gordon stated, "My problem is I was trying to think of how to incorporate fractions into that process (of making)." On one of the intervention days, Gordon decided to use more of a direct instruction model with no making activity. This was reflected in his responses to both conflicts and strategies: "What I want to do is provide her with a book that is going to give her reference sheets and give her information that she could look back to if she is in a situation where she is doing some problems or something in her classroom and needs to look back for reflection or to get an idea or basic reminder."

Cross Case Analysis

The five case studies presented here provide insight into the research questions guiding this study. These insights explore special education preservice teachers' responses to the experience of using making to support the academic development of students with special needs.

RQ1: How do special education preservice teachers conceptualize teaching through making?

The participants' conceptualization of teaching through making was varied and connected to their previous teaching experiences. The preservice teachers initially defined making as focused on the technology-specific application of Tinkercad. Their understanding of teaching through making shifted to represent a more holistic approach to making and became more inclusive of all aspects of creating involving both digital and nondigital mediums. Allowing preservice teachers more opportunities to engage in authentic maker learning may increase their understanding of teaching through making (Cohen et al., 2017).

We anticipated participants' lack of knowledge or experience with pedagogy, and with technology-based pedagogy, specifically, as predicated by previous research (Kumar & Vigil, 2011). Preservice special education teachers were involved in an early field experience, and we expected their grasp of pedagogy and instructional technology to emerge over time. We anticipated that their skills in these areas would increase as a result of this experience, and we expected the preservice teachers' skills in these areas to develop as they continued in their program of study.

RQ2: How do preservice special education teachers' perceptions of making for learning shift over time when enacting a making for learning intervention with students with multiple disabilities?

The PSTs' understanding of teaching through making evolved as they worked with their partner students. Initially, they struggled to facilitate rather than engage in a direct-teach model. The observation of that struggle reinforced the understanding that when learning new teaching strategies and processes, PSTs at times resist fundamental changes in teaching actions away from didactic models (Koh & Frick, 2009). Conflicts PSTs experienced in the intervention served as a catalyst for divergent thinking for the PSTs. The PSTs responded to conflict with perseverance and inquiry as they developed and attempted teacher-centered solutions that solved the learning conflict in hopes of meeting the students' needs through making.

Initial data coding identified a shift over time in PSTs' understanding of the special education students' abilities and their own conceptualization of teaching through making. As noted in the data, PSTs' understanding of the needs and capabilities of special education students evolved throughout the process and was an observable phenomenon. PSTs developed a clearer perspective of the potential these students had when engaged with relevant, hands-on learning experiences.

RQ3: What struggles and barriers occur when preservice teachers enact a making for learning intervention for students with multiple disabilities?

The results from our iterative qualitative coding indicated that our PSTs identified conflicts that they perceived would prevent the learner from reaching the math learning goals. Four first-level codes emerged as we examined the primary category of conflict. The first-level codes included three categories focused on students, and another on the PSTs. Of the second level codes, 67% were focused on the teacher. We examined the teacher-focused conflicts to find five second-level trends in the data. These categories, as shown in Table 3, illuminated the PSTs' struggle with the knowledge areas defined in the TPACK framework (Mishra & Koehler, 2006). The barriers that our PSTs experienced when leading a making-for-learning intervention was their lack of PCK and TPK. This lack of knowledge illuminated by our research indicates that these experiences are of great value for PSTs, because it allows them to strategize, learn, and overcome some of the deficits through the process of teaching in a supportive environment. Additional instruction and experience that increases PCK and TCK is needed for PSTs to develop additional intervention strategies for teaching students with disabilities.

RQ4: How does the experience of facilitating a maker learning experience for students with disabilities impact preservice teachers' efficacy?

The results suggest that the intervention of a one-on-one making for learning experience has the potential to increase PSTs' efficacy in enacting constructionist pedagogy. Only one participant had a decrease in self-perceived efficacy (Gordon), but all other PSTs reported an increase.

Teaching through making requires a different pedagogical approach from traditional direct-teach models (Bullock & Sator, 2015). It is essential that teachers use facilitation strategies and scaffold tasks for students to learn through making. Teachers must have a foundational knowledge of content, pedagogy, and technology (TPACK; Mishra & Koehler, 2006) to use making as a vehicle for learning in the special education classroom. The participants in this study struggled at times with content knowledge and design experience needed for meeting the needs of their partner students (Lortie, 1975; Sator & Bullock, 2017). However, when they identified the pedagogical conflict in their work with students, their response was to create strategies to overcome that conflict. Applying appropriate guidance and scaffolding can nurture this inclination, speaking to a need for involving PSTs in guided experiences using making for learning with special needs students. PSTs need scaffolded experiences in making to acquire skills and knowledge aligned with this approach (Cohen et al., 2017). Perhaps the most impactful takeaway from this study is that exposing preservice special education teachers to experiences that include making for learning can add to their pedagogical experience and the possibilities of using varied methods to teach students with disabilities as they enter the classroom.

Limitations

This study is limited to the participants and the context in which it occurred. The conclusions from this study are not generalizable, but adds to the exploration, development, and discussion of making for learning as a viable model for teaching discipline-specific content to students with special needs. (Cohen et al., 2017; Corbat & Quinn, 2018).

Conclusions

The findings of this study contribute to the discussion of preservice special education teacher education and the implementation of teaching through making during novice field experiences. Students with disabilities who can engage in learning through hands-on experiences and student-centered, project-based learning have the potential to improve their academic performance overall (Han et al., 2015). Therefore, it is important to provide PSTs with a variety of experiences that include pedagogical strategies supporting students with disabilities. In particular, conducting learning interventions that include making can support preservice special education teachers' development and adoption of pedagogical tools aligned with constructionist approaches for teaching students with special needs.

The findings of this exploratory multiple case study revealed that these PSTs' perceptions of the effects and benefits of making for learning changed over time. The participants reported experiencing positive learning experiences throughout the 6-week intervention. However, they expressed the need for additional scaffolding and practice incorporating making in the special education classroom. Four of the five participants increased their efficacy in teaching students with disabilities. These findings provide evidence that there is potential for maker-centered interventions as a possible catalyst for novice teachers to diversify their pedagogy when teaching students with disabilities.

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