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"I Need to Sit on My Hands and Put Tape on My Mouth": Improving Teachers' Design Thinking Knowledge, Skills, and Attitudes Through Professional Development

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Abstract
This case study reports the quantitative and qualitative findings of a professional development program focused on design thinking. The program took place in two rural southeastern counties in the USA. The professional development program was designed for elementary school teachers with limited science, technology, engineering, and mathematics (STEM) engagement. The goal of this program was to broaden the teachers' understanding of incorporating STEM in their classrooms through the implementation of design thinking lessons. Design thinking is a powerful process that can allow teachers to transcend teaching STEM content areas alone and effectively integrate these disciplines into one problem-solving process. Through a weeklong professional development program, the teachers improved the knowledge of, skills in, and attitudes toward design thinking. Based on quantitative measures, there was a statistically significant increase in all three areas. Through thematic analysis, we found that participants specifically learned about implementing the design thinking process. This included providing students an opportunity to fail and struggle as they worked through the learning process. Also, providing students an opportunity to share their progress and ideas was highly supported by participants. Based on the evaluation of the professional development program, it was impactful due to the authentic opportunities for the teachers to practice what they were learning and opportunities for collaborative planning with their peers. We discuss the findings of this case in the context of relevant literature and provide suggestions for future professional development programs.

Keywords Design thinking · Professional development · Elementary education · STEM

The purpose of this paper is to share how a weeklong professional development activity influenced teachers' knowledge, skills, and attitudes toward the implementation of design thinking in their elementary classrooms. Design thinking can be simply defined as iterative problem solving. The steps of design thinking typically include empathizing with and understanding a problem, conducting research, brainstorming ideas that could serve as solutions to the problem, consolidating those ideas into a design plan, prototyping that design, redesigning that prototype, and sharing progress/learning (Razzouk & Shute, 2012). The professional development program was designed for elementary school teachers with limited science, technology, engineering, and mathematics (STEM) engagement. The goal this program was to broaden the teachers' understanding of incorporating STEM in their classrooms through the implementation of design thinking lessons. As a process, design thinking allows for the exploration of various topics in a learner-centered format. The professional development program aimed to demonstrate that incorporating STEM in the classroom is less about conducting specific activities or teaching specific content areas and more about taking an alternative approach to teaching. Design thinking is a strong method for the integration of these content areas and the strategies (e.g., interdisciplinary inquiry, collaborative problem solving, brainstorming, etc.) that are typically of interest in STEM (Cook & Bush, 2018). Through its use, teachers can effectively integrate STEM disciplines into one connected problem-solving process that allows learners the opportunity to explore, ideate, and learn from one another.

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The professional development was a result of a Governor's Office of Student Achievement grant. The grant funding provided teachers a stipend to participate, as well as covering the cost of a STEM summer camp for elementary students. The professional development included two 1-week-long professional development opportunities emphasizing design thinking. The project targeted K-5 schools in two different rural, southeastern counties with each county receiving a 1-week-long professional development session for 20 teachers (i.e., 40 elementary teachers total were served). While the teachers focused on professional development, the 1-week STEM summer camp occurred at the same site as the professional development. These camps served 50 K-5 students in each county. The events were planned simultaneously to allow the teachers an opportunity to observe, demonstrate, practice, and assess the design thinking approach to STEM education that this project emphasizes, thus modeling effective pedagogy participants could implement in their classrooms.

We anticipated that this first exposure to design thinking would have a lasting and profound influence on their teaching practices. Additionally, we employed the use of formative evaluation data throughout the process to strengthen the professional development's relevancy to their professional practice. Lastly, design thinking itself is a formative process as it tasks designers (i.e., learners) with iteratively exploring a problem and iteratively designing/testing a solution. This article focuses on the impact of the professional development session, but the entire project continued throughout the first year of implementation and beyond for the participants and facilitators.

The following question guided this exploration; how does professional development in design thinking influence teachers' knowledge, skills, and attitudes toward the implementation of design thinking in the elementary classrooms? This experience sets the stage for participants' ongoing interest and willingness to implement design thinking in their classrooms moving forward. We set forth with the hope that this professional development would have a positive influence on their future educational practices. To begin to assess how this professional development influenced participants, we gathered data from two sources. The primary source was a questionnaire on the participants' design thinking knowledge, skills, and attitudes, which was administered before and after the professional development (i.e., pretest/posttest). Additionally, each day, we asked participants to reflect on their learning and offer feedback about the professional development program.

Literature Review

To support teachers' implementation of design thinking in their elementary classroom, we explored design thinking holistically and considered teachers' application of design thinking in school settings. Then, our review turned to K12 students engaging with design thinking and the influence of failure within the design process. Lastly, we explored best practices related to professional development projects.

Design Thinking

Design thinking is not a new or innovative idea. This approach has been studied and applied in various fields. The design thinking process includes several steps and can be undertaken individually or collaboratively. First, it begins with empathizing and understanding a problem. Designers must understand their users and the problems those users are experiencing before diving into their problem solving. To understand both of those characteristics fully, designers also conduct research on these topics. After collecting more information, designers begin to brainstorm solutions to the problem, which is followed by synthesis of those solutions into a concrete design plan. Once the plan is created, designers begin to develop a prototype of the plan and evaluate the prototype. The final step is sharing the final solution and any learning or progress that was gained throughout the design (Razzouk & Shute, 2012). At any point when designers obtain more knowledge, they can return to a previous step and tweak the design or search for more information. When used as an instructional strategy, design thinking can be boiled down to a problem solving approach or process that encompasses the behaviors previously mentioned. As a formative process (i.e., one that relies on iterative exploration and analysis of a problem and solution; Kenny, 2017), design thinking has the possibility to be a powerful pedagogical tool.

Design thinking requires learners to be creative and reflective in their practice as they work through a problem. They have to consider the perspectives of others as they design their solutions. These types of behaviors are related to increasing learner autonomy within the learning space (Henriksen et al., 2018). Various professionals use this approach when solving problems that are related to their fields (Dorst, 2011). The design thinking process mirrors the instructional design process with evident alignment between design thinking steps and iterative instructional design. Because of how universal this process can be, it is an extremely beneficial process for students at any level to experience as they are learning content. For example, at the collegiate level design thinking has been used as a framework in undergraduate and graduate degrees to improve the students' abilities to respond to problems of practice (Hawryszkiewycz et al., 2015). When it comes to a K12 environment, design thinking can be an impactful instructional strategy for students and have positive impacts on teachers (Cook & Bush, 2018).

When considering the implementation of design thinking, teachers need to commit to the instructional approach if they intend to implement it. The environment required for design thinking is different from other traditional models and requires a release of control. Without the appropriate support, design thinking will not be able to impact the students as intended (Cook & Bush, 2018). While there are many benefits for students, teachers can also find the approach beneficial. Teachers found this approach more satisfying as compared to other project methods, with it resulting in more quality student-instructor interaction. Unsurprisingly, positive experiences with this instructional approach led teachers to be more likely to repeat the instructional strategy (Scheer et al., 2012).

Design thinking is most beneficial for students in terms of the skills that they cultivate through the approach. Design thinking has been identified as an approach where students can foster twentieth century skills (Noel & Liub, 2017). These types of skills are highly sought by employers when considering the future of the workforce (Hart Research Associates, 2013). Design thinking allows students an opportunity to critically analyze a problem, creatively brainstorm and plan solutions, collaborate with a group of individuals on the same plan, and communicate their thought process and the benefits or shortcomings of their solutions. These skills are also transferrable in that they typically can be learned in one context and applied in another. Aflatoony and Wakkary (2015) found that students who had experience with design thinking were able to apply the design, prototype, and redesign steps to other scenarios. Thus, this instructional approach equips students with skills that they can carry forward into their future learning as well as their future careers.

Another strength of the design thinking approach with K12 students is its ability to impact students' attitudes and interpersonal skills. In the design thinking process, students must thoroughly understand a problem and design a solution that responds to the needs of that problem. Students learn to empathize with other perspectives (Cook & Bush, 2018) and potentially learn to be more caring than peers learning from different approaches (Koh et al., 2015).

Design thinking is also a beneficial approach as it can provide an opportunity for students to encounter failure. Failure in design thinking can be conceptualized as the potential that the learners' initial short-term performance (i.e., their initial designs/prototypes) will not represent the ideal or successful solution. Through some method of feedback, these learners will integrate and redesign, thus leading to more meaningful learning (Kapur, 2008). Carroll (2014) identified that the ability for students to persevere in the face of failure was one of the biggest takeaways for students. Scheer et al. (2012) concluded that students were more likely to foster positive attitudes when learning under design thinking as compared to other approaches. These positive attitudes toward failure could better prepare students for overcoming future challenges. These types of educational challenges could potentially bolster other skills in students (e.g., perseverance and grit).

While there are benefits of implementing design thinking for teachers and students, K12 teachers face many barriers when it comes to implementing instructional strategies that deviate from their "normal." Studies that investigate similar approaches (e.g., problem based learning) found typical barriers or obstacles faced by the teachers are a lack of support, a lack of time for planning, and a lack of resources/curriculum that lends itself to the intended approach (Jerzembek & Murphy, 2013; Nurlaily et al., 2019; Park & Ertmer, 2008). Thus, forms of professional development on these innovative strategies should be designed to counter these barriers.

Professional Development

Professional development should serve as the vehicle for linking the why (i.e., the theoretical components) and how (i.e., concrete methods for integrating into practice) of an innovation or strategy (Smith, 2016). Avery and Reeve (2013) explained the rise in STEM education in schools has led to a need for STEM professional development. Additionally, the types of strategies require teachers and administrators to take on new responsibilities and practices (Guskey, 2002). Nadelson et al. (2013) further state that professional development can help teachers who are not familiar with science best practices as it provides the link between theory and practice.

When planning any professional development experience, there are several areas of consideration, such as the population of teachers, the motivation for participation, the format of the event, and ensuring active engagement (Guskey, 2002). Avery and Reeve (2013) found that teachers were motivated by:

> 1) serving good and healthy meals, 2) providing teacher stipends, 3) having a willingness to listen to teacher ideas and recommendations for PD improvement, 4) having good PD presentational and organizational skills, 5) showing respect for what teachers do and teach, and 6) providing the necessary support for teachers to sustain what they learn through STEM PD. (p.10-11)

Beaudon et al. (2013) explain that teacher knowledge and application are essential components for teacher professional development related to STEM ideas. Nadelson et al. (2013) state when teachers are not comfortable with teaching in a particular way, they tend to avoid teaching that way, or attend to the task superficially. Teachers need to

feel confident with their instruction and lesson plans; thus, they need opportunities to authentically practice what they are learning. Additionally, teachers need the opportunity to shape the professional development process (Darling-Hammond et al., 2017).

The research conducted concerning professional development specific to the integration of design thinking at the elementary level focuses on the difficulty for teachers to transition from a more teacher-led curriculum to a student-driven design and the need for professional learning to support these efforts (Kongkiti et al., 2019; Lor, 2017; Wrigley & Straker, 2017). The best professional development would be ongoing and include a support system (Kongkiti et al., 2019). Finally, Panke (2019) notes that professional development needs to address teachers' concerns that design thinking is too challenging for students due to their (1) lack of creative confidence; (2) wrong priorities, shallow ideas; (3) anxiety and frustration; (4) creative overconfidence; (5) teamwork conflicts; (6) sprint instead of long-term focus; (7) idea creation over evaluation; and (8) tensions between learning content and design thinking process.

By allowing teachers the opportunity to actually work through the design thinking process in an authentic environment, professional development could be more impactful.

The following questions guided this study:

1. How does professional development in design thinking influence rural teachers' knowledge, skills, and attitudes (KSA) toward design thinking in the elementary classroom?
2. How do rural teachers react to professional development on design thinking?

Method

Design

This study used a case study method that examined the delivery and impact of the professional development in these two counties as one case (i.e., the overarching project was treated as the case). A case study is used to explore a phenomenon within the context in which it occurs (Creswell, 2009; Merriam, 1988). This study specifically targeted design thinking at the elementary level in two school districts designated as rural-low income districts by the Department of Education. This case was a mixed approach in that we employed a pretest/posttest comparison of quantitative data along with an analysis of qualitative data collected through open-ended questions from the pretest/posttest and exit tickets (i.e., daily online anonymous formative evaluation surveys).

Setting

The two school districts are in a southeastern state in the USA. The districts are very similar in key demographics (i.e., students living in poverty/students receiving free and reduced lunch). In District One, 24.3% of their 3360 students live under the 20th percentile of poverty, and 53% of students receive free and reduced lunch. In District Two, 25.2% of their 2109 students live under the 20th percentile of poverty, and 67% of students receive free and reduced lunch (National Center for Education Statistics, n.d.). The districts have a few minor differences. District One splits primary (K-2) and elementary schools (3–5), while District Two uses an elementary school to address all students (K-5). The other difference is that District One houses an in-house STEM teacher within each of their schools, while District Two does not. Due to the similarities and our focus being on the impact of professional development, we treated the counties collectively as an individual case.

Participants

The two partner school districts were responsible for selecting the participants from each district. Twenty elementary teachers from each district were selected to participate in one of the weeklong professional development programs. In total, 40 elementary teachers participated. On average, the teachers had 13.8 years of experience in the profession. The least experienced teacher had 3 years of experience, with the most experienced having 33 years in the profession. Thirty-six of the participants identified as female, while four identified as male. These teachers taught a wide range of subjects and grade levels (kindergarten through fifth grade). Table 1 provides a more holistic overview of the participants.

Table 1 Participant demographic information

Demographic characteristic	Sample	
	n	%
Gender	4	10
Male	36	90
Female		
Years of experience	5	12.5
0 to 5	10	25
6 to 10	13	32.5
11 to 15	2	5
16 to 20	10	4
More than 20		
STEM certification	3	7.5
Yes	37	92.5
No		
Previous STEM PD	21	52.5
Yes	19	47.5
No		

Intervention/Professional Development

The professional development program focused on introducing the participants to design thinking. For this professional development program, we defined design thinking as iterative problem solving including empathizing with and understanding a problem, conducting research, brainstorming ideas that could serve as solutions to the problem, consolidating those ideas into a design plan, prototyping that design, redesigning that prototype, and sharing their progress/learning. Below, we detail both the design of the program and the implementation.

Design

We collaborated with both the school district partners and local STEM nonprofit to design the professional development program. From the forefront, we wanted this experience to offer the participants the opportunity to practice the knowledge and skills they obtained in the professional development in a somewhat authentic environment. By partnering with the STEM nonprofit, our team planned a summer camp to coincide with the weeklong professional development. Thus, the teachers would have an opportunity to practice design thinking with small groups of elementary-aged students. Within the overarching professional development program, teachers engaged in small group discussions, worked collaboratively to develop tools/instruments, and practiced their design thinking skills. Additionally, professional development should respond to the needs of the attendees. For this reason, we included daily check-ins, where we allowed the teachers to ask questions/voice concerns anonymously. We would then do our best to address those as we moved throughout the process. The overarching goal of the professional development program was to improve the teacher's knowledge, skills, and attitudes toward design thinking; thus, helping them change their instructional practice.

Implementation

The weeklong professional development sessions introduced design thinking to the participants, highlighted how to plan and assess design thinking, provided teachers an opportunity to practice their design thinking skills, and offered an opportunity for participants to plan design thinking activities for the upcoming year. Below, we describe what each day of the professional development entailed.

Day 1—What is Design Thinking?

The first day of the professional development focused on introducing participants to one another and the overarching concept of design thinking. Before beginning any of the activities, participants completed the pretest. Afterward, the participants participated in their own design thinking activity to start the professional development. We used this as a learning experience to highlight the entire process of design thinking and how each step is equally important. Additionally, we introduced participants to various definitions of design thinking and resources available to them (e.g., such as those available from the Stanford d. School, which is a center that provides a variety of design-oriented resources). The participants spent the remainder of the day crafting two instruments to use when implementing design thinking activities (i.e., one for student behavior and one for teacher behavior).

Day 2—Planning for design thinking

During the second day, participants observed design thinking in action at the summer camp. Afterward, the participants revisited the instruments they had worked on previously. We also discussed how design thinking and incorporating this approach typically requires a paradigm shift within the classroom. Additionally, it requires students to embrace their own struggles. The remainder of the afternoon was spent planning for implementing their design thinking activity with the camp attendees starting the next day. Participants were all working with the same problem that dealt with participants needing to protect chicken eggs from predators (i.e., predator-free chicken coop). Participants worked in teams of two and implemented their lessons with four to five camp attendees.

Day 3 and 4—Implementing Design Thinking

The third and fourth days included the participants implementing the design thinking lessons they planned with students. One participant led the session while the other supported and observed using the participant-created instruments. On day 3, the participants worked through the following steps of design thinking with the camp attendees: empathizing with and understanding a problem, conducting research, brainstorming ideas that could serve as solutions to the problem, and consolidating those ideas into a design plan. After implementing the first half of their lessons,

participants shared their experiences in a whole group setting. They then learned more about questioning strategies to use with students as they worked through the design thinking process.

On day 4, participants switched places, with the previous observer now serving as the instructional lead. The second day of their lessons focused on the following step of design thinking: prototyping that design, redesigning that prototype, and sharing their progress/learning. Participants were encouraged to have their student groups share about their process and the product through Flipgrid. After wrapping up the lesson, the participants shared their experiences and revised the lesson plan. The remainder of the afternoon was spent planning design thinking lessons based on state standards to be implemented during the upcoming school year. These lessons were not necessarily based on STEM standards and could include standards from any subject as long as they could integrate the design thinking process.

Day 5—Future Planning and Support

On the final day, the participants completed a final design thinking project where they designed a visual aid for their class, which represented the design thinking process that met specific parameters (e.g., included all steps of the design thinking process and included a three-dimensional element). Then, participants completed the posttest. Before leaving, participants shared their lesson plans. They also learned about the support that our team was going to offer as they integrated design thinking into their classrooms for the upcoming school year.

Measures and Data Collection

We developed the primary measure used throughout this case study. This instrument served as the pretest and posttest and was administered on the first day, before beginning the professional development, and on day 5 at the conclusion of the professional development. This instrument incorporated both scale and open response questions. The instrument was based on the behaviors associated with design thinking in Razzouk and Shute (2012). Participants rated their familiarity (i.e., knowledge) with certain concepts (i.e., design thinking and iterative problem solving), their skills in design thinking (e.g., identifying appropriate resources and creating and testing solutions), and their confidence (i.e., attitudinal data) related to the implementation of design thinking in their classroom (e.g., allowing students to face challenges and allowing students to be innovative) on a four-point scale (e.g., not familiar, somewhat familiar, familiar, very familiar). The items used for this measure are reported in the Appendix as well as the max scores for each section. Short-answer questions tasked the participants to define design thinking. Psychometrically, the instrument produced high internal consistency (Cronbach's alpha = 0.945).

When the instrument above was administered a second time on the fifth day, we also included evaluation questions about participants' reactions to the professional development. These questions were rated on a four-point scale (strongly disagree to strongly agree). Additionally, open response questions were provided that asked them about their experience in the professional development and their anticipated barriers to changing their instructional practice.

Lastly, we collected daily feedback at the end of days 1 through 4 in the form of an exit ticket (i.e., daily online anonymous formative evaluation surveys). Participants had the opportunity to share feedback via a survey regarding the professional development. Participants could share things they found particularly beneficial, questions, and concerns for transferring what they were learning to their classroom.

Data Analysis

The alignment between our guiding questions and the data collection measures is highlighted in Table 2. The pretest and posttest were administered via Qualtrics. We downloaded the data files and used SPSS to conduct all quantitative analyses for the data. This included running the descriptive statistics for all data and a repeated-measures *t* test for comparing the pretest and posttest scores.

Table 2 Alignment of measures to guiding questions

Guiding questions	Quantitative measures	Qualitative measures
How does professional development in design thinking influence rural teachers' KSA towards design thinking in the elementary classroom?	Pretest/Posttest on KSA (repeated measures t-test)	Posttest Open-Ended Questions and Daily Feedback Questionnaires (open and axial coding)
How do rural teachers react to professional development on design thinking?	Posttest Scale Evaluation questions (descriptive statistics)	Posttest Open-Ended Questions and Daily Feedback Questionnaires (open and axial coding)

Table 3 Themes, axial codes, and sample of codes

Core themes	Axial coding	Sample of codes
Knowledge of design thinking	Design thinking skills Integration of design thinking Creating Assessment Empathy Engagement	Empathy driven planning Six steps of the design thinking process
Failure	Children's failure Teacher's failure Teacher not intervening	More time consuming than thought Persisting through failure Walking away Not carrying a pencil Learning from your mistakes Don't be scared of failure Failure is not final
Communication	Questioning Wait time Student focused	Ways to ask questions Prompting questions
Connection to the real world	Authentic learning Learning with students Lesson planning	Allowing children control Already available to implement
Collaboration	Student Teacher	Students got together to design More you to the better Working with colleagues
Facilitation	Knowledgeable instructors Willing to support	Facilitators as a resource Appreciation for the partnership Daily feedback

Qualitative data from the evaluation of the professional development survey and the daily exit tickets were analyzed using codes and identifying themes (Braun & Clarke, 2006). We read the responses from the teachers and conducted open coding of the data. Through a process of axial coding, the researchers used these codes to create categories or themes (Merriam, 2009; Saldana, 2009). Table 3 depicts the final themes and related codes. The goal of this analysis was to determine how teachers described their change in knowledge, skills, and attitudes as a result of the professional development experience. Also, attention was paid to specific elements of the professional development that teachers attributed to this change. To ensure the trustworthiness of the data, the dataset was coded by both researchers independently. The codes were compared, any disagreements were discussed, and the results below include the consensus between both researchers.

Results

Participants in the professional development completed a pretest and posttest that asked them to report their knowledge of, skills in, and attitudes toward design thinking. Additionally, the participants completed questionnaires about their experiences daily as well as a final evaluation survey that was administered with the posttest. The results are organized using the guiding questions (GQs) as a framework. First, we examine the influence of the professional development on teachers' design thinking knowledge, skills, and attitudes. Then, we report on their reaction to the professional development.

GQ1. Teachers' Design Thinking Knowledge, Skills, and Attitudes

To examine the impact of the PD on participants' knowledge, skills, and attitudes, we used a repeated-measures *t* test on the posttest. We split the posttest into three categories and used a repeated-measures test. The results of the analysis are reported in Table 4. From the professional development, participants' self-reported knowledge of, skills in, and attitudes toward design thinking were improved. The results for all four comparisons were statistically significant ($p < 0.001$).

From the qualitative data, the themes for KSA changes included knowledge of design thinking, failure, and communication. There was additional mention of the importance of empathy and tools for sharing of information at the end of the design thinking process. Ten percent of participants mentioned specifically how connecting students to the purpose through empathy was meaningful for them. Similarly, four participants mentioned learning about the tool Flipgrid and their interest in continuing to engage with this tool. The themes highlighted below were consistently present across the dataset.

Table 4 Repeated Measures *t* test for the pretest and posttest

Outcome measure	Pretest		Posttest		*t*(40)	*p*
	M	*SD*	*M*	*SD*		
Knowledge	3.60	1.50	6.80	1.20	12.87	< 0.001
Skills	14.00	3.22	20.07	3.28	9.51	< 0.001
Attitudes	30.70	8.48	40.60	5.77	8.09	< 0.001
Total	48.30	11.14	67.48	9.59	11.55	< 0.001

Knowledge of Design Thinking

All the teachers who participated learned the steps of the design thinking process. Of the forty qualitative responses, thirty-three of the participants mentioned design thinking explicitly as one of the top three things they learned during the professional development. For most participants, this was their first time learning about design thinking. Of the responses, many focused on the steps of design thinking and the connection of design thinking to real-world problems. Participants understood that they did not have to do the steps in order, and the emphasis is on process over product. One participant remarked, "(I) learned what design thinking is. I learned how to implement it into my classroom. I also learned how to tackle some of the problems I thought I would have while doing it in my classroom."

There was a focus on students and their engagement with design thinking, "allowing students to communicate their process is very important," "Students are very engaged," and "I learned the importance of student planning during the process." Beyond considering the process of design thinking, participants also mentioned design thinking in relation to how teachers facilitate differently, "Design thinking is the students working and the teacher is observing and questioning."

Failure

Part of the design thinking process is allowing students to solve problems independently and learn from their failures. Codes that fell into this category mentioned failure specifically and not intervening to help solve problems for students. Twenty-one of the teachers indicated a change in how students are interacted with and viewed, allowing them more opportunities to think, struggle, and fail. Participants mentioned, "that not helping the students is more beneficial for them. They learn better when they fail." Also, they emphasized the importance of "allowing children to fail" and "finding their own solutions when their design fails." One teacher even remarked that "I need to sit on my hands and put tape on my mouth to refrain from jumping in and immediately helping students or directing them to do things the way I would do them." Many of the teachers recognized that their behaviors inhibited the students' opportunity to fail and, as a result of the professional development, now saw failure as a beneficial experience.

Communication

This theme focused on how teachers expressed a change in their communication as a result of the professional development. One of the key takeaways was the importance of questioning when facilitating design thinking activities. The participants remarked that they needed "to ask better questions" and to "ask questions instead of giving answers." Like failure, some participants learned ways "to ask questions instead of just telling the answers—even when [the] child/adult is frustrated." Another communication tool mentioned by participants was the use of wait time, allowing students' time to think before asking for responses. Finally, some participants discussed the importance of allowing students to share their process and to explain the solutions and the failures they experienced.

GQ2. Teachers' Reaction to Design Thinking Professional Development

Unsurprisingly, the teachers positively reacted to the professional development based on the four-point scale questions.

Table 5 Descriptive statistics for the five evaluation questions

Question	M	SD	Median
I see the value in the content of this professional development	3.65	0.74	4.0
I will be able to immediately apply what I learned in this professional development	3.50	0.78	4.0
I was engaged during this professional development	3.53	0.78	4.0
It was easy for me to get actively involved during the professional development	3.60	0.74	4.0
I was given ample opportunity to practice the skills I was asked to learn	3.50	0.85	4.0

All 40 participants completed these questions. The descriptive statistics for each of the questions are reported in Table 5.

The themes for aspects of the professional development that supported KSA changes were a connection to the real world, collaboration, and facilitation. The qualitative responses for this question were completely open-ended; thus, participants discussed a variety of topics. Participants could share anything else about their experience with the professional development. Some reiterated the knowledge they learned, and a few commented on aspects of the professional development.

Connection to the Real World

This theme was the most supported theme within this guiding question. Within this theme were both the immediate connection with students in the STEM camp and the opportunity to design lessons for immediate implementation in their future classrooms. Several participants felt that working with students during the professional development activities was rewarding. Their comments included, "I certainly enjoyed the interaction with the kids at STEM Camp this week!!" and "I really enjoyed working with the students instead of just sitting and listening to a lecture." The teachers appreciated the opportunity to take what they were learning and immediately try it with students. One participant remarked, "I really liked that we had the opportunity to put our plans to work with students and see how it looks and what we as teachers need to improve on."

Another aspect was the opportunity to design and plan a lesson they could implement when they returned to school. Several participants appreciated this aspect of the professional development. One participant summed it up well.

> There were several aspects of this professional development that I feel was beneficial. Being able to work directly with students to see how they interact throughout a lesson and actually being able to implement a lesson with the students from beginning to end allowed us to see what a design lesson would look like. Also, being able to create a lesson that I can use for my grade level while in the training instead of trying to remember what we learned and go back after a couple of months of being out for the summer and try to create a lesson.

Collaboration

Participants mentioned that they appreciated opportunities to collaborate with their colleagues during the professional development. A great deal of time was spent collaborating during the professional development. Teachers sat together at tables and worked together with groups of students. This aspect of the professional development was mentioned as being meaningful. As one participant indicated, "I loved having the opportunity to collaborate, work, try, and share ideas. Oftentimes there isn't time for collaboration during the school year."

Facilitation

A few participants mentioned that they appreciated how the professional development was facilitated. They appreciated the facilitators' "knowledge and easy to approach personalities." The participants felt the facilitators were both knowledgeable and helpful. One participant remarked, "I feel y'all did a great job of answering my questions when I was stuck and needed help. I really appreciate that. I have attended PLs, where the instructors are not as nice when it comes to answering questions and helping. You made me feel comfortable and able to ask."

Discussion

Considering the quantitative and qualitative data gathered as part of this case study, it was clear participating teachers' design thinking knowledge and skills were positively impacted. Much of what the participants learned can be attributed to the teacher's changing role when using design thinking. Teachers must change their way of thinking and approaching instruction. This finding is connected to our point at the onset of this paper. Quality STEM teaching is more about changing the methods of teaching and integrating these strategies across content areas than the content areas themselves. Design thinking as a strategy allows teachers to integrate a variety of STEM concepts and strategies that are encouraged for STEM (e.g., collaboration and creative problem solving) within their instruction. One example of these strategies that teachers discussed heavily was questioning (i.e., communicating with students differently). As facilitators of design thinking, teachers must use a variety of questioning methods to keep the students progressing through the process. The development of these questioning skills aligns with the point raised by Henriksen et al. (2020) that the role of a facilitator in design thinking is built around essential tension. The questions and the methods for navigating the process can create and facilitate tension within the environment that is necessary for learning.

Additionally, participants noted that they learned about the importance of failure in the learning process, especially when using design thinking. One of the beneficial factors about design thinking is its ability to equip learners with more positive attitudes (Scheer et al., 2012). This approach could also cultivate interpersonal skills (e.g., perseverance, grit, etc.) that benefit their learning process. Previous studies indicate that allowing learners to struggle can be beneficial

(Hiebert & Grouws, 2007). Additionally, productive failure outcomes can often be more impactful than if the students are successful in both their initial performance and learning (Kapur, 2016). Through this professional development, teachers learned that it is essential to allow students to encounter this struggle. While at the elementary levels, the struggle may manifest in ways that make teachers uncomfortable (e.g., outbursts); they need to redirect and encourage students to work through their struggles. Lastly, these teachers also experienced their own productive failure experiences in a sense. In their initial performance (i.e., facilitating the design thinking lessons), the teachers struggled with allowing the students to explore and combating the urge to provide the students with the answers. However, upon reflection and discussion, the teachers indicated that they learned to better support students and facilitate their exploration rather than guiding them to a solution.

Participants also responded positively to the professional development, as evidenced by their responses to the evaluation questions. The professional development was designed so that the teachers were not only exposed to design thinking as learners (Azukas & Gaudelli, 2020) but had the opportunity to put the instructional strategy into practice immediately. The qualitative data further explained why the professional development was favorable as it provided an opportunity for authentic practice of what the teachers were learning. Due to the simultaneous teacher professional development and the student summer camp, teachers were able to put into action the material they learned. Teacher application of material is important to build efficacy and improve the likelihood of implementation (Beaudon et al., 2013; Nadelson et al., 2013). The element of collaboration with their peers also supported their learning experience. Teachers are often involved in professional learning communities or common planning within their schools. By working with their peers, the teachers were able to mirror their traditional roles and apply what they learned as they planned. Lastly, both behaviors are related to the fact that the professional development allowed participants to work on material for their upcoming school years.

All the above factors were included in the professional development in the hopes of encouraging participants to transfer their knowledge and skills into their actual professional practice. Because of these design characteristics, the teachers were ready and able to implement design thinking into practice when they began their upcoming school year. Teachers had already practiced and refined their strategies for implementing this approach. Additionally, they were equipped with lessons to implement in the upcoming school year. These two barriers, which were raised for implementing similar approaches (i.e., PBL; Jerzembek & Murphy, 2013; Nurlaily et al., 2019; Park & Ertmer, 2008), were addressed as part of the professional development. Additionally, a variety of the items raised by Panke (2019) were addressed through this design. We allowed teachers to interact with various challenges (e.g., navigating the relationship between the design thinking process and instructional content, dealing with students' frustration, and addressing teamwork disputes). Again, these factors were pivotal as they improved the likelihood that the participants would be able to transfer what they learned in the professional development to their professional practice during the upcoming school year.

This case study presented the impact of professional development on teachers in two rural counties in a southeastern state in the USA. Our design included formative elements as we were adapting based on the needs of the participants. Design thinking as a process is formative. These participants explored applying design thinking in their own learning as well as within the learning of their students. They saw this process as a transformational instructional approach that could be used within their teaching. Through the collection of the exit tickets, our team was able to address the daily questions and concerns of the participants. In a sense, teachers were provided information as it related to the complex task of integrating design thinking when they needed it. This type of support is similar to just-in-time information that is in the 4C/ID model (van Merriënboer et al., 2002). In a sense, teachers were provided information as it related to this complex task (i.e., integrating design thinking) when they needed it. This just-in-time support allowed us to address these concerns and provide support as they carried out their design thinking tasks. Thus, providing a more impactful process for the learners. Additionally, from the results of the entire program, we created a plan to support these teachers throughout the school year so that they could implement this new strategy in their classrooms with fewer barriers (Kongkiti et al., 2019). This professional development is part of an overarching project to create changes in the learning climate of these districts. We hope that from these experiences, other designers of professional development will begin to not only utilize the process or strategies that are being shared in the instruction but provide opportunities for meaningful and authentic practice.

Conclusion and Future Research

This exploratory case study identified several implications for future professional development, both broadly and focused on design thinking. Broadly, professional development should be designed to openly address the challenges and barriers teachers will face when integrating the content or strategies covered in the session. Additionally, providing teachers an authentic opportunity to practice the focus of the professional development is crucial. Lastly, structured professional development sessions should respond to the needs of the learners and be viewed as iterative. Facilitators and

designers should be ready to respond to the immediate needs and questions learners have as they progress through professional development. Specifically for design thinking, it is crucial that professional development addresses the instructional climate and methods for shifting that climate both within the classroom and the school at large. This discussion should include how to better transition to a facilitator role (e.g., how to support student struggle and failure, fostering communication and collaboration skills between students) within the classroom. From this study, we have identified various avenues of future research.

Further research is needed on the role failure plays in the design thinking process, specifically how students respond to this in various settings and levels. Students likely experience failure and struggle differently. This research could include explorations of the most effective strategies teachers use for navigating those failures or struggles. Lastly, these types of professional developments need to be ongoing to support transfer. As mentioned, this professional development session was part of a larger ongoing program where support was offered following. While this aspect was not discussed in this manuscript, we argue that further research is needed on the best practices for sustained engagement to support the implementation of the covered content or strategies.

Limitations

This case study is not without limitations. First, the participants within the professional development were selected by their administrators. The administrators were in full support of this innovation; therefore, they selected individuals who were open to change. Secondly, our instrument was based on a framework developed through a systematic review (Razzouk & Shute, 2012); there are still some potential content validity issues regarding it. Lastly, the participants' opportunities to practice their design thinking skills do not represent a completely authentic learning environment for the participants. The learners were able to work in pairs and with small groups of students. So, the opportunity to practice did not completely mirror a typical classroom setting. While it is not the intent of a case study to generalize to a larger audience, the results indicated above paint a picture of successful professional development experiences for teachers.

Appendix

Pretest/posttest Design Thinking Knowledge, Skills, and Attitudes Questions Maximum score = 80
Knowledge (rate your familiarity with the following terms) Maximum score = 8
Design thinking
Iterative problem solving
Skills (rate your skill level in the following areas in terms of your skills) maximum score = 24
Identifying applicable resources
Analyzing the system within which the problem exists to identify its given components
Creating and testing solutions that address the problem
Incorporating feedback from tests to improve your design
Communicating the solution to various audiences
Adapting to unexpected changes in problem solving
Attitudes [confidence] (rate your confidence in the following behaviors as they relate to your instructional practices) maximum score = 48
Allowing students to have self-guided instructional time
Allowing students the opportunity to face challenges and shortcomings in their learning
Allowing students the opportunity to trial solutions to the problem in a consequence free environment
Allowing students creative freedom to be innovative
Creating learning experiences that allow students the opportunity to explore
Creating learning experiences that encourage students to face challenges or fail in their initial attempts
Creating learning experiences that require students to engage in iterative problem solving
Creating learning experiences that allow students the opportunity to be creative while mastering content knowledge
Facilitating lessons where students are consistently exploring
Facilitating lessons where students are expected to fail or encounter difficult scenarios
Facilitating lessons where students are working on a similar problem and trialing different solutions
Facilitating student creativity and innovation

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