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Makerspaces and Making Data: Learning from Pre-Service Teachers' STEM Experiences in a Community Makerspace

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Abstract: As the student population in the United States (US) is becoming more diverse, educator preparation programs are seeking ways to make the teacher workforce more diverse, which involves diversification of training experiences. Informal spaces, which can include integrated science, mathematics, engineering and technology (STEM) opportunities, are not traditionally part of teacher preparation, although teachers are being asked to occupy these STEM spaces with more frequency. Including informal experiences in a community STEM makerspace, which highlights digital fabrication, creativity, and problem solving, diversifies teacher preparation by extending beyond both the university setting and the elementary classroom. This exploratory case study with elementary (primary) pre-service teachers in a science and math methods (vis a vis STEM) class examines experiences they have in a community makerspace in a qualitative study, which uses Data Engagement (DE) as a methodological framework. DE draws upon intersectional feminist, critical, and materialist theories. Assembled and made data from observations in the makerspace, pre- and post-maker reflections, and responses to a modified in-person interview protocol reveal that, despite more open-ended and complex challenges than those experienced in class, participants reported positive future-thinking, less content dread, and more agency in perceived efficacy. These results invite further study and conversation about including informal STEM maker experiences in US teacher preparation as a step to increasing diversity in the teacher workforce.

Keywords: informal STEM education; community makerspaces; elementary teacher preparation

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1. Introduction

As the student population in the United States is becoming more diverse across many categories, such as race, ethnicity, and economics, educator preparation programs are seeking ways to make the teacher community more diverse. Educator preparation programs continue to prepare teachers with little change to field experiences [1]. Elementary (primary) teachers express not feeling prepared or efficacious in their STEM teaching [2–4]. If a teacher is not confident and efficacious, they may not offer lessons that are inclusive of all learners or aligned with standards, preventing students, especially those who have been traditionally excluded, from obtaining experiences at an early age.

Informal teaching and spaces, which can include the integration of science, mathematics, engineering, and technology (STEM) content areas and experiences, are not traditionally part of teacher preparation, although teachers are being asked to teach in these integrated spaces with more frequency. Informal teaching and spaces may also provide for different inclusion and invitation to experiences. Including informal experiences in a community makerspace setting that highlights digital fabrication, creativity, and problem solving provides pre-service teacher preparation that extends beyond both the university setting and the elementary classroom. As part of the efforts to diversify the teacher workforce and meet the needs of diverse students, it is important to diversify how elementary pre-service teachers are prepared, which has largely been absent from the conversation. This exploratory case study, with pre-service elementary teachers, examines experiences they have in a community makerspace as part of their coursework in science and mathematics teaching methods. The design of the study is qualitative, and it uses data from the following sources:

(1) observations in the makerspace
(2) pre- and post-makerspace experience notes and reflections
(3) completion of two modified, semi-structured interviews through Google Forms (to protect anonymity)

Exploratory case study design can be used as a precursor to further more in-depth research [5–7]. It provides for detailed examination of a particular event, group, or unusual scenario. The researcher gathers initial information and, upon collection and analysis, may determine additional research questions for further exploration. These additional questions may be explored through case studies or, depending on the research questions that emerge, through alternative qualitative or quantitative work. Due to the unique situation of pre-service elementary teachers with an opportunity to work in a community makerspace, exploratory case study design was chosen for the initial investigation into the phenomenon.

The methodological framework used in this exploratory study is that of Data Engagement (DE), a newer framework, drawing upon intersectional feminist, critical, and materialist theories [8]. DE incorporates making, assembling, and the becoming of data through underlying commitments to pragmatism, compassion, and joy. DE is aligned with several qualitative methodologies, and uses a variation on standard qualitative language, as is used in this manuscript. The exploratory nature of the study includes the use of the DE framework regarding which data to include and how to interact with the data. This includes the people, materials, and places of the interactions. In accordance with the DE framework, observations of the interactions of participants with the space, each other, materials, and the instructors will be note. These are aspects of making data and reflect the dynamic nature of data being assembled and becoming.

Although there is a widening variety of ways to become a teacher in the United States—including measures to emergency certify, alternatively certify, and traditionally certify candidates—students who complete a traditional educator preparation program continue to be most of those teaching in US public schools [9]. Educator preparation programs, in general, consist of obtaining a university degree that include (but are not limited to) classes in content, pedagogy, field experiences, assessment, and child development. They also include a practice teaching semester, often called student teaching, that must be successfully completed. There are accreditation requirements from state and national governing bodies that provide standards for grade point averages, credit hours required in various subjects, and number of hours students are in the schools working with children.

How teachers are prepared, specifically related to math and science methods courses, has remained largely unchanged for decades. Schools are embracing models and culture related to innovation, STEM, or project-based learning. This shift may look similar to classes in robotics, after school clubs, makerspaces, or STEM classes, any of which may be novicing teachers by requiring them to teach out-of-field [10]. The shift may also position teachers with reduced efficacy and experience, stemming from traditional educator preparation programs having changed very little in their field experiences and practica for pre-service teachers. Outside of a standard definition of STEM [11,12], these newer spaces have characteristics of what has been called informal learning in informal spaces. A shift to STEM in many US schools provides a wider space of informal teaching and learning—one that typically is not included in educator preparation programs. However, this provides an opportunity to diversify the methodologies of preparing teachers, which may be part of a larger conversation into diversifying who is teaching and how they teach the variety of students in today's American classrooms.

This exploratory case study is informed by literature on informal teaching and learning, making and makerspaces, and teacher preparation. The background literature intersects with the data framework to form the following research questions:

(1) How do pre-service teachers experience an informal makerspace environment?

(2) What are the affordances and constraints of pre-service teacher preparation in an informal makerspace environment?

Informal learning has been examined by the US National Research Council [13]. Their report indicates that informal learning environments—which include persons' everyday experiences—can promote STEM learning. Including everyday experiences, or "lived experiences", is important to make the content, in this case STEM, accessible to students, especially those traditionally marginalized. Lived experiences are how all students come with background knowledge and perspectives, which the teacher can see as an asset [14,15]. The report also discusses spaces designed for people to pursue and develop interests, engage in inquiry, reflect, and make sense of their experiences. Programs of informal learning can take place in schools and community organizations, with aspects of self-organizing activities, and may positively influence student achievement and expand consideration of future career options. Lived experiences of those preparing to teach elementary students must also be considered and have been addressed in efficacy and identity research [3,4,15].

Falk and Dierking [16,17] discussed the traits and contexts of informal learning spaces, such as museums, STEM clubs (afterschool as well as summer camps), robotics clubs and competitions, and STEM makerspaces. Student participation can be mostly voluntary, and the element of choice in participation may lead to diverse learning opportunities. Additional research on informal learning has reported that it has the potential to guide and facilitate active interaction and engagement with community contexts [18–20]. Engaging in community contexts is also important in re-belonging students who have been marginalized. Cultures and people groups were making and problem-solving with a variety of materials long before the currently named maker movement, in which the primary beneficiaries and users of the spaces have been white, upper middle class cis-males with discretionary time and income [21]. Including pre-service elementary teacher preparation in informal learning spaces, such as a community makerspace, will provide insight into expanding access to these spaces, including who is in the space and how to teach in these spaces.

In addition, the absence of formal assessment in many informal learning spaces may allow facilitators to incorporate student's lived experiences and background knowledge. As a result, students may find these experiences relevant to their lives in authentic ways [16]. Authentic assessment may be more aptly used in these spaces, as opposed to the "teach to the test" approach that many teachers in formal environments are pressured to adopt, despite evidence of its bias against students from poverty, as well as multilingual and multicultural students [22]. Student experiences are more relevant to their lives when they are afforded the choice to participate in meaningful experiences and freedom to choose the extent and type of participation based on their backgrounds, interests, and needs [23]. While formal learning seeks to be inclusive of many learners and can be modified to improve inclusivity, informal learning, by nature, has affordances (e.g., choice, voluntary participation, less testing pressure) that provide for inclusive teaching and learning. Informal learning is where many people, especially those that have been marginalized in formal learning environments, may pursue inquiry based on personal interests. Informal learning environments such as the community makerspace in this study or a similar space embedded in a school—which is becoming more common—can be considered alternative or third spaces for learning [24,25]. These are spaces that allow students to bring their own experiences and have them embedded in the content and practices of the space, thus creating a new space for integrating content and experiences. This phenomenon provides challenges and opportunities for teachers to navigate with their own experiences and identities [26]. However, pre-service teachers are traditionally not prepared regarding informal environments and the affordances they may provide.

Students of all ages and backgrounds are interested in a variety of making experiences [21,27,28]. There are multiple types of making and making environments. Some programs focus on entrepreneurship (where participants make products to take to real or mockup markets), others focus on workforce development (experiences that primarily support engineering/design skills), while still others are more broadly educative.

The types of spaces can intersect [27]. Although these types of makerspaces are in reference to after-school programs, the context is informal, and it is descriptive of STEM makerspaces. STEM makerspaces include elements of entrepreneurship, opportunities for design and engineering skills to be learned and practiced, and are broadly educative across STEM disciplines and contexts.

The Institute of Museum and Library Services describes STEM and making, which is a useful definition of a STEM makerspace:

> Making is a broad grassroots movement that inspires young people to be creative, imaginative, and inventive, and offers new and powerful approaches to STEM learning. At the heart of making is creating hands-on experiences that are student driven, invite creative exploration of materials, and harness children's inherent love of play as a developmental resource to blend STEM learning. It also allows for a variety of entry points and pathways for learning, empowering young people to advance their understanding and skills as they develop and build out their ideas or inventions . . . [29] (p. 1)

Teaching in a STEM makerspace requires a classroom environment of co-constructing knowledge via exploration, creativity, innovation, and collaboration [27]. STEM makerspaces, as informal learning spaces, have the potential to be inclusive places, where students can bring their experiences as assets to their STEM making [13,14,16]. Traditionally, informal learning has provided students with avenues to participate and be included in ways that may not have been available in formal schooling. Researchers have discussed inclusion and equity issues in STEM education and workforce contexts and continue to do so [18,30,31]. The conversation can extend to equity issues in STEM making and opportunities for equitable teaching and learning for all students.

STEM teachers may be open to presenting new learning opportunities to their students. However, research suggests that many teachers do not have confidence in teaching specific content areas, such as science or engineering, and see themselves as generalists [32,33]. Teachers may experience ambivalence in their identities as they struggle to create spaces for STEM teaching due to testing expectations in mathematics and language arts and their own discomfort with science and STEM pedagogical content knowledge [4,34]. These lived experiences of pre-service teachers may frame equity or inequity in how experiences, norms, and values are enacted in the classroom [35]. In addition, teacher preparation courses that prepare new teachers, as well as professional development for practicing teachers, may not always focus on creating or increasing equitable learning opportunities in STEM teaching or how to navigate the intersection between informal and formal teaching and learning [36]. Teacher preparation in STEM informal environments, such as makerspaces, is an area to explore and examine in more depth. As more schools include STEM experiences, however they define the term, preparing teachers for teaching in these spaces needs to be included in educator preparation programs by means of additional opportunities and experiences, which prepare and support teachers in deeper and more nuanced ways [26]. Diversifying how pre-service elementary teachers are prepared is part of a larger conversation about diversifying the teacher workforce and meeting the needs of a variety of students.

2. Materials and Methods

The data framework used in this exploratory case study is called Data Engagement (DE). DE draws upon intersectional feminist, critical, and materialist theories [8]. The framework is a newer contribution, emerging in 2020 and selected to diversify how this study's data is seen, explored, and reported. Adopting DE as a framework is another avenue to advance the broader conversation of diversity in educational spaces. DE expands on how data is viewed and offers an alternative construct—that of making data—in qualitative research. Three elements of the Data Engagement model include (1) data are made rather than found, (2) data are assembled rather than collected, and (3) data are dynamic rather than complete or static. Making data includes nuances of lived experiences and embodied, material processes. Data are made in and through the materiality of participants and researchers' bodies and material technologies, as well as how these interact. The experiences that participants, the researcher, and Maker Lab personnel completed are all available for inclusion in the DE framework [8].

Making data [8] involves researchers bringing data into being—it is made. In addition, not only do researchers make data, but those in the study contribute to making data, as does the place of study. Making data includes a fluid process of encountering and engaging lived experiences and material documentation. Assembling data requires moving beyond the common post-positivist term used to refer to all materials and collections of data: the data set. The term data set sounds tidy, orderly, and fixed, which obstructs the messier reality of any study. Assemblage is a more realistic and inclusive term [8]. Data assemblage is an ongoing process through intra-actions with researchers, participants, material objects, and cultural discourses. DE situates all data as dynamic. It is always in motion and in relation—always in a state of becoming, not passively waiting to be found, which is an assumption of other data frameworks. Data Engagement examines the dynamism specifically related to agency and materiality in relation to becoming teachers in a makerspace. Becoming data is radically specific to the people and places in which it is encountered [8]. This expanded narrative into the nature of DE as a framework is part of framing the study, which aligns with the culture, expectations, and experiences often found in a maker environment. For these reasons, the author has chosen to diversify how qualitative data is collected, thought about, organized, and named by employing this framework.

The participants were four pre-service education students accepted into an educator preparation program at a regional private university. They were all upperclassmen and in their professional education coursework series, which includes methods classes and field placements in local schools. They all identified as female, with two students being multilingual Spanish- and English-speaking with cultural heritage from Mexico and Spain. They all planned to complete their professional educational studies and continue upon graduation to be employed as a professional elementary (primary) teacher in either the United States or abroad. Their ages were between 21–23 years of age. In keeping with the DE framework, the actual makerspace and the interactions with the program manager, the researcher, each other, the tools and equipment, and the actual space are organized as participant experiences. A summary of participants and their expressed STEM Identity is given in Table 1. STEM Identity Artifacts were completed in an introduction to the class, according to Hoffer [37], and included pre-service students reflection on their identities as users of science, technology, engineering, and mathematics, both currently and in their past lived experiences as primary students. Using Hoffer's definitions as a guide, they then created an artifact of their choice to communicate their experiences related to their identity. In addition, Hoffer's definition of STEM Identity includes one's self-efficacy in relation to future teaching and references Bandura's definition as an individual's belief in their capacity to execute behaviors necessary to produce specific performance attainment.

Participants had two 3.5-h field experiences in the community makerspace. The space is called Maker Lab (pseudonym) and is a six-thousand square foot building that includes a woodshop, a three-dimensional printing area, a sewing area, and a laser cutting area, as well as a general construction area, multipurpose classroom, and several offices for staff. The overall focus of the space is digital and material fabrication, serving the community, including professional development experiences for STEM teachers, mobile outreach to schools, and career retraining for adults displaced from employment or looking to change careers. It is a membership-based organization, with a variety of levels, including recently added memberships that cater to university students. The space is part of an emerging Research Practice Partnership (RPP) with the local regional university. This experience is the first-time pre-service teacher candidates have been included in Maker Lab's repertoire of service. The inclusion of local mid-career teachers and their administrators is in the onboarding process, with a pilot study beginning in Spring of 2023. RPPs investigate problems of practice within a non-hierarchical structure in which researchers and practitioners collaborate to determine how to work together in a way that addresses priorities of all involved and problems of practice relevant to all parties [38].

Table 1. Participant and STEM Identity.

Participant	STEM Identity Summary
Participant 1 SB Transfer student, 23 y.o. female White, monolingual	Expressed a few positive experiences that waned as she moved up in grade level. Family frustrated with her lack of progress, especially in mathematics. Was identified with learning disabilities in late elementary (primary) school. Awareness of students with special needs and desire to provide positive STEM experiences.
Participant 2 SS Transfer student, 22 y.o. female White, monolingual	Expressed struggle, frustration and dislike with a few "little successes" in science. Mathematics included remedial classes and tutoring with emerging hope for future students and ability to teach science and mathematics.
Participant 3 SCV 21 y.o. female Latinx, bilingual	Expressed wonder and delight that waned, both in science and mathematics, and a relief when no longer required to take these courses.
Participant 4 LCM Student athlete 22 y.o. female (Intn'l) White, bilingual	Expressed relational aspects of math and science, and appreciation of gender parity from family and teachers. Became more stressful as athletics became more centered and relational aspects diminished.

Data were assembled and analyzed using content analysis and the constant comparative method, two methodologies used in qualitative research [5–7]. After entering Maker Lab and interacting with the materials, physical space, and their associated embodied experience, research participants completed a pre-experience written artifact on what they were thinking, wondering, or anticipating about the upcoming experiences. Since being in the actual space was a new experience, participants received an opportunity to document their thoughts and questions as they contemplated the upcoming tasks. Participants then completed tasks in the space, which included tours, sampling the machines and equipment, and using software and its corresponding laser cutter. Although there is a staff of five and an executive director, as well as a governing board, the participants were led through the experiences by the program manager. They had access to Martin (pseudonym), of whom they freely asked questions. They also heard how Martin learned to use the equipment, solve problems, and iterate solutions. The experiences were completed during a soft opening of the space, as it was not completely ready for the public due to supply chain issues. However, it was fully functioning for our purposes.

Participants also completed, as the final task in Maker Lab, an open-ended design challenge. They were tasked with using their emergent skills and experiences to design a shape and then laser cut the object. Participants discussed, anticipated, and reflected in writing both before and after their Maker Lab experiences. They completed a modified semi-structured interview after each of two 3.5-h sessions in the makerspace. Rather than interview students one-on-one, the semi-structured interview questions were placed in an online format (Google Forms) for participants to complete anonymously. These were questions that were more open-ended and nuanced than a survey, with the participants able to expand their answers and contact the researcher if they desired, outside the bounds of confidentiality. No participant chose to do so. The questions from the first and second semi-structured interview are included in Appendix A.

After the two sessions at Maker Lab, written artifacts and the modified semi-structured interviews were analyzed for content and emerging themes. In qualitative work, trustworthiness is established. Trustworthiness includes the categories of credibility, transferability, and dependability [39,40]. Credibility was established by member checking ideas and information conveyed by participants while they were in the makerspace. Member checking allows for participants to give the researcher feedback on how information is processed and interpreted in accordance with what the participants wanted to convey. In addition, credibility is established by triangulating data from multiple sources—in this study, between pre- and post- Maker Lab writing exercises and the modified semi-structured interview, as well as the spontaneous utterances and comments about the space. Although qualitative work cannot be exactly replicated, results help deepen understanding of a particular context (in this study, pre-service teacher preparation) and provides for the possibility of further study, which shows transferability. Dependability shows that the findings are consistent. A faculty member from outside the institution and whose expertise is pre-service science and mathematics (vis a vis STEM) teacher preparation performed an audit on the experiences and framework of the study. They determined the study to be of value and informative related to teacher preparation in informal spaces in the community makerspace. They also had access to the data sources and how the data were analyzed. The auditor examined the themes that emerged from the interview data and made suggestions on where there was overlap and the potential to combine themes. In quantitative work, particularly in experimental design, reliability and validity are established. However, in qualitative work, reliability and validity do not align with the purpose and design of the studies. Therefore, trustworthiness is examined via the constructs of credibility, transferability, and dependability.

Limitations of this case study include no flexibility in the number of participants able to be included in the study. The participants were the entirety of a mathematics and science methods course in a pre-service educator preparation program. Members of the methods courses are not recruited; enrollment is part of their professional educator preparation program. Participants who completed the experiences were homogenous regarding their length of time in their educator preparation program and gender identification as female, but heterogenous regarding aspects of identity, such as cultural background, socio-economic status, and ethnicity. To protect individual identities and responses, names were not included on any of the pre- and post-experience writing artifacts. Names were not included on the modified semi-structured interview, completed online. If interviews had been conducted in person and audio recorded, even with pseudonyms or numeric markers being used in place of names for transcription purposes, identities would have been able to be determined. Modifying the format of the semi-structured interview to that of an online form, with guided questions and prompts for including any other pertinent information the participant wanted to share protected identity as much as possible with a small group of four participants.

An additional limitation was the amount of time in the makerspace. Time was determined by Maker Lab availability. In this instance, two full sessions of 3.5 h in length were able to be procured. In addition, within the bounds of the class itself, two full sessions of 3.5 h replicated two full class periods and could not be adjusted.

In case study research, since the researcher is a main instrument, acknowledging bias is necessary. Peer debriefing addresses Bias A, the effects the researcher has on the participants, and Bias B, the effects the participants have on the researcher [41]. However, with the DE framework [8], the researcher and those involved in research, including the participants (pre-service teachers), are part of the dynamic nature of the data and, rather than alluding to bias as a limitation, language would be that of materiality and experiences. Reflecting and debriefing with Martin, the Maker Lab personnel that led the experiences, as well as keeping notes on the processes, were part of the materiality of the experience for the researcher and contribute to reflexivity, a component of the critical feminist lens included in DE.

In this study, the author's experiences with materials, making, and teacher preparation, including additional research with women engineers and physicists, influenced the choice of study design and location of the study at Maker Lab. The author's cultural and familial background, as well as their lived experiences as a teacher, researcher, and professor, influenced the materiality and embodied experiences during the entire study design, execution, and manuscript preparation. The author's identity and lived experiences also influenced the choice of the DE framework. The framework is used as a different lens when looking at how many pre-service teachers are prepared in only formal classroom spaces. The DE framework can be considered a diverse way of including and interacting with data, and, as such, may provide a more nuanced, holistic, and engaged experience for all involved. In this regard, the use of a newer diverse way of interacting with data and diversifying how teachers are prepared can be part of the larger conversation on diversifying the teacher workforce in order meet the needs of a variety of students future teachers will encounter. Ethical considerations were addressed by completing the Institutional Review Board components and working with the outside faculty member who audited the research process.

3. Results

Content analysis was completed, and themes were identified and analyzed with the constant comparative method using the written reflections, makerspace experiences, and semi-structured interviews. The results, as well as selected quotes and excerpts from participant responses, are shared here and used to answer the research questions, revisited in the Section 3.

3.1. Efficacy

Pre-service teachers revealed a different view of themselves and their abilities after informal experiences at Maker Lab, specifically related to the use and importance of technology. Participants described the importance of technology and its integration into lessons for their upcoming students.

> *" ... it has changed my way of seeing technology ... Thanks to (Maker Lab) I have realized the amount of things and materials to teach that can be created through technology ... in the long run, technology will be very important in the educational process."*

> *" ... I liked the experience in (Maker Lab) ... I am more comfortable with technology and see it is compatible with education ... "*

Additionally, related to efficacy, per the Data Engagement framework [8], participants not only commented on efficacy from without, but described themselves in a new identity, having been changed by the experience.

> *" ... I am more confident in my STEM identity ... and how I can implement STEM into my classroom."*

> *" ... Everything seemed very difficult to me and I did not see myself capable of knowing how to use any of the machines ... the second day I saw myself doing it by myself, which surprised me ... since I thought I wasn't going to be able to do it."*

> *"After making this project today and problem-solving to improve it and make it better helps me realize I am capable of doing these kinds of things in STEM! Thank you so much!"*

3.2. Curiosity

Rather than a dread or fear of content, participants expressed a post-experience curiosity regarding what else could be performed and how to include similar experiences either at Maker Lab or in spaces they would encounter as future teachers.

> *" ... Planning the lesson, I am curious of how I can introduce this into my lessons ... "*

> *" ... I feel very curious as to what I could create with all of the different tools."*

> *"I am wondering how our projects will look when we put them through the laser (cutter). I am curious about metal with the laser cutter."*

> *" ... I am curious about what other projects we could do. Something for our day-to-day lifestyle ... "*

The curiosity spanned a general curiosity regarding machines and equipment and the space itself, as well as lesson possibilities.

" . . . I felt more curious about what could be made with the different machines . . . "

" . . . I was curious about experimenting and creating something with the machines . . . I realized the many uses they could have . . . "

" . . . I felt more curious about wanting to do more projects . . . after seeing our cutouts . . . actually being able to do something made me feel happier."

Specifically related to curiosity about the actual space, participants commented in their reflections and modified semi-structured interviews, but also in spontaneous utterances.

" . . . I had no idea this place existed . . . what in the world will we do here?"

"This place is amazing that I have not heard of before. I want to learn more about this place."

"I have never heard of a makerspace before and am grateful to learn more about this place . . . "

"This place is great . . . what are we going to do next time? . . . "

In contrast to curiosity, there were disclosures of fear related to content and teaching.

" . . . I'm not exactly well versed in it (makerspace experiences), kind of like how I felt with my STEM identity . . . "

" . . . I don't have the best STEM identity . . . "

" . . . I don't feel the most confident going into STEM experiences . . . based on past experiences or identities."

3.3. Teacher as Learner

Participants revealed that, in their time at Maker Lab, it was not only important, but necessary, for the teacher to be a learner, too. Participants positioned themselves with not only the lab director Martin who disclosed constant learning of new equipment and how to apply the capabilities of the machines, but also to other professionals who participated in Maker Lab experiences. A desired and acceptable state of being, that of learner, was revealed in participant responses and reflections.

"I feel more confident in my STEM identity and open to learning more how I can implement STEM into my classroom."

"I have realized that even not being confident going into math and science . . . if you have the right mindset, you can learn and do anything . . . "

" . . . the world is changing and how us as soon to be teachers need to always be open to change . . . "

" . . . when you are learning it is okay to be confused and new at something and that you will get the hang of it with enough practice . . . "

" . . . if we think we are not capable of teaching something that we do not feel good (about), we need to trust in ourselves and start learning . . . "

" . . . I experienced that even if you do not have that much knowledge (of a subject) that you should not be scared of it since you can always start learning and discover new things . . . "

Specific comments related to personnel are included in the teacher-as-learner theme.

" . . . it was . . . inspiring that many of the makers at Maker Lab are people with jobs . . . and not necessarily pros at all these things . . . "

" . . . being new at something is different and exciting . . . it is inspiring the director guy also has to learn all new things."

" . . . (the director) is so passionate and excited about all that Maker Lab offers, even though he said he always makes mistakes and has to learn lots of new things . . . "

> *" . . . very cool place. I love all the things there are to do here. The main (Maker Lab in-structor) is very informative and very passionate about his work and learning.*

> *" . . . I really like the information and excitement (Maker Lab instructor) has. I really appreciate his time and expertise he has learned and is sharing with us."*

3.4. Alternative Experiences

The informal experiences in Maker Lab revealed participants concluded that it was possible for them to provide different experiences for their students compared to what some of their experiences as primary students were in STEM subjects. The participants disclosed wanting their future students to have a more hands-on/minds-on approach to learning not only a concept of a lesson, but the integration of using tools and real-life experiences.

> *"Without a doubt, Maker Lab has helped me to see (my future) classes in a different way. I have discovered that using advanced technology children could learn and have fun . . . "*

> *"These kinds of experiences are a very dynamic way of putting into practice what children will learn in class . . . "*

> *"This (Maker Lab) experience has definitely opened my mind on how I want to incorporate engaging lessons for my students to be creative and express themselves . . . "*

> *"I would like to use experiences like these where students can be leaders and help each other in their projects . . . "*

> *"I plan on definitely including more STEM lessons and introducing myself to being able to teach those kinds of things . . . "*

> *"I will try to always use technology if possible."*

> *" . . . I think these tools would be very intriguing to kids. I feel very motivated."*

Participants also mentioned specifically how they would want to alter their perceived future practices, as well as using Maker Lab as a unique resource.

> *"I can for sure see myself coming back and encouraging my future school to come and experience all the things Maker Lab has to offer!"*

> *"I really liked doing this. Is so interesting since it was a mix of math, science, technology and engineering. Kids would really like to do something similar . . . "*

> *" . . . very useful to use to learn and have fun at the same time."*

> *" . . . I would go to create materials for mathematics, for example, or even to get inspiration on how I can make my classes more enjoyable, since once you get there it's like it's all originality."*

> *"I would use the makerspace in my teaching to provide a more enriched STEM experience for my students and have a space where there are other people who want to immerse themselves into STEM."*

> *" . . . I would like to learn more about using laser cutting and 3D printing to teach STEM concepts according to my curriculum."*

> *" . . . this (makerspace) is an excellent resource for schools to use . . . "*

3.5. Spontaneous Utterances

The dynamic data being made and found according to the DE framework necessitates the inclusion of responses to the physical space [8]. The large, brightly colored outside with an open architectural plan on the inside was awe inspiring. Comments and spontaneous utterances included "*Wow, I can't believe this!*", "*What a cool place!*", "*I wonder what we are going to do here?*" and "*Look at all the machines!*" Instead of being potentially overwhelming, the space itself provided curiosity, engagement, and interaction with modern and sophisticated equipment. These utterances were not initially anticipated, but are included as part of the physical experience of the space itself. This includes joy and expressions of wonder and delight, as well as anticipation of what may occur in the space. See Figures 1–3 (used with permission).

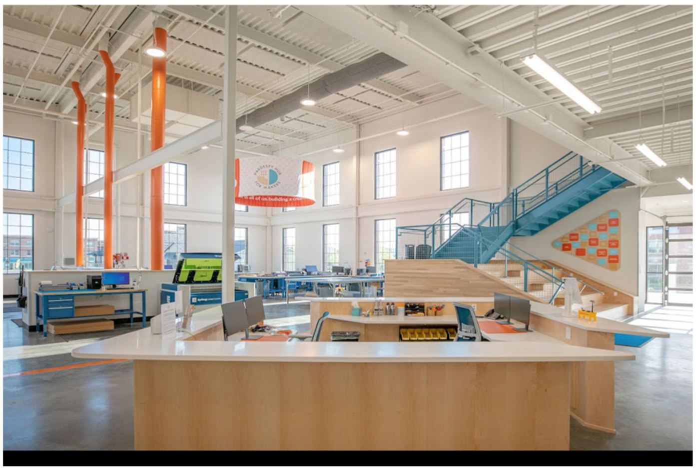

Figure 1. Front entrance reception area of Maker Lab.

Figure 2. View from second level of a studio/workspace.

Figure 3. Outside view of main entrance.

4. Discussion

Results from the makerspace experience with pre-service teachers answer the following research questions:

(1) How do pre-service teachers experience an informal makerspace environment?
(2) What are the affordances and constraints of pre-service teacher preparation in an informal makerspace environment?

As future teachers, these pre-service teacher candidates in upper-level teaching methods courses had experiences of being the data, according to the newly adopted Data Engagement Framework [8]. According to their responses before and after Maker Lab experiences, the participants expressed positivity, creativity, and joy in the prospects of teaching their future students. Pre-service elementary teachers, as well as elementary teachers, can, at times, express fear and dread related to teaching STEM content [4,26]. These pre-service participants previously commented on their identities and teaching prospects negatively, including efficacy in the subject matter.

As relational agents, the experiences at Maker Lab may promote a more positive, efficacious outcome in their future classrooms. Three out of four of the pre-service teacher participants recounted a negative experience and efficacy regarding their own STEM scenarios and the future dread they have regarding teaching STEM. All four pre-service teacher participants expressed a desire to improve experiences for their future students. The design challenge not only centered learning to use a digital fabrication tool, the pre-service teacher participants had to also use problem solving, measurement, unit conversion, and arithmetic to complete and iterate the challenge—creating a complex combination of shapes in the form of an animal using the laser cutter.

When doing content analysis and constant comparison among data, there was both affirming and tentative language used [26]. However, there was an overwhelming consensus that, when working with the equipment, solving a design challenge, and accessing each other, Maker Lab personnel and the space were exhilarating and empowering. This is in contrast to their experiences in both previous methods courses and their own elementary (primary) school STEM experiences, as referenced in the STEM Identity Artifacts completed earlier in the class.

The experiences at Maker Lab, although challenging and using materials none of the participants had used before, resulted in curiosity, excitement, and interest in the possibilities for use with future students. The experiences included a tour and demonstration of digital fabrication equipment, including three-dimensional printers and laser cutters, as well as creating and correcting a shape to be cut by a laser cutter, in essence calibrating the machine to account for the width of the laser in relation to the cut material (which, for the participants, was cardboard and plastic.) Learning a software program for use with the laser cutter was also necessary. In addition, the culminating experience in the form of a design challenge required students to combine all the experiences and skills they acquired and to apply them to creating a seamless, complex shape in the form of an animal. Although these experiences were much more difficult than the previous experiences pre-service teacher participants had in their methods classes or in their field placements in elementary (primary) schools peer teaching, participants expressed a newfound sense of accomplishment and efficacy. Previous research has reported on the hesitancy and low efficacy with teachers and their STEM identity, including what has been termed "content dread." Content dread did not appear to be present in these experiences, despite the complexity and increased difficulty in addition to the use of new technology and tools [3,4,26].

Along with the reported sense of efficacy, participants expressed a curiosity and even wonderment of not only the space, but the abilities and experiences they were having in the space. Instead of what may have been expected based on the previous STEM identity revelations and the literature, there was an excitement related to the possibilities of creative content and problem-solving opportunities for themselves and what they could do. Even though every experience was new, and all participants expressed not having ever heard of

Maker Lab, nor having any idea of what to expect, rather than fear or dread or expressions of inability, curiosity and an accompanying growth mindset [42] were expressed.

In addition to an expressed efficacy and curiosity, the participants revealed an assertion of teachers as learners. Experiences at Maker Lab revealed a sense of not having to be experts or even what would be termed "good" at something to participate and improve in the tasks. Iterations and multiple paths to a right answer or solutions to the problem did not keep participants from engaging or create frustration-level struggle. The productive struggle that was necessitated by the complexity was embraced by each participant, as well as the lab director [41]. Interactions were also experienced with the director of the Maker Lab and other members of the group, regarding what is termed legitimate participation as a novice member, which includes interacting with experts and multiple iterations [42].

Participants also expressed the assertion they could design lessons using information and experiences from their Maker Lab tasks to provide alternative experiences for their future students. Each participant successfully created a solution to the design challenge as evidence of their learning. This included multiple iterations to arrive at a solution and did not produce discouragement. The iterative nature of problem solving was embraced and enacted. The expressions from experiences at Maker Lab were of efficacy and possibilities. Participants wondered how to create and design experiences that included facets of makerspace tasks they had completed when they would have their own classrooms and students.

Affordances of pre-service teacher preparation in this context (four methods students completing two sessions in a community makerspace) include participants expressing increased efficacy, curiosity, and teacher-as-learner when engaging in the experiences and with the staff and space. These are in contrast to some of their expressions when entering the methods class related to themselves and their future teaching. Intersecting formal educator preparation with informal experiences may be beneficial for preparing teachers differently and for offering different experiences to their future students. There may be more connection to a community space. There may also be a positive experience in interacting with maker staff. Hearing another person's experience with learning how to use digital fabrication tools and the iterative process of learning and creating may be encouraging and act as a model or reference point in their own future lesson planning and delivery. Constraints of preparing pre-service teachers in an informal makerspace environment may be similar to the constraints of this study. Time and resources are limited, as well as location for those who will be teaching outside the community boundaries.

Regarding the use of the relatively new data framework, Data Engagement [8], the researcher as well as the participants and personnel at Maker Lab are encouraged with the possibilities for future research. The shift in working with data aligns with many tenets of the maker movement and is a more realistic alignment with the process of working with places, people, and experiences. There is a challenge, yet a promising fit, in changing the use of language and in the tensions of working with all the complexities involved in qualitative research. However, the framework provides for the inclusion of the dynamic and ongoing process of learning and working collaboratively in an expansive rather than reductionist way. The acknowledgment and assumptions that data become and are assembled, and each interaction provides a critical embodied experience is something to continue to explore. This exploration is especially promising given the physical realities of a maker environment, which includes the interactions with material reality, as well as relational and embodied experiences, which participants did reveal in their data.

Additionally, the underlying commitments in the Data Engagement Framework include pragmatism, joy, and compassion [8]. Although using these categories as a priori themes would go against the tenets of the framework, that data become and emerge, there were several references to what could be considered the participants' commitment to these ethical underpinnings. These include participants' spontaneous utterances about their excitement and enjoyment of the actual place (joy). They also include the participants' desire to provide different and meaningful experiences in the affective realm in addition to the conceptual and content needs of their future students (pragmatism and compassion.) The assemblage of data and the dynamic nature include the transactional and relational rendezvous with others in the space, as well as the materiality of the body and the technological experiences. These occurrences were both observed and recorded in the participants' comments about the space, the interaction with the lab manager, and with each other.

Although typically not part of pre-service teacher preparation, experiences in an informal STEM environment provided the opportunity to pursue inquiry via different paths, bringing lived experiences to the inquiry and space and having voice and choice in at least partial ways of carrying out creative problem solving. When considering the research questions that were interrogated, the answers include increasing an awareness of efficacy and continual learning as future teachers, as well as curiosity and consideration of future students' and their STEM experiences.

5. Conclusions

The inclusion of experiences at Maker Lab appear to provide a benefit to the participants. Including informal contexts diversifies current field placement experiences of the pre-service teachers in this study. Maker Lab provided (1) the space and the learning experiences to expand the participants' identities related to their future teaching and (2) the interactions with applications of STEM content. The research will continue in further exploration on the affordances of informal learning with in-service teachers. An additional study with mid-career teachers (those with five to ten years of experience) has been funded. Teachers in the region are being asked to teach STEM in what is increasingly an informal space or with an informal structure in place, which has not been part of their preparation or professional development. The researcher is hopeful that informal STEM education and spaces can be leveraged as an asset and provide diverse preparation and professional development for both pre- and in-service teachers.

In the ongoing desire to meet the needs of an increasingly diverse US student population and to diversify the teacher workforce, this exploratory study investigated diversifying the experiences pre-service teacher candidates received in their formal education preparation. Diversifying pre-service teacher experiences to include informal contexts has largely been absent from the conversation on diversity. The inclusion of informal experiences via a community makerspace in elementary (primary) teacher preparation shows promise and possibilities to explore further.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of The University of Tulsa as "exempt" protocol code 23-04 on 1 December 2022 for studies involving humans.

Informed Consent Statement: Participant consent was waived due to activities as part of regularly scheduled classroom experiences.

Data Availability Statement: Data are not publicly available due to student privacy laws and protection.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Questions from the first semi-structured interview:

1. What is something you could imagine (or are curious about) that could be laser cut?
2. What is something you could imagine (or are curious about) that could be laser etched?
3. After the tour and class at Maker Lab, did anything you saw or did inspire you? Please describe.
4. What ideas do you have for future lessons in your classrooms, based on the Maker Lab experience?

5. Thinking back to Hoffer and your STEM identity artifact, did you experience anything related to your identity? Please explain.
6. Any other thoughts on Maker Lab?

Questions from the second semi-structured interview:

1. What were your thoughts/responses when you got to cut your piece?
2. What would you do differently, if anything, next time?
3. How did you approach the measuring challenging to make the cut more accurate?
4. Can you compare your thoughts coming to Fab Lab on Day 2 with Day 1? Did anything change? Can you describe the change if anything changed?
5. Can you compare your actions coming to Fab Lab on Day 2 with Day 1, related to the laser cutter and materials/tools used with the laser cutter? Did anything change? Can you describe the change if anything changed?
6. Considering your future classrooms and the experience(s) you had with Fab Lab, has anything changed with what you plan on doing with your students? With you how you plan and execute lessons? How you incorporate technology? How you incorporate challenges?
7. If we had one more session with Fab Lab and laser cutting (and any/all tools software associated with laser cutting), what would you want to do and experience?
8. Has anything changed with you related to STEM identity or efficacy compared to before your time at Fab Lab? If so, please describe. You may want to consider your identity reflections and experiences from the methods courses.
9. Please comment on anything else related to the experience at Fab Lab, teaching, identity or anything else you want to express.
10. Are you willing to be contacted for further information about your answers? If so, please provide contact information. Thank you.

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