Proceedings of the ASME 2018 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference
IDETC/CIE 2018
August 26-29, 2018, Quebec City, Quebec, Canada

DETC2018-86276

"A MAKERSPACE IS MORE THAN JUST A ROOM FULL OF TOOLS": WHAT LEARNING LOOKS LIKE FOR FEMALE STUDENTS IN MAKERSPACES

Megan Tomko
Georgia Institute of Technology
Atlanta, GA, USA

Amanda Schwartz
Georgia Institute of Technology
Atlanta, GA, USA

Wendy Newstetter
Georgia Institute of Technology
Atlanta, GA, USA

Melissa Alemán
James Madison University
Harrisonburg, VA, USA

Robert Nagel
James Madison University
Harrisonburg, VA, USA

Julie Linsey
Georgia Institute of Technology
Atlanta, GA, USA

ABSTRACT

Postulating that the act of making stimulates learning, a widespread effort prompted the integration of makerspaces on college campuses. From community colleges to research-based higher education institutions, large investments were and still are being made to advance the making spirit and encourage non-traditional learning in academic settings. While optimistic that students are taking advantage of the makerspace resources and are in fact learning from their experiences, there needs to be a more direct effort to understand the learning, if any, that is occurring in the makerspace. The makerspace is labeled as an open, learning environment where students are able to design, create, innovate, and collaborate [1, 2]. In response, we investigate the claims of this statement through the research question: how is learning experienced by female students in an academic makerspace? Female students in STEM, especially those engaged in makerspaces, have unique and uncharacteristic experiences that can lend way to various learning and pedagogical implications. The purpose of this paper is to highlight our methodological process for incorporating in-depth phenomenologically based interviewing and for utilizing open and axial coding methods to establish grounded theory. We interview five female students through purposeful maximum variation sampling and snowball sampling. Through a rigorous and iterative data analysis process of the ten-percent of the overall, we created a preliminary coding scheme that articulates how learning is occurring, what design skills are being learned, and what life skills are being learned. These preliminary findings show that not only are these female students learning by doing and learning how to problem solve in design, but they are also overcoming fears, developing patience, and communicating ideas in these design-oriented makerspaces.

1 INTRODUCTION

Makerspaces are labeled as unique learning environments that center around the act of 'making' in all its' forms [3]. To articulate, what 'making' entails has been left ambiguous [4] so as to allow for all types of making, from sewing to machining, to allow a variety of making to be able to be a part of a maker community, a maker's hobbies, or a makerspace. These spaces promote both the use and making of advanced technologies amidst the sharing of ideas and projects [3] and the sharing of tools, machines, and knowledge [1]. The collaboration, discovery, and innovation are seen as daily occurrences in a makerspace [2] where a community of people are provided access to an open space that allows innovative thought and resourcefulness via the tools, equipment, and environment [1, 5]. Seen as the next generation classroom [6], the makerspace seems to provide that bridge and fills the gap between universities and industry for the engineering, technical, science, and math fields [1].

The success of integrating the maker movement into universities and academia via makerspaces necessitates initiating a shift from a structured and systematic approach to an environment ripe for creating, innovating, collaborating etc. [7-9]. An educational system rooted in making has the potential to revolutionize thought on pedagogy and learning [10].

Ultimately though, for such a revolution to take place, an understanding of the learning occurring in the academic makerspace is first needed, which can therefore inform pedagogy. It is not enough to insist that students are learning in these spaces without empirical evidence. In this work, we

investigate learning in academic makerspaces for engineering and design students. We examine the learning of female students who are highly involved in different university makerspaces through in-depth interviewing. Given that there still remains a low population of female students in STEM fields and that a makerspace is meant to bridge the gap between university and industry in STEM, eliciting and understanding the lived experiences, or first-hand accounts, of female students using the makerspace generates rich, transformative insights that can truly revolutionize pedagogy, learning, and also initiatives for women in STEM – especially given the atypical notion of a females in makerspaces. In our work, we conducted three 90-minute interviews with each female participant resulting in over 500 pages of transcripts. In this paper, we articulate the methodology and rigorous data analysis processes that we follow, and the findings reflect the data analyzed to date.

2 BACKGROUND

2.1 Makerspaces and Learning

Learning in makerspaces integrates constructivism [11], constructionism [12] and situated learning [13]. In constructivism, social interaction and context facilitate the learning that occurs, ranging from the explicitly defined learning of gaining competency or of the implicit understanding of meaning and purpose. The constructivist theoretical framework is physically manifested through the Maker Movement and is postulated to transform educational system [14]. Extending from the constructivist theoretical framework, constructionism accentuates that the act of building or making a physical artifact affords learning [15], as the maker interprets the actions and elicits meaning from the activities that he or she engages in [16]. For constructionism, learning spawns from an individual thinking through the process of making a tangible, physical object that can be talked about, analyzed, and admired [16, 17]. This begets a greater understanding of the conceptualization and transformation of ideas as expressed within particular contexts [18]. Playing on the 'context' of learning, situated learning theories articulate the notion that learning corresponds to interactions of authentic, natural, real-world environments [13]. As such, a student's participation in an academic makerspace allows them to engage in authentic, natural, and real-world experiences, which fosters their understanding of principles and concepts through concrete, contextual learning.

Further, learning in makerspaces has been explored in a variety of fields including arts education and museum studies [15, 19], library sciences [20], and K-12 education [21]. For example, in a children museum's makerspace, Brahms and Werner [19] examined the means through which learning occurs, and identified that the interactions and engagement of children and families is facilitated through the tools and materials available to them. Even more so, rooted in the constructionist theoretical framework, making activities in K-12 and informal learning resulted in learning engineering, design, electronics, art, and computer programming [5, 21]. Such learning in makerspaces can be characterized as experiential, interactive, collaborative, self-paced, and problem-based [5, 17, 22]. These characteristics and overarching theoretical frameworks establish a need for a methodology that matches the complexity of these adaptive, dynamic, and interactive environments. While previous studies have investigated learning in makerspaces, the research still has yet to clearly examine learning in makerspaces within the professional development of engineers in higher education.

2.2 Makerspaces and Qualitative Research Methods

Makerspaces encourage an individual to engage in engineering design, in the design processes, and in designerly thinking. To understand and support the type of strategies that are being used in this form of design practice, one must investigate the intricacies of the contextualized processes and interactions [23]. Given the complexity of the makerspace, these spaces are not at all suited to controlled experiments or quasi experimental designs, which can only explore a few factors at a time. Makerspaces are speculated to instill determination, creativity, innovation, independence, technological competence, and preparation for the real world [10, 24]. While no standardize metrics exist to study these outcomes and no data exist on the tangible learning outcomes, the potential learning in a makerspace is beyond tool usage and manufacturing knowledge, which can be illuminated via qualitative research methods.

In qualitative research, the goal is enlightenment, understanding, and transferability [25], as opposed to the goal for generalizability in quantitative studies. Transferability allows an individual to extract findings from one study site towards identifying elements that may transfer to similar studied sights. So, findings in one makerspace could be found to transfer to another space or not. In a way, this is similar to design-by-analogy, where insights from one domain are transferred to that of another. Further, the focus for qualitative research is context [26, 27] in which a wealth of detail is necessary. Because of the need for detail, the detail-oriented approaches of interviews and observations are common, as is textual analysis of the form of surveys with open-ended questions or focus groups [26-30]. For these approaches, the data implementation and data analysis are very time consuming and rigorous. The findings are presented in the form of thick descriptions [31] as per the way the research questions frame the study. Such thick descriptions and detail-oriented approaches allow for in-depth insights into people's lived experiences in making and makerspaces. For example, using artifact elicitation interview, Oplinger, et al. [32] investigated the leadership roles of makers at United States Maker Faires and identified that makers demonstrated external leadership traits as innovators, directors, and producers. In a similar vein, parents were found to take on supportive roles of a designer, builder, cheerleader, or teacher when their children are taking part in making activities at a museum makerspace [33]. Clearly, qualitative research methods can support the deep insights that

we aspire to gain in understanding learning in making and makerspaces.

2.3 Background on the Methodology

Interviewing is an effective means to gain rich insights into the lived experiences encapsulated in a person's personal narrative or story. In essence, interviews elicit stories, a story is a way of knowing, and the act of telling a story prompts meaning-making [34]. The interviewing process of in-depth phenomenologically based interviewing, used in the study presented in this paper (see methodology section for details), utilized open-ended questions aimed to provoke participants to reconstruct experiences pertaining to a specific topic (i.e. making, makerspaces). This approach has been used in a variety of education-oriented studies including first year teaching experiences for English teachers [35], the experiences of ESL students and ESL teachers [36, 37], and the experiences of student teachers [38, 39]. Moreover, the in-depth phenomenologically based interviewing approach illuminated the experiences of African-American performing artist teachers and Black jazz musician teachers at colleges or universities [40, 41], along with the gender issues in student teaching [42].

While this interviewing process is based in phenomenology, or the study of subjective understandings of the world as opposed to objective understandings, we implement the method due to the need to generate rich, in-depth, and thorough accounts of the lived experiences for female students who are making in makerspaces. We utilize the in-depth interviewing as a method for data collection; while based in phenomenology, this still allows for the generation of grounded theory (explained later) as a result of qualitative data analysis. This decision is supported by the thought-provoking work of Wimpenny and Gass [43] that discusses the intersection and differences of interviewing in phenomenology and grounded theory.

3 RESEARCH QUESTION

As demonstrated by the number of makerspaces increasing over 14-fold in the last decade [44], there is a significant increase in the number of individuals, organizations, and universities advocating for the making experience. The value of making experiences and makerspaces must be ascertained [45], so as to testify to the expensive investment into these spaces by understanding how these spaces are functioning for educational and learning purposes and what the challenges are that accompany these spaces. Challenges include: non-standard results, immense teacher preparation for integrating making into curricular activities, limited accessibility to resources and technology, and the diverse and widespread experiences and interests of students [46]. The inability to face and understand these challenges has contributed to an increase in the gender gap of users in makerspaces [47]. We postulate that in order to understand the value and further articulate the challenges of makerspaces regarding female involvement, it is key that we investigate the learning experiences of females in these makerspaces through qualitative means, more particularly through open-ended qualitative interviewing. While interviews have illuminated the underlying reasons for the gender gap of users in makerspaces and the barriers to female engagement [47], an in-depth interviewing process provides opportunity to elucidate the learning of these female students. In turn, we approach our investigation with the research question:

How is learning experienced by female students in an academic makerspace?

The question opens the opportunity to understand and unveil the unique lived learning experiences that female students are engaging in through making activities and makerspaces.

4 METHODOLOGY

Since the research question seeks to capture *how* female students are experiencing learning in a makerspace, we needed a research methodology that would explore the lived experiences of females using these academic makerspaces. Gaining insight into lived experiences demands an in-depth qualitative approach. Because of the intriguing insights that emerged from previous ethnographic work on makerspaces [48-50], we proposed employing ethnography and observation as a means to record the lived experiences of students carrying out their projects over a period of time in the makerspace [51]. This would allow for simultaneously collecting a student's thoughts and actions during their process of ideating, designing, and creating, which ultimately obtains a thorough account of the student's design process. Capturing the lived experiences through ethnography and observation suggests a few preconditions: 1) established credibility and trust and 2) negotiated access and availability. If a researcher is to observe a student in a makerspace, there can be an obscure level of skepticism within a student; it is imperative for the researcher to address and to then build both trust and credibility with that student. As such, the trust and credibility further impacts a student's willingness to provide access to and be available for the researcher. We reconciled these preconditions by integrating a student auto-ethnographic approach (where students are documenting and reflecting on their experiences in the makerspace culture) and an in-depth phenomenologically based interviewing approach; the latter method is described in detail in this paper.

The in-depth phenomenologically based interviewing approach is a specific process of phenomenological interviews that is outlined in Irving Seidman's *Interviewing as a Qualitative Research* (see Seidman [34] for more details). The method couples the theoretical frameworks of life history interviewing [52] and in-depth interviewing based in phenomenology by Alfred Schutz [53]. In this process, three consecutive 90-minute interviews are conducted and designed to evoke a person's lived experiences or narrative through an open-ended, semi-structured protocol. Each interview delves into different aspects of a person's lived experience (Figure 1) as it pertains to a specific topic, which in this case are

Figure 1: The in-depth phenomenologically based interview process

experiences pertaining to *making or makerspaces*. In short, a phenomenological interview seeks to answer the question: "What is the meaning of X?" In our case, "what is the meaning of making for females working in academic makerspaces?" or "what does making mean to females in academic makerspaces?"

First Interview. The first interview concentrates on a person's life history. The participants are asked to reconstruct their making experiences up to their current involvement in a makerspace. In order to gain insight into their lived experiences in making from a life history standpoint, the interview is centered on *how* the participant became involved in a makerspace as opposed to *why* they became involved. An interview focusing on *how* allows for the participant to openly describe her experiences, whereas an interview on *why* confines the scope of the interview has a particular objective and can prevent the participant from recollecting and reflecting on her experiences. By focusing on *how* a person becomes involved, this starts off and establishes the interview series to be in context of the participant's lives. Through this, the participant shares the experiences that led them into the makerspaces, and because learning occurs through experience then it is important to capture the life history and context of the making lived experiences.

Second Interview. In the second interview, the person is invited to then describe the details of their current lived experience. Since this study focuses on making and makerspace experiences, the interview questions are crafted and executed in order to help participants reconstruct and elaborate on their experiences making, especially in regards to making in a makerspace. In order to elicit a thorough account of the present lived making experiences, participants were asked to bring some of their own personal or school-related projects to the interview with them. While this is not a part of the standard protocol for in-depth phenomenologically based interviewing, the project provided a starting discussion point for the interview and also provided a tangible reference for more contextual support to the participants' descriptions. Given the tangible reference, the participants were able to reconstruct their experiences in making these projects (i.e. how they came up with the idea, what their design process was), which became the gateway into the participant expanding on their current lived experiences in making and in the makerspace. These projects then informed the interviewer on follow up questions that which would invite the participants to provide thorough accounts of the meanings they have around making in this specific context, lending way to the third interview.

Third Interview. The third interview directs the participant to reflect on the *meaning* of their lived experiences. Because talking about an experience elicits meanings [54], meaning making inherently occurs within first and second interviews as the participant describes their past and current experiences in making and makerspaces. In turn, the developed narrative from the first and second interviews creates a foundation for the participant to reflect on their lived experiences. In order to focus the third interview contextually on the meaning of *making* experiences, the interviewer started off the interview by asking the participant to draw out a timeline on paper of their making experiences that served to motivate their involvement in makerspaces. Again, the prompt for a timeline is not in the protocol that is articulated by Seidman for the in-depth phenomenologically based interviewing approach. Based on the narrative developed in the first and second interview, the interviewer speculated that drawing out a physical timeline would create a starting point to springboard the conversation off of while also helping the participants to reiterate their lived experiences, to potentially fill in gaps that may not be noticeable in a verbal narrative, and to then have a tangible timeline that they could reflect on throughout the interview. Hence, the act of creating a visual timeline allowed the participants to reflect on their life history and current lived experiences in a concrete way – similar to how television shows will have a "previously on" segment at the beginning of each show. This provided context and a quick refresher for the participants who were then able to extract meaning from their experiences using the visual timeline in front of them.

Interviews and Learning. The in-depth phenomenological interviewing approach has great potential to contribute toward understanding the learning that evolves from making and makerspaces, as it invites participants to offer deep reflection of their lived experiences in a learning environment, whereas inviting students to respond to the prompt, "what are you learning from making this project?" is likely to result in a conventional, academically conditioned, or incomplete response. In contrast, place such a question after the person has reconstructed their experience and informed you about their whole process for making a project. In such a way, the interviewer can point to different moments in the participant's reconstructed narrative and question the relevance to the participant learning through making. Context is needed. Otherwise, there is little chance of actually investigating the meaning of an experience [55] and understanding how a student is potentially learning through making. From reconstructing their lived experiences through life history, current experiences, and meaning, the participants provide stories and describe experiences that are abundant in implicit and explicit learning characteristics.

4.1 The Interviewer

When using interviewing as a research method, a social relationship is developed between the interviewer and the participant that is then maintained throughout the process and ended respectfully when interviews have been completed [56,

57]. Every interviewer-participant relationship is personalized and unique, reflecting how the interviewer and participant interact with each other. In particular, since in-depth phenomenologically based interviewing is a three-series interview process, the relationship between the interviewer and the participant is different than a relationship developed for a one time interview. Because the interviewer-participant relationship characterizes the interview, we make it a point to discuss the interviewer along with the participants in the study. Certain features have been omitted in order to ensure anonymity.

The interviewer was a 25-year old female graduate student studying mechanical engineering at a large public university in the South. She had received her Bachelors of Science degree in mechanical engineering at a northeastern public university. She was trained in qualitative and ethnographic methods from studying qualitative research for three years, taking a course on survey methodology and two courses on qualitative research methods, and working with three different qualitative researchers. In implementing qualitative methods, she employs an interpretive lens and also utilizes her youthful look (often being confused for a freshman) and her coy personality to incorporate "competent naivety". Her interest in making and makerspaces stems from her personal lack of hand-on experience and inability to physically build and solve open ended, real-world problems. She is inspired by the female engineering students who are making in makerspace and is intrigued by their stories.

4.2 The Participants

Phenomenological interviewing requires the selection of participants who are most poised to offer insight into the meaning of the phenomenon under investigation; in this case, learning through making. Female participants were selected through purposeful maximum variation and snowball sampling. In purposeful sampling, cases are selected based on their potential to provide rich information regarding a certain topic given the available resources [28, 58]. Whereas, maximum variation sampling pertains to selecting sites and/or people [59] that are truly representative of larger population and that will result in a wide audience that can relate [34]. As such, this study sought out women who were highly engaged and involved in the various makerspaces at a single university.

We also implemented snowball sampling – the process where current participants refer the researcher to other viable participants. This method was used to recruit females who were highly involved in making at the different university makerspaces. Given the low population of female students engaging in the makerspaces, this helped to easily identify and validate the highly involved female users. Thus, the first female participant was introduced to interviewer by one of the corresponding authors. The interviewer set up an initial meeting to describe the study, to allow for any concerns or questions to be addressed, and to begin developing trust with the participant. It is important to note that an initial meeting always preceded the interview process. The first participant agreed to continue with the three-series interview process. After the second interview, the first participant provided two additional names of other females who were interested in the study. The interviewer contacted these female participants to set up an initial meeting. Meanwhile, the interviewer contacted and set up initial meetings with two other female users who were both student-workers at different makerspaces at the same university. While all four agreed to participate, one did not complete all three interviews and another of the student-workers provided an additional contact, who also agreed to participate in the study during the initial meeting. Overall, this process resulted in five female undergraduate participants: two senior biomedical engineering (BME) students, one sophomore industrial engineering (IE) student, one sophomore industrial design (ID) student, and one senior aerospace engineering (AE) student. The student who did not complete all three interviews was a senior mechanical engineering (ME) student. These female participants had various interactions with the different spaces on the campus; the spaces that they were involved in are highlighted in Table 1 which points to the main makerspace that each participant was involved in along with the others that they utilized. More details regarding the number of rooms for the different makerspaces is provided in Table 2.

For phenomenological inquiry, five participants is an adequate size to construct findings since a large sample size is not the goal. Most of these types of studies have relatively small cases, since the focus is to understand the structures of meaning, not generalizing findings based upon representative samples. Consider two criteria when evaluating the sample size: sufficiency and saturation [34]. Sufficiency is when there are an

Table 1: Makerspaces that the participants are involved in (bolded are the main space that the participant is involved in).

Participant	Makerspaces Involved In		
AE	**AE Space**	ME Space	
BME1	**BME Space**		
BME2	**Grad Research Space**		
ID	**ID Space**	ME Space	Library
IE	**ME Space**		
ME	ME Space	BME Space	Grad Research Space

Table 2: Number of rooms for the different campus makerspaces.

Makerspace	# of Rooms
AE Space	Two rooms
BME Space	Single room
Grad Research Space	Multiple rooms
ID Space	Building
Library	Single room
ME Space	Multiple rooms

adequate number of participants that illuminate the various experiences in the population in such a way that an external audience is able to relate to those experiences [34]. Moreover, saturation is when there is no new information being reported in the data [60-62]. While describing what constitutes 'enough' in phenomenologically based interviewing, Douglas [63] suggests 25 as a number of participants for where saturation begins, yet Seidman [34] emphasizes that such a number does not reflect the resources available and the variety of interview topics and studies being investigated. In this particular study, the primary population of interest could very well be around 25 in number. Two confounding factors play a role that make it challenging to actualize the true population count: 1) incorrect labeling: female students may incorrectly label themselves as highly involved or not highly involved, and 2) different labeling: female students differ in what they label as a makerspace. For example, one participant was an industrial design student and labeled her studio building as a makerspace, but since it was not a familiar casual space similar to that of the other makerspaces on campus, then other students neglected to mention the industrial design studio as a makerspace. Although it may be challenging to affirm the true population size, the population of females who are highly involved in the university's makerspaces is visibly low. Therefore, the sample of five female participants supports the potential for sufficiency and saturation.

4.3 The Interviewing Procedure

The interviewing process was conducted over the course of two months. While initial meetings varied in location (i.e. Starbucks, on-campus makerspaces), each interview was conducted in the same room with the same experimental set-up (Figure 2). This was to ensure that there were little-to-no external distractions. In addition to the room set-up, the interviewer prepared for the interviews by jotting down a list of questions or topics that would help guide the interview, if needed (see Table 3 for list of questions for the second interview). There were both advantages and disadvantages to having the questions. They did help the participants to reflect on different aspects to their experiences and help the interviewer to have questions ready if the participant ended a thought, but there were also times when the participant and interviewer relied too heavily on the questions and failed to have a more natural conversation. Ultimately, these are inherent contingencies with conducting interviews.

Furthermore, the interviews were audio-recorded, as authorized by the participant's consent. After each interview, the audio recordings were uploaded to the computer, edited to remove superfluous banter at the beginning and end of the interview or to remove highly confidential information, and then outsourced to be transcribed. In order to check the accuracy of the transcripts, the researcher listened to each interview and corrected any errors and incorporated untranscribed utterances that the transcriber failed to capture. The process of listening to over 9 hours of audio recording and editing the over 500 of single spaced pages of transcriptions occupied 75 hours of the interviewer's time.

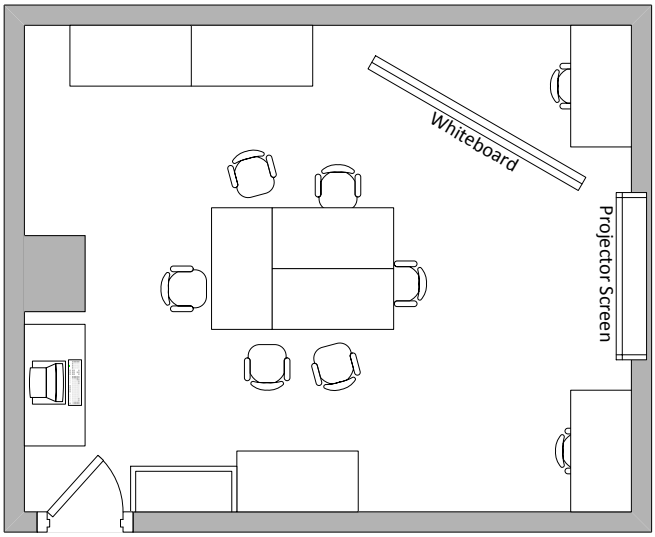

Figure 2: Room set-up for the interview.

Table 3: Questions to help guide the second interview.

Questions/Topics for Second Interview
What you do?
What do you call what you do?
How do you go about making something (walk me through the process)?
Could you describe some experiences you've had in the space?
How does using the space come about in a typical week (or day)?
Interactions with other students, faculty, staff – daily, monthly, etc.?
What is it like for you to be involved in this space, in making?
What brings about a project, design, etc.?
What are the different roles in the makerspace?
Are there any rules for the space?
For someone who has never been here, how would you characterize/talk about the space?

It is important to note here that this paper presents the analysis of the second interviews of the first two participants whom were interviewed (30 pages of single-spaced textual transcriptions for each interview, resulting in a total of 60 single-spaced paged of transcriptions). This is in part of a larger effort to analyze and compare only the second interviews of the female users. While learning is reported in the transcriptions of all of the interviews, the second interviews captures what are the current lived experiences and thereby, what is currently going on in the space. In efforts to narrow the focus of the analysis, we selected to first examine the second interview and how learning is understood by females in the current makerspace experience. Further work will expand the analysis to the first and third interviews in order to build upon and contextualize the findings.

5 ANALYZING THE DATA

The in-depth phenomenologically based interviewing approach produces a thorough and detailed data corpus. Qualitative analysis of this data aims to extract important findings from this text, which is an exhaustive and iterative process. For this study, the interview transcriptions were analyzed using analytic induction and constant comparison methods so as to create grounded theory [61]. To clarify, when a researcher aspires to develop grounded theory, they examine the data systematically for emerging themes, with the goal that these themes will explain the workings of some aspect to the social world (grounded theory). This process of identifying and establishing emerging themes/patterns involves the use of two methods: analytic induction and constant comparison

In the process of inductively analyzing the data to arrive at grounded theory, we analyzed the data through multiple cycles of open and axial coding. A code is "most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" [64]. 'Coding' is the process of eliciting codes from the data; in this case, the data are the language-based interview transcriptions. The process of coding falls into two cycles: first cycle coding and second cycle coding. First cycle coding methods extract and investigate attributes within the data, whereas second cycle coding methods refine the codes produced in the first cycle. In our work, we used the first cycle coding method of open coding. Open coding is an exploratory process that decomposes the data into distinct parts while examining these parts for similarities and differences [64]. It is crucial that this process allows one to open their interpretations of the data to any potential theoretical directions [65]. Then, we implemented the second cycle coding method of axial coding. Axial coding expands on the open coding, collects the codes, and reorganizes the codes to eliminate, converge, and compare so as to build categories. This process of identifying codes and eventually themes through analytic induction is then further complemented by constant comparison.

Through constant comparison, the data is continually being processed, examined, analyzed, and compared so as to inform the next steps for data collection and/or analysis. During this process, the data is being analyzed inductively, meaning that the researcher is not addressing and not trying to match the data with a predetermined hypothesis or *a priori* sets of categories [61]. Evidently, researchers must engage in the analysis process with a willingness to be receptive to what emerges from the data. As a result, this process produces a coding scheme.

To provide more specificity, we articulate the steps that we implemented for generating a coherent coding scheme. To start, there were four researchers who participated in the analysis process: 1) the interviewer, 2) an undergraduate researcher (UGR), 3) a design Principle Investigator (PI), and 4) a qualitative faculty researcher. The undergraduate researcher had two semesters of training in qualitative research methods and coding methods under the oversight of the interviewer, while the design PI had localized training from the qualitative faculty researcher. For this study, the interviewer is considered the expert on the material since she developed the research protocol, conducted the interviews, and is immersed in the data. In the discussion, the "first dataset" will refer to the second interview of the first participant and the "second dataset" will refer to the second interview of the second participant.

First, in order to identify the emergent categories of learning in the data, the interviewer conducted both open and then axial coding on the data. The focus of this first round of coding was to answer the question "what is this participant learning?" [66]. The interviewer, the design PI and the qualitative researcher then open-coded ten-percent of the first dataset and participated in a series of debriefing sessions to discuss the emergent codes (categories of learning), determining that additional focus on the processes of learning was important to the inquiry. It is important to clarify that coding ten-percent of the data is suggested by [67]. As a result, the interviewer and the UGR independently open-coded the same first dataset of the interview data with a focus on the question "how is one learning in a makerspace?" The interviewer and the UGR met to discuss the emergent codes, discussed points of conflict, and resolved those conflicts in coding through discussion. Following that meeting, the interviewer consolidated the open codes and organized them into categories of learning through axial coding.

Second, the interviewer unitized a sample of the data [67]. Data were unitized by units of meaning. The UGR and qualitative researcher were trained in the coding scheme by the interviewer. Following training, the UGR, the qualitative researcher, and the interviewer coded the sample of unitized data using the coding scheme. The interviewer then calculated intercoder reliability, as described by Miles and Huberman [68]. The process involves dividing "the number of coding agreements by the number of agreements and disagreements combined" [67]. For example, the undergraduate researcher and interviewer agreed on 8 number of codes while the undergraduate researcher identified 29 total codes and the interviewer identified 32 number of codes. Therefore, the intercoder reliability would be 8/32 = 0.25, using the interviewer's total number of codes because it was the larger of the two. This process was also conducted for the interviewer and the qualitative researcher (intercoder reliability = 0.094) and for the undergraduate researcher and the qualitative researcher (intercoder reliability = 0.2759). While these percentages are clearly very low and there are alternative statistical approaches for analyzing intercoder reliability, the purpose of calculating intercoder reliability on this data was to provide quick insights into the codes and the coders' discrepancies so as to further edit and improve the coding scheme and analysis process. Further insights were provided from noticing that there were instances where coders agreed on the upper level categorical code attributed to a coding segment. For example, for one coding segment, the interviewer identified the code 1.2.2, the undergraduate researcher identified the code 1.2.2.2, and the qualitative researcher identified 1.2 to be the code. To account for these agreements, the interviewer analyzed intercoder reliability based on upper level coding agreements,

as suggested by Campbell, et al. [67]. This resulted in an increase by 18.75 for both the interviewer-undergraduate and the interviewer-qualitative researcher intercoder reliability, while the undergraduate-qualitative researcher intercoder reliability increased by 0.07 percent. This indicated that there was agreement to what was emerging from the data, but the coding scheme was not well articulated and was too complex (evident in the fact that some categories had 4 subcategories).

Third, the undergraduate researcher and interviewer open-coded the second dataset in efforts to succeeding expand, refine, and revise the coding scheme. After consolidating the codes from that interview, the undergraduate researcher and interviewer discussed the new codes, the coding scheme, and the challenges faced in trying to code the data. This discussion illuminated that there were codes not accounted for in the coding scheme, that there was ambiguity in whom and what a coder should code for, and that some codes overlapped or were too similar. Based on these insights, the interviewer condensed and combined the codes into primary and secondary categories, created three separate sections for the coding scheme (how learning is occurring, what design learning is occurring, and what life skills learning is occurring), and re-unitized the previously unitized sample upon a more thorough read of the transcript. After refining the coding scheme, the interviewer reviewed the revised categories and the coding process with the UGR and design PI, and then the three again coded the same sample of unitized data. This resulted in an intercoder reliability of 0.47 between the UGR and the interviewer. Intercoder reliability with the design PI could not be calculated due to miscommunication in the training process. Then, the undergraduate researcher and interviewer participated in a series of debriefing sessions to review the data, discuss discrepancies in codes, and negotiate agreement. Through negotiating agreement, the interviewer and UGR were able to achieve 96 percent intercoder agreement. Intercoder agreement is calculated the same as intercoder reliability, but the difference is that intercoder agreement accompanies the negotiate agreement method, which is the process of coders examine the discrepancies in their annotated codes to determine if they agree or not via discussion. Through negotiating agreement in this study, the discussion illuminated ambiguity and overlap in the coding scheme along with a need for a more thorough training process. To help reconcile ambiguity, the interviewer refined and revised the coding scheme to include examples from the data for each of the codes (see Appendix for coding scheme). While this paper henceforth presents the findings to date, the iterative qualitative data analysis process will proceed to refine the coding scheme through open and axial coding of all of the data, to develop clear training instructions, and to incorporate additional researchers/coders.

6 PRELIMINARY FINDINGS

While a code captures the essence of a segment of data, a coding scheme embodies the ecosystem of the data, illuminating the relationships and intricacies of the data. The data generated in this research reveals the social, academic, cultural, and intrapersonal intricacies of undergraduate females' lived experiences in making in academic makerspaces. The efforts to distill and characterize these intricacies in the context of learning resulted in a coding scheme consisting of primary and secondary codes. The resulting coding scheme is shown in detail in the Appendix; we present the primary codes that emerged from the transcriptions and the analysis process, which as previously mentioned are classified by how learning is occurring, what design learning is occurring, and what life skills learning is occurring.

How learning is occurring aims to look at the different means through which learning happens. The *learning by doing* code captures when a student illustrates that they are learning from physically doing or making a project. The student who states that they are "very hands-on. I have -- to learn something, I have to do it" is showcasing that in order to develop a thorough understanding of principles or the way that something works, then they have to build something that helps them to tangibly experience the principles in action. Further, the *learning by being* codes expresses the notion that the students are learning from observation, conversation, or just being in the makerspace. The nature of the space allows a student to observe or interact with other students who working on projects. This code illuminates that students are learning from "just talking to people." Moreover, in efforts to articulate the occasions where learning does not result, the code *not learning by doing* emerged. The code is meant to be read as the anti-code to *learning by doing*, where the students express that they do not learn from textbooks or from just being told what to do on the machine. One student expresses that "it's much more important to be able to fix problems even if you don't have all of the information, rather than just have textbook knowledge on stuff." Here, a lack of learning results from having only textbook knowledge.

What design learning is occurring focuses on the technical and problem solving knowledge or skills that the students are developing from making and makerspaces. The *technical terminology* addresses the student learning the jargon and vocabulary that correspond to using the machines, computer software, and material in the makerspace. This code is the only code in the coding scheme that does not contain secondary codes. Though, accompanying the *technical terminology* code is the *technical tools* code, which encompasses a student learning how and when to use the tools (designated as computer software, and material) along with how the tools work. For example, "sewing is a little different since your material is so flexible, you have to kind of be aware of how the material is going to all come together." In this example, the student demonstrates an understanding of not only the flexibility of the material in sewing but also the need to be meticulous and aware of how the material comes together. Having the *technical terminology* and the *technical tool* codes then inform the third primary code of *design thinking/problem solving process*: "Anything you learn, like 3D printing, any of the tools, the 3D print, the CNC mill, the bandsaw, all of those are tools in your toolbox of design." The design thinking/problem solving

process code harnesses the ability for the student to ideate, create, and think through a problem while recognizing both the purpose of their work and the limitations to their work. Whether or not the student is following an articulated design process, these students are developing problem solving and design thinking skills that are transforming the way that they view problems and engineering design.

What life skills learning is occurring encompasses the intrapersonal and interpersonal skills that the students are acquiring from their experiences in the makerspace. The *intrapersonal – perceptions and attitudes* code entertains the ability for these students to understand more about themselves, whether likes or dislikes, values, passions, or perceptions. The fact that "like I really -- I get a lot of validation -- I really like it when people use my stickers and like have them on things" showcases the value of validation that this student has learned about herself. Of similar concerns for intrapersonal skills emerged the *intrapersonal – character, emotions, feelings* code. Observing that students were developing patience and resilience or learning to overcome their fears facilitated the second intrapersonal code. "And so I had like half a shelf, and I took it outside to paint it, and the legs fell off. I was like, "Okay, need to be more patient." While not always explicitly stated, the students' intrapersonal skills are being fostered and nurtured through the nontraditional making and makerspace activities. In conjunction, the interpersonal code exemplifies the learned skills that students are demonstrating through interactions with others. For instance, while the students are becoming familiarized to the space, they are learning the roles of the people in the space, the implicit and explicit rules for the space, and the unique look that a student gives "if you've never been there before, you have a problem you need to solve, and you don't know what to do, they'll walk in, and they'll look like this." Through picking up on social cues and gaining interpersonal skills, the students are developing a unique and diverse range of skills that allow them to communicate, connect with, and engage others in their lived making experiences.

7 DISCUSSION

In defining learning, Donaldson [7] emphasizes that learning is developing an understanding through making things and sharing that with others. Through investigating how this learning manifests in experiences of female students in academic makerspaces, we implemented an in-depth phenomenologically based interviewing process and grounded theory data analysis methods in order to capture the lived experiences and the meaning of these experiences through emerging codes. Strikingly, investigating the lived experiences of female students making in makerspaces through qualitative inquiry has illuminated both breadth and depth to the forms of learning that the students are engaging in. The breadth and depth of these findings would not have been attainable through even a small number of controlled design studies, surveys, or quasi-experimental designs. Qualitative inquiry produces an extremely rich dataset for highly uncontrolled and unstructured environments; such environments are extremely difficult to study using other approaches that demand initial detailed information on what is being learned and how learning is occurring.

The dataset generated from the in-depth interviewing process of this study was further enriched by the ability to adapt the interview protocol to cater to the participants and interviewer. The adaptations made to the interviews (such as having individuals create timelines, and bringing previous prototypes) added tactile and tangible references that aided both the participants and the interviewer in the discussion, creating a sound foundation for the discussion to springboard off of and to return to when the conversation lulled. Moreover, the verbal timeline that participants provided in the first interview was validated and endorsed by the timeline that they drew in the third interview. The previous prototypes also validated the notion that these females were invested in making, while also showcasing their unique personalities and style. The participants became more dynamic when they had the prototypes in front of them to talk about. On a similar note, the participants would also pull out their phones or laptops in order to show pictures, presentations, or computer-based models. Because this prompted a more open and casual environment to the interview, the participants seemed more open to sharing their stories with the interviewer. Even so, the participants' willingness to share their stories with such openness is primarily based in the mutual respect between the interviewer and the participant. It is important for other researchers, who are considering qualitative methods, to seriously evaluate and articulate how mutual respect will be attained. Otherwise, the in-depth interviewing process and the adaptations will provide little valuable insights. Another important consideration is that developing the appropriate research questions and interviewing protocol requires a great deal of time. In this research, two years were spent simply in exploration and an additional year was spent in developing the appropriate protocol. The in-depth interviewing process is not suggested to be used for a study that aims to explore a field. This is because the in-depth interviews are targeted to delve deeper into certain phenomenon.

In this work, the phenomenon under study is female learning in the makerspace. In delving deeper by interviewing and performing rigorous data analysis, preliminary themes of learning emerged in the form of how learning is occurring, what design skills are being learned, and what life skills are being learned. The female students are learning by doing, learning by being through conversation and observation, and also not learning by doing – meaning that they are not learning from lack of training or not learning from just textbook knowledge. These processes for *how learning is occurring* cultivate the learning of design skills (technical terminology, technical tool knowledge, and design thinking/problem solving skills) along with both intrapersonal and interpersonal life skills. Given what has emerged in the data, this study reveals the ways that content knowledge, behavioral knowledge, and dispositional characteristics (intrapersonal) are cultivated in makerspaces. While these are often features that we assess in program evaluation, this knowledge is not only important for

development of educational uses and practices in makerspaces, but has the potential to contribute to assessment practices in makerspaces.

Given that the RQ was about how women account for and experience learning, implications about the gendered experiences in makerspaces is important. First, this work points to the significance of understanding what is and is not contributing to learning of women in makerspaces. Moreover, this work emphasizes the significance of focused study on women's experience and the potential this has to shape pedagogies that enable women to thrive in engineering curriculum. Further, understanding how and what learning takes place in makerspaces also allows us to better understand and make sense of quantitative studies that track men's and women's success and competencies in engineering programs.

8 CONCLUSION

In the work presented in this paper, our objective is to investigate the learning of making in makerspaces and create a coding scheme via emerging codes and themes of second interviews conducted via the in-depth phenomenologically based interviewing process. This paper emphasizes the importance of qualitative techniques and how these qualitative approaches can be appropriately applied in engineering design as a means to obtain deeper insights. The qualitative techniques described in this paper are used to create a coding scheme which is used to develop insights and findings. As such, this paper the presents an example to the preliminary and refined coding scheme of learning that emerged from the second interviews of two out of the five female participants. This work designates the beginning findings of efforts to generate a thorough and rigorous coding scheme. From this coding scheme, we may articulate and understand the learning that is in fact occurring in makerspaces. While makerspaces are labeled as 'open, learning environments', this work acknowledges the skills and knowledge that are being learned by female students in these spaces. The insights obtained from this work have immense implications for engineering design research methods and pedagogy.

ACKNOWLEDGMENTS

This work is supported by the National Science Foundation through grants EEC- 1733708 and EEC- 1733678. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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APPENDIX

WHAT IS BEING LEARNED AND HOW: THE CODING SCHEME

ID	Code	Description	Example
		HOW	
1	LEARNING BY DOING	discussion of learning by physically doing and making	Like I'm very hands-on. I have -- to learn something, I have to do it.
1.1	Through failures and mistakes	discussion of failing or making mistakes and learning from those failures or mistakes	And so I went in and I'm like, "Okay, so let me just take this wood and cut it down." And I cracked a piece of wood. And I'm like, "Shoot, okay, I can't do it this fast."
1.2	Through struggles	discussion of struggling and not knowing what to do but still going through and learning from that	Of like how the machine -- in the same way that like people believe flipped classrooms work is of you struggling through a problem, right. … That same idea or concept is how like I think I've learned through design.
1.3	Through practice	discussion of making projects in order to get the hang of how a tool works or how to make something	Like once you've made something four or five times, you're fast, you're good at making it. You know all the shortcuts. You know where it's going to give you trouble.
1.4	Through iterations	discussion of repeatedly making the same thing and learning from those iterations	But I made -- like the first one, it was too big. And the second one, the engraving didn't come out really well. But about the fourth one, I realized I had misspelled [something]. I did all those iterations.
1.5	Through guidance	discussion of being trained on or guided through making something	"Okay, well, come in for training, and I'll teach you how to do this, and then we can work together to make what you want to create, a feasible, tangible thing."
2	LEARNING BY BEING	discussion of being present in a space and learning from just being there and interacting in that space	"Why don't I go hang out there and see what I can do with my project," I think is a lot of what happens. Which is pretty cool of like it's not something you think about, but I think it's something that I've observed, that it's very cool.
2.1	Through observation	discussion of observing what someone is doing or saying	And they're like, "Oh, how can I apply your knowledge to what I'm doing?" I think it's a lot of what I've seen and experienced myself with like how people learn in that environment.
2.2	Through helping (giving or receiving)	discussion of giving or receiving help in order to learn a tool or figure out what to do (one person is a helper in this situation)	I can be like, "Hey, I want to try this. Tell me if it's stupid, or if there's a different way I should do this." And they'll be like, "Yeah, you could totally do this. Like let me help you."
2.3	Through conversation/just talking	discussion of when interacting with others and talking with them results in learning	And I think it's a lot of the way that people learn in the machine shop, from what I've seen or like encountered, is just talking to people.
3	NOT LEARNING BY DOING	discussion of when learning is not occurring	Yeah, it's something you've done because you've designed things wrong, but how do you learn from that to make it right versus just accepting that you've failed and maybe could try something else, if that makes sense.
3.1	Not learning from being successful	discussion of when one does not learn because there was no failures or mistakes	I've learned a lot through those [mistakes] rather than the project that I've like just laser cutted, and it worked fine, because you know, you learn to like make something cool, but you don't learn from that.

3.2	Not learning from textbooks/lectures	discussion of how textbooks and lectures alone do not lend to learning	It's much more important to be able to fix problems even if you don't have all of the information, rather than just have textbook knowledge on stuff.
3.3	Not learning from improper training	discussion of when a lack of proper training results in failure to learn (i.e. someone doing something for you or going through quickly)	Someone can teach you and train you on how a machine works, but I like to spend time just like doing things on a machine.
WHAT (Design)			
A	TECHNICAL TERMINOLOGY	words or phrases that are learned from involvement in making or makerspaces	It's super-useful to know the difference between like bitmap and vector images.
B	TECHNICAL TOOLS(Machines, Computer software, Materials)	competence in using machines, computer software, or materials	Anything you learn, like 3D printing, any of the tools, the 3D print, the CNC mill, the bandsaw, all of those are tools in your toolbox of design.
B1	How to use	competence in knowing how to use a machine, computer software, or material	I could only know how to laser cut, but I could be awesome at it, and I could teach people how to laser cut things that would make them good at different things. So I think it's cool to learn from other people in the shop.
B2	When to use	competence in knowing when to use a machine, computer software, or material	If you do that, you're probably going to want to use these kinds of metals.
B3	How it works	competence in knowing how a machine works, how a computer software works, and how a materials works - aka the properties of the material	Sewing is a little different since your material is so flexible, you have to kind of be aware of how the material is going to all come together.
C	DESIGN THINKING/PROBLEM SOLVING PROCESS	discussion on intuition and problem solving skills for designing or making something. Note: this section is posed as 'learning how to __'	I enjoy the process of having a problem and like being able to solve it through being like this is the list of the possible outcomes that I think are why this problem is occurring. Let me tick of the boxes of like oh.
C1	Identify Objectives (Goals, Aims, Direction)	discussion on what do you want to or need to do	How do you make like an idea or a concept that is so easy that you could hand it to like a kid and make it work? That was our goal was to make something simple.
C2	Interpret the Problem	discussion on what is wrong or what is the problem that needs to be solved	"What's your problem?" And then someone will be like, "Oh, I need to build a box."
C3	Generate ideas/solutions	discussion on ideas, concepts, or ways to achieve goal or solve problem	Okay, so what we did was we came up with a bunch of ideas. It was like a session where you're like nothing is a -- like don't say no.
C4	Prototype, Build, and Model	discussion on physically representing the concept or building something	And then realizing that two 45-degree angles come together to make a 90-degree angle. So it was like that was such a dumb thing that we should have realized. But doing that and be like, "Oh, okay, visually I understand how this works now."
C5	Be Resourceful and Efficient	discussion on using time and resources wisely	Let me think what I can do with what I have.
C6	Fix Something	discussion on repairing an object to a better condition or fixing an item	"How are you going to fix that?" And then like watch him fix it, and he'll like explain to me what he's doing. So then like the next time the [machine] or something else leaks, I'll be able to know how to fix it.

C7	Understand the Meaning or Purpose	discussion on why is one doing what they are doing and finding meaning to the work that one is doing	Or someone will walk by see me spending three hours sanding something be like, "What are you making? Like why are you spending so much time on this?" I'm like, "Well, I'm making this. And it's super-cool," and I talk about it.
C8	Incorporate Unorthodox Means or Strategies	discussion on using unique ways in the design process and to solve a problem (i.e. going to a toystore)	We were just playing with kids' toys of how kids blocks join together. And that's when we got -- we found -- we saw those kid's blocks that are like a snake that you can -- you could make it a different shapes. And we were like, "Okay, what if we're trying to do that with that idea of taking multiple blocks and making this?"
C9	Examine or Rectify Barriers/Limitations	discussion on what is preventing someone from achieving their goal or solving the problem, or how one is limited in achieving a goal	But then you see a lot of people that start off with designs and 3D printing. And then because they don't know other tools, then they're stuck on 3D printing, and then it becomes inefficient for them to continue 3D printing for their current project.
C10	Make Connections	discussion on connecting an idea from one domain to another or realizing something that could help to solve a problem Note: not to be confused with connecting with people	Yeah, I think a lot of people do random things all the time in the shop that don't seem inter-related, but when you talk to people and you're, "Like I made this cool thing." And they're like, "Oh, I'm trying to do something." And then people are able to connect that together. And then make something cool.
WHAT (Life Skills)			
10	INTRAPERSONAL - PERCEPTIONS AND ATTITUDES	discussion on how one perceives things and what they have come to understand about themselves	Yeah, I think that I've never not enjoyed being in the shop. But that might be a me thing.
10.1	Learning what one values	discussion on what one considers useful or important; can be stated explicitly or implicitly (i.e. putting time and effort into a project OR someone can even value feeling validated)	Like I really -- I get a lot of validation -- I really like it when people use my stickers and like have them on things.
10.2	Learning what one likes or dislikes	discussion on what one has come to like or does not like	And I was like, "Well, I just like making stuff."
10.3	Learning what one is passionate about or interested in	discussion on the things that excite a person, on what their passions or interests are	And then they're able to 3D print something. They're like, "This is tangible of what like I'm passionate about."
10.4	Gaining perspective	discussion on how one perceives things, usually in the form of seeing things more holistically, rectifying one's attitude or mindset	And I think it's a lot of the way that people learn in the machine shop, from what I've seen or like encountered, is just talking to people.
20	INTRAPERSONAL - CHARACTER, EMOTIONS, FEELINGS	discussion on how one has developed character	It's like, "Oh, no. Are they not going to respect me because I don't know the answer to this question? Are they not going to listen to me? Are the other [student workers] going to think I'm less competent?"
20.1	Learning Resilience	discussion on coming back from a bad situation – toughness, grit	After all those little, tiny challenges you faced, it finally came together, and you made the thing you wanted to do.
20.2	Learning Fortitude	discussion on the ability to confront fear – courage, endurance, strength	At first it was a little scary for me. … But now I'm like -- I'm competent enough in all the rooms, but there's a lot of tools that I'm not totally solid on.

20.3	Learning Prudence	discussion on judging between actions and what action is appropriate at a given time – time management, priorities	Sometimes I'm just sitting there doing homework if no one comes in and it's quiet. If I have a lot of work to do, I prioritize work, because I'm a student.
20.4	Learning Patience	discussion on steadily going through a process or persevering	And so I had like half a shelf, and I took it outside to paint it, and the legs fell off. I was like, "Okay, need to be more patient."
20.5	Learning Confidence	discussion on being more comfortable or confident in completing a task - motivation, pride	And so I feel much more confident knowing that if someone comes to me with a question I can't answer, I kind of know the steps to walk through the problem solving.
20.6	Learning to overcome unwanted emotions	discussion on overcoming and no longer having an unwanted emotion	Now that I know people in the shop and I'm not afraid to talk to them, they're like normal-ish people.
20.7	Recognizing one's fear or negative emotions towards a situation	discussion on when one is afraid to do something or has an emotion that negatively impacts their perspective	I'm very frustrated at it, my perspective is not going to help me at that point, because I'm frustrated, and I just need to take a step back.
30	INTERPERSONAL	discussion on skills that pertain to working with others	He's been doing woodworking projects since he was eight. So if like he's around, I'm going to ask him for advice, because chances are he's going to be able to give better advice than me who has only been woodworking for about a year now.
30.1	Learning what the culture is like (roles, rules, etc.)	discussion on what are the nuances of the culture, what are the roles and rules in the culture, how is it managed	A lot of people come in here and make stuff for class, or a lot of people typically come in to make gifts or little pet projects of their own.
30.2	Learning how to communicate to others	discussion on how one has picked up on social cues and is able to communicate ideas or concepts to others; also, able to describe what they are working on, or working with people to achieve a goal	I can tell because if you've never been there before, you have a problem you need to solve, and you don't know what to do, they'll walk in, and they'll look like this.
30.3	Learning how to manage, network, and plan	discussion on working on and handling more of the back-end tasks for keeping the space running or planning events	When I'm like on the shift as a [student workers], like my main goal is to keep people safe, right, whether I'm in the wood room and like watching people, making sure nobody drills through their hands, making sure everybody's got their hair tied back and has got like safety glasses on, and everything.
30.4	Learning how to connect with people or engage them in what they are doing	discussion on relating to people (whether person-to-person or getting them excited about the work that they are doing)	I've learned through teaching is being able to connect with someone allows them to understand you better.