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Comparison of Student Learning in Two Makerspace Communities

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Abstract

The Maker Movement has led to a boom in academic makerspace development over the past 15 years. Academic makerspaces—which are those located on community college and university campuses—enable students to engage in solving challenges that are meaningful to them, while uniting students of varied expertise levels to learn from one another. Using a typology of learning developed through in-depth phenomenologically based interviews (PBI) with 35 students, this study investigates how student learning differs at two Universities with differing amounts of making integrated into the curriculum. Big City U offers a large program with traditional engineering degrees, while Comprehensive U offers a smaller program with a single design-oriented B.S. in Engineering. Interviews were coded using a previously developed learning typology and categories of learning were compared across institutions to identify similarities and differences in experiences. Preliminary findings show students are gaining comparable content knowledge, cultural knowledge, and ingenuity, but Comprehensive U students are more self-aware and learn through relationships with others more than students at Big City U.

1 Introduction

To prepare our engineering students to be successful in complex real-world environments, universities must develop well-rounded engineers. This goes far beyond the technical—the 21st century engineer is a strong communicator; they are a collaborator and highly innovative. To develop students in multi-disciplinary and collaborative efforts, academic institutions around the world have begun incorporating makerspaces into their campus communities.

Makerspaces afford students an opportunity to come together with other students from varying backgrounds and expertise to solve hands-on challenges. Through engaging in makerspace activities, students develop improved self-efficacy and self-esteem, while becoming members of a greater community [1-3]. While makerspaces are espoused as being a benefit to students in many ways [1, 4-10], they require large monetary investments, ample space, and significant planning and management—a fact noted at both Big City U and Comprehensive U studied herein. While there are many resources on the development of a makerspace [11], very little considers how and if you should integrate the makerspace with the Universities' curricula.

Our previous work investigated the breadth of learning and the interaction of competencies for women students in makerspaces. Through iterative qualitative analyses of in-depth phenomenologically based interviews with women students who identified as makers at two different universities, we developed a learning typology that describes how and what women students are learning from their makerspace involvement [References removed for double blind review]. Using the same interview-based methodology and a data set that includes interviews with men, this study investigates how student learning compares at two Universities, Big City U and Comprehensive U. Big City U is a large, tech-focused public University in the south with an "opt-in" makerspace. Comprehensive U is a public, mid-Atlantic University with a small engineering program with a curriculum heavily integrated with making and the makerspaces.

This study aims to answer the question: *Do design competencies and learning types differ across learning communities with varied degrees of making integrated into the curriculum? And if so, how?*

2 Background

Mersand [12] broadly defined makerspaces as "places where participants may work together to create and co-create knowledge and physical or digital products" (p. 175). Activities can range from engineering, tinkering, circuitry to crafting and forms of artistry, as well as much more [4, 13]. Makerspaces are open spaces for any student to work on academic, extracurricular, or personal projects, and for many, makerspaces are the embodiment of *learning by doing*.

Over the last fifteen years, the number of makerspaces has increased dramatically as the Maker Movement has grown in popularity. Halverson and Sheridan [1] define the Maker Movement as "the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others" (p. 496). The Maker Movement has come with enthusiasm spread around the world for maker-centric events such as hack-a-thons and Maker Faires as well as integration into community centers, libraries, primary/secondary schools, and academic institutions [14].

While the Maker Movement developed outside of academia, there appear to be many benefits to incorporating aspects of the movement into education. Making affords students the opportunity for social engagement surrounding a shared experience, uniting participants of varying experience levels together and facilitating learning [4-6]. As a result, making communities foster an environment of collaboration and afford an opportunity for students to engage in solving meaningful problems. While there is little empirical data regarding student learning in makerspaces, these spaces are recognized as a means to developing 21st century skills, by inspiring participant's creativity, critical problem solving, curiosity, determination, independence, and grit [1, 7-10]. In summary, the Maker Movement centers *learning by doing* providing makers with contextualized experiences to further their understanding and bridge theory to application.

3 The Learning Typology

In prior work investigating how and what women students are learning from their makerspace involvement a typology of learning was developed [Reference removed for double blind review]. The learning typology showcases the breadth of student learning and competencies developed in the makerspace. The typology is broken down into six primary categories (Table 1).

Table 1: Typology at a glance: The primary categorization

1	LEARNING BY DOING
2	LEARNING THROUGH OTHERS COMMUNICATING & MANAGING
3	CONTENT KNOWLEDGE AND SKILLS
4	CULTURAL KNOWLEDGE AND SKILLS
5	INGENUITY
6	SELF AWARENESS

The first two categories are modes of learning, accounting for *how* the students are learning. ***Learning by Doing*** refers to learning through hands-on activity or experiences. ***Learning through Others*** refers to any form of learning from someone else, whether it be from interacting with them or observing. The key distinction between these modes is learning by doing is a *physical activity* while learning through others is a *social activity*.

The remaining four categories are products of learning, accounting for *what* the students are learning from their experiences in the makerspace. ***Content Knowledge*** is the understanding ***and Skills*** associated with an array of topics. ***Cultural Knowledge and Skills*** refers to the participant coming to understand the nuances and rules of the community. ***Ingenuity*** represents informally using innovative means or strategies to find a solution. ***Self-Awareness*** is the understanding of motivating factors towards one's attitude and personal characteristics.

4 University Selection: Big City U and Comprehensive U

Big City U and Comprehensive U were selected for this study because of their differences in makerspace & engineering curriculum structure allowing us to gain insight into how significant curricular differences impact students learning outcomes in the makerspace.

Big City U is home to the nation's largest volunteer student-run makerspace. Each student volunteer works 3 hours per week and in return has 24/7 access to the makerspace facilities. Big City U integrates the makerspace into multiple classes, particularly sophomore and senior design, but overall, it is an opt-in makerspace. Students are encouraged to pursue personal projects in the space in addition to academic and extracurricular. Big City U's engineering program offers what many might consider to be a traditional B.S. in a specified discipline of engineering (e.g. mechanical). In total, there are around eight makerspaces across Big City U's campus.

Comprehensive U offers a less traditional path toward an engineering degree with a single, design-oriented B.S. in engineering. The undergraduate engineering experience at Comprehensive U is based on a philosophy of learning by doing. The engineering program is small, especially when considered in the context of the university; this size enables supportive mentoring from faculty and staff resulting in high student engagement. Comprehensive U's makerspaces are staffed by paid student workers as well as three technically trained staff members. Makerspace use is highly integrated into the curriculum, especially in the first and second year, bringing students in their first semester and nearly every semester following.

5 Methodology

In prior work investigating how women students learn in academic makerspaces, a methodology was developed suited for the complex, interactive makerspace environment. In-depth phenomenologically based interviewing (PBI) methodology is outlined in Irving Seidman's *Interviewing as a Qualitative Research* [15]. The original interview protocol comprised three 90-minute interviews and was used for all of the interviews conducted at Comprehensive U. To increase the sample size, a modified single-targeted interview protocol of 60-90 minutes was developed. Interviews conducted at Big City U utilized the single-targeted interview protocol. All interviews conducted, regardless of protocol, centered around understanding the participants lived experience in the makerspace. In total, 34 interviews were conducted with a total of 19 participants.

5.1 Participants

In order to gain the most insight into learning in makerspaces, we sought out participants who were highly involved in the spaces. To do this, snowball sampling was used – connecting the interviewers with potential participants via referrals from other participants. The interviewers also recruited potential participants through Facebook page, word of mouth, and mutual connections. In total, 19 participants participated in this study: 5 men and 5 women from Big City U and 5 men and 4 women from Comprehensive U.

5.2 Interview Process

For each interview, a private experiment room was used to ensure there were minimal distractions. Each interview was audio recorded per the participant's consent and later transcribed. Transcriptions were checked and edited for accuracy and to remove any personally identifying information to protect participant confidentiality.

Each interview in the original protocol focused on different aspects of the makerspace. The first 90-minute interview sought to understand the participant's background experiences in learning through making. The second 90-minute interview focused on the revisiting the details of these past experiences in the makerspace, and participants were asked to bring a project they have made with them. Finally, the third 90-minute interview dove into understanding the meaning of the participant's involvement in the makerspaces. In this interview, participants were asked to draw a timeline of their making experiences throughout their life leading up to and including their experiences in the makerspace. This encouraged the participants to reflect on their experiences and extract the meaning associated with each set of experiences.

The modified single-targeted protocol is a truncated combination of the activities in the three-series interviews in which participants share a chronology of their making journey and its meanings to them. The full protocol is in Appendix A and the questions center around the themes of the original protocol: life history, details of experience, and meaning. This modified protocol also asked participants to draw a timeline of their experiences in making.

5.3 Data Analysis

In total, over 1000 pages of single-spaced interview transcriptions were produced and analyzed in this study. NVivo qualitative data management software was used to manage this large volume of data. All interviews were analyzed by an interviewer and an undergraduate researcher (UGR), who were trained by a faculty researcher with expertise in qualitative research methods.

The two student researchers immersed themselves in the data as well as the learning typology, and over the course of several months were trained to code the interview data using the developed typology. In that process, as new themes emerged in the data, the typology was updated to reflect these new themes and coding rules were further refined. No new primary categories of the typology emerged, reinforcing the learning typology captures *how* students are learning in the makerspace.

In order to ensure coding agreement between the two researchers, Miles and Huberman's [16] methods for assessing interrater reliability were used, and an interrater reliability of 83.7% was established after coding four interview transcripts. Miles and Huberman assert that a baseline of 80% coding agreement on 95% of the codes is the benchmark for acceptable levels of agreement. Once reliability was established, the student researchers divided the remainder of the data set and coded independently.

6 Findings & Discussion

After all of the interviews had been coded, the frequencies of each primary category of the learning typology were analyzed. Frequencies were determined based upon how many times each category was coded (referenced) in the data. To ensure reference count was an accurate measure of occurrence, the interviewer checked and re-unitized (when necessary) all of the interviews the UGR coded. The distribution of the learning typology for each University is shown in Figures 1 and 2.

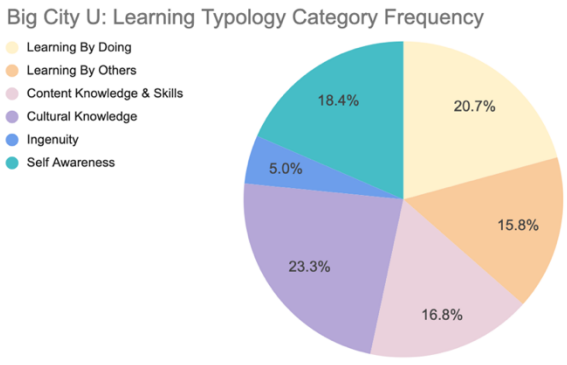

Figure 1: Big City U Learning Typology Breakdown

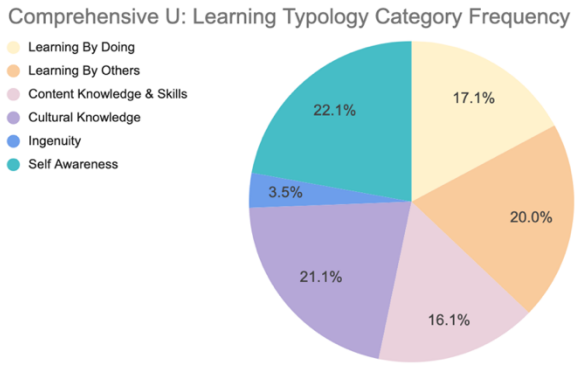

Figure 2: Comprehensive U Learning Typology

Overall, the two universities appear to have fairly similar learning outcomes for their makerspace participants. By comparing these pie charts, the most significant differences between the students learning at each University is in the modes of learning. Big City U students have a higher rate of learning by doing while Comprehensive U students have a higher rate of learning by others. Comprehensive U students also have higher self-awareness. The remaining categories: content knowledge, cultural knowledge, and ingenuity are similar at each University with a difference of less than 2.5%.

6.1 Similarities

One of the interesting findings suggests that cultural knowledge is of relatively equal importance at each Universities' makerspace. Cultural knowledge was referenced when a participant discussed navigating the makerspace community and coming to Big City U since the makerspace is entirely run by student volunteers, and for the most part, participation is elective. Navigating such a community, where the participants completely shape the culture and experience of the makerspace was a common discussion in our interviews. At Comprehensive U, the makerspace culture and structure are more explicitly communicated to the participants. There is much more structured experiences with faculty, and the makerspaces are heavily integrated into the curriculum with advising bringing engineering students into the spaces their first semester. We expected cultural knowledge to be less of a topic of discussion, but our data suggests otherwise. A participant at Comprehensive U noted:

> *"You're quite literally thrown onto project on day one of your time here as an engineering student. Literally on the first day of class, we were assigned a project with our leaders from the leadership program."*

Regardless of how the makerspace is structured and integrated in the curriculum, learning how to navigate the space matters to students.

Students at both universities also are developing comparable amounts of content knowledge and ingenuity. Students display an understanding of a wide array of topics as well as being able to informally solve problems using innovative means—nearly the same at each University as a result of their experiences in the makerspace. This is particularly interesting given the differences in engineering curricula. By integrating the makerspace into the curriculum, every engineering student at Comprehensive U is at least foundationally a maker, but at Big City U, it is only through optional, extracurricular participation that students engage as a maker. Since we sought out participants who were active in the makerspaces, every participant at Big City U was a self-identified maker. We see that regardless of whether that identity as a maker was optional (Big City U) or directed through curricular requirements (Comprehensive U), students are gaining similar levels of technical learning. This demonstrates that there is noted value to bringing students into the makerspaces and keep them involved as whether involvement is self-motivated or not, students learn and develop engineering skills in makerspaces.

6.2 Differences

The main difference between Big City U and Comprehensive U students' descriptions are the modes of learning. At Big City U students describe more experiences of ***learning by doing*** whereas Comprehensive U students describe more experiences of ***learning by others***. Learning by others can range from simply observing someone in the makerspace to leading or managing a team.

Comprehensive U's hands-on, learning by doing focused curriculum with many classes having team projects encourages collaboration. Students have to learn to work together, as well as can gain leadership opportunities from their academic experiences. For example, one student at Comprehensive U noted:

> *"But I mean, I kind of serve in the Project Manager role in the fact that I keep in contact with -- like, I set meetings with our Advisor, Dr. Z, and I set meetings with our clients and kind of keep us on track, so to speak, of what we need to do our progress checks."*

Big City U also has team projects centered around making, sophomore and senior design, but Comprehensive U has these types of projects much more frequently in their courses. Comprehensive U is also a much smaller engineering program; the students for the most part all know one another and get to form relationships with the faculty. By forming such a community, students may be more open to asking for help and offering help. Big City U's program is very large, the makerspaces at Big City U form their own community, part of the much larger engineering population.

Further, Big City U is well-known for its competitive engineering program as noted by a student:

> *"I think it's almost more like I really dislike having to feel like I'm on my guard or I need to defend myself, so I think if for some reason I needed to use the Invention Studio, that would, I guess, just be my expectation of how it would go is that I needed to defend my qualifications or my knowledge."*

This competition is noted to likely result in the more independent learning style observed at Big City U, which is supported by literature: competitive goals can weaken relationships amongst colleagues and lead to ineffective interactions [17].

We also observed Comprehensive U participants have higher self-awareness – a trait that is linked to increased confidence and adaptability to challenges [18]. For example, one student at Comprehensive U noted:

> *"I'm not a total extrovert now, but I've definitely come more out of my shell and that's because of Dr. Y being like, "You're gonna do this thing for me." And I'm just like, "Well I don't have much of a choice now do I." <laughter> Like the presentation I gave yesterday, I got the assignment to do it on Tuesday at 4 o'clock. I was like, 'Okay!'"*

In this study, self-awareness was coded when a participant displayed an intrapersonal understanding of their growth, attitude, motivation, and character. This understanding can be facilitated by reflective practices, questioning one's own learning, justifying one's methods, and trying new learning methods [18]. Comprehensive U's engineering program encourages this through pedagogical tools such as ePortfolios, learning records for course assessment, and student-agency in teaming and project selection.

7 Conclusion & Future Works

This paper presents a look into how learning compares across different university makerspaces. At Big City U and Comprehensive U, students are gaining comparable content knowledge, cultural knowledge, and ingenuity from their involvement in the makerspaces. But preliminary findings suggest integrating making into the curriculum encourages students to collaborate, one of the essential 21st century skills [19]. Regardless of whether your University integrates the makerspace heavily into the curriculum or not – your students are learning from engaging these spaces. Creating catalyst experiences to bring students into these spaces and affirming them so they stay matters.

To ensure the findings presented in this paper are significant, further analyses are needed. Using the interview data from this study, statistical analyses will be conducted to quantify the significance of any similarities and differences observed in the learning typology. Further, to minimize variables, these analyses will break down each University by gender.

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APPENDIX A – Interview Questions

IN-DEPTH PHENMONOLOGICALLY BASED INTERVIEW JOTTINGS

Interview One

- Interest in how you got involved
- Before GT; Growing up, what was is like for you with creating or making things
- attracts you to this space or types of spaces
- inspires you to use the space
- elementary school
- High school
- Keeps you going
- Person who has influenced you
- Clubs, activities
- What did you do growing up, things you were involved in

Interview Two

- What you do
- What do you call what you do
- How do you go about making something
    - Walk me through the process
- Describe experiences you have
- Typical week, day
- Interaction with other students, faculty, staff --- daily, monthly, etc.
- What is it like for you to be involved in this space
    - In making
- Roles
- Rules
- How does using the space come about in a typical week
- Dynamic of class + leisure + anything else come into fruition in makerspace … in making
- For someone who has never been here, how would you characterize/talk about the space

Interview Three

- Timeline
- For someone who has never been here, how would you characterize it
- What do you call what you do here
    - Making, crafting
- Given what you have said about your experience before + now, how do you understand __ in your life
    - What sense does it make to you
- Where do you see yourself going in the future?
- How has this changed/shaped your life?
    - Role as student, learner
    - Types of skills
    - Way of thinking
    - Goals + how to achieve them
- Takeaways
- What in your life do you attribute to this space?
- Experiences = important, impactful
- Speak to what is like being female in these spaces
- Confidence
- Role of space/making in life?
- How do you see yourself (your role) in these spaces?

SINGLE, TARGETTED INTERVIEW PROTOCL

Thank you for agreeing to meet with me today. I have us scheduled for an hour together. Does that still work for you? I want to honor our time constraints today. If we reach the hour and you would like to expand on the questions more, I would compensate you for the additional time. Nevertheless, while I encourage you to elaborate on your answers to my questions, there may be times when I redirect, so that we may be sure to cover all the topics in the hour.

<go over IRB>

This meeting is focused on your making, design, and learning experiences as a woman involved in the makerspace. So I want you to think of your experiences making and what you've learned throughout these experiences. I want you to imagine that you've had this toolbox and every time that you've learned something, you add it to your toolbox. And what I'm interested in is what is in this toolbox because of your involvement in the makerspace, so what it looked like before and what it looks like now.

In order to help you navigate the loads of things that you've done in your life, I want you to first start off with creating a timeline of your making experiences growing up to now.

Could you highlight the point for where you began your involvement in the makerspace at Georgia Tech?

Now, looking at this region for growing up to your involvement, what would you say was in your toolbox?

Now since your involvement, what has changed in your toolbox?

What has changed in regards to:

- Knowledge in course-related topics such as design, manufacturing, materials
- Ability to understand and navigate a specific culture or community
- Creativity
- Personal growth and your perspective on making
- Navigating your identity as a woman in the makerspace
- Communication skills
- Leadership skills

Has your way of thinking through a problem changed? Could you walk me through an example.

How would you characterize *how* you learn in the makerspace?

What are some of the things that you have learned how to make in the makerspace?

Overall, how has your experience in the makerspace impacted your life?