

Board 112: Contextualizing Learning: Exploring the Complex Cultural System of Learning in Engineering Makerspaces

Dr. Robert L. Nagel, James Madison University

Dr. Robert Nagel is an Associate Professor in the Department of Engineering at James Madison University. Dr. Nagel joined the James Madison University after completing his Ph.D. in mechanical engineering at Oregon State University. He has a B.S. from Trine University and a M.S. from the Missouri University of Science and Technology, both in mechanical engineering. Since joining James Madison University, Nagel has helped to develop and teach the six course engineering design sequence which represents the spine of the curriculum for the Department of Engineering. The research and teaching interests of Dr. Nagel tend to revolve around engineering design and engineering design education, and in particular, the design conceptualization phase of the design process. He has performed research with the US Army Chemical Corps, General Motors Research and Development Center, and the US Air Force Academy, and he has received grants from the NSF, the EPA, and General Motors Corporation.

Dr. Melissa Wood Aleman, James Madison University

Dr. Melissa Aleman (Ph.D. University of Iowa) is Professor of Communication Studies at James Madison University and has published research using qualitative interviewing, ethnographic and rhetorical methods to examine communication in diverse contexts. She is particularly interested in multidisciplinary studies of communication, culture, and learning in makerspaces, as well as broadening participation of women and underrepresented minority students and faculty in STEM fields.

Ms. Megan Tomko, Georgia Institute of Technology

Megan E. Tomko is a Ph.D. graduate student in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology under the guidance of Dr. Julie Linsey. She completed one semester in her graduate studies at James Madison University with Dr. Robert Nagel as her advisor. Her B.S. degree in Mechanical Engineering is from the University of Pittsburgh where she also worked as a Field Telecommunications Intern for three consecutive summers at EQT, a natural gas company headquartered in downtown Pittsburgh, PA. Megan's research interests correspond to identifying ways to teach students how to become better designers and learners through creative and non-traditional means.

Dr. Julie S Linsey, Georgia Institute of Technology

Dr. Julie S. Linsey is an Associate Professor in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technological. Dr. Linsey received her Ph.D. in Mechanical Engineering at The University of Texas. Her research area is design cognition including systematic methods and tools for innovative design with a particular focus on concept generation and design-by-analogy. Her research seeks to understand designers' cognitive processes with the goal of creating better tools and approaches to enhance engineering design. She has authored over 100 technical publications including twenty-three journal papers, five book chapters, and she holds two patents.

Oumaima Atraoui , James Madison University

Oumaima Atraoui is an undergraduate research assistant for the Department of Engineering at James Madison University. She has been involved in observing and researching makerspaces and informal learning environments with an emphasis on leadership development. Oumaima is passionate about studying human behaviors and incorporating that knowledge within the scope of engineering.

Caroline Clay, James Madison University

Caroline Clay is an undergraduate student at James Madison University in the Engineering Department. She is a student researcher studying how engineering students learn in informal learning environments and makerspaces, with an emphasis on how students learn in structured and unstructured settings. After participating in the University Innovation Fellows program Caroline is pursuing an honors thesis studying how students learn to become changemakers. Following graduation, Caroline plans to work in the intersection between entrepreneurship, engineering, and agriculture.

Zachary Harris De Bey, James Madison University

Zachary De Bey is an undergraduate student researcher at James Madison University in the Department of Engineering. He researches informal learning environments and makerspaces with an emphasis on how trust in engineering teams plays a role in learning. He is passionate about engineers using integrated electronics and computer programming to solve contemporary issues.

Johannah Daschil, James Madison University

Johannah Daschil is a junior engineering major minoring in political science and math at James Madison University. Daschil is a continuously curious individual who is always asking question of how and why. This curiosity has driven Daschil to explore the bridges between engineering and political science, particularly the influence of gender in the decision making processes of both disciplines. Daschil currently works on a research project to understand how learning occurs in informal learning processes such as making and the influence of gender on learning.

Bethany Popelish, James Madison University

Bethany Popelish is a Communication and Advocacy graduate student at James Madison University researching learning in makerspaces as communities of practice. Bethany holds a Bachelor of Arts in Sociology from Mary Baldwin University. Her scholarly interests include exploring methods of qualitative research and the social nature of learning and development.

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1. Introduction

The Engineer of 2020 recognizes creativity, invention, and innovation as indispensable qualities for engineering. It may be argued, however, that traditional engineering programs do not inherently foster these qualities in engineering students, and with limited resources and time, adding innovation-fostering experiences to already over-packed curricula may seem like an insurmountable challenge. Longitudinal studies carried out by the authors have shown that makerspaces can foster improvement in engineering students' design self-efficacy, and three-part phenomenological interviews have shown that students in makerspaces engage in non-linear, open-ended, student-driven projects that require hands-on designing, prototyping, modeling, and testing. These studies provide initial evidence that makerspaces may have the potential to enhance students' deep learning of engineering and engineering design.

To arrive at the more complex cultural factors related to student involvement and success related to participation in makerspaces, we describe the processes of ethnographic methodologies we are using to study the intersections between the structure of an engineering curriculum and the learning that occurs outside of the classroom in makerspaces. Ethnographic methodologies of participant observation, unstructured and semi-structured interviews enable exploration of how students (1) interact within and construct the culture of makerspaces; (2) talk about makerspace culture as important to their commitment to engineering; (3) learn within makerspaces; and (4) choose the type and direction of projects.

This paper specifically describes the ethnographic methodologies used to track four different undergraduate student teams participating in a two-year senior capstone project, as well as students participating in a sophomore design class in which they use makerspaces to build a human powered vehicle for a client with a disability. Initial interpretations are presented that inform our understanding of the complex cultural system in which learning occurs, ultimately helping us to consider ways to improve university makerspaces.

2. Background

2.1 Expertise and Learning in a Community of Practice Situated learning and communities of practice offer a means to understand the learning processes and expertise development that occur within makerspaces. Expertise and learning are challenging to determine – especially in informal learning spaces such as makerspaces. Situated learning and communities of practice introduce students to an environment that integrates culture, participation, and practice in order to facilitate learning and meaning [1, 2]. Situated learning theory presses that knowledge is socially-constructed [3, 4]. Whether this fully encompasses how knowledge is formed or not, the notion that knowledge is socially constructed indicates that makerspaces, which are social environments, are where knowledge is gained. Situated learning activists would argue that makerspaces are the crux of where knowledge and education occur since they surround students with community and real-life experiences.

Communities of practice facilitate the quest for knowledge/learning and identity through experience and social interaction where members work side by side, generating a circular operation through which participants guide and receive guidance from one another [5]. Actively engaged members in communities of practice are demonstrated to cultivate identity and connection to both their work and other members of the community [6]. In the makerspaces of interest to this research, the work and identity are oriented towards engineering. Thereby, students are forming an

engineering identity and developing a greater connection to engineering work and other engineering students due to involvement in the makerspace. Moreover, a key component of a community of practice is the negotiating competence within a domain [7]. Since a community of practice is a group of people, who are oriented towards a specific domain, a member's involvement, and qualification is certified through constantly negotiating competency of and developing expertise in that specified domain, in this case engineering. While communities of practice are built on this knowledgeable ability, student experience and identity develops from working and practicing in an engineering makerspace.

This paper describes our methodological processes for studying learning within a communities-of-practice. Specifically, we argue that to understand the complexity of engaged learning practices *in situ*, the methodology must enable researchers to follow learners over time in the contexts in which learning is occurring. This paper makes a case for using ethnographic methodologies to study sophomore design students throughout a one-year project in which they work in teams to design a human powered vehicle for a disabled client and two-year engineering capstone teams as they engage in variety of engineering projects unique to each team.

2.2 An Ethnographic Approach to the Study of Engineering Makerspaces Our long-term project goal is to identify the interplay between expertise, learning, and creativity that occurs in makerspaces. Since little is known about student learning in makerspaces, ethnographic methods offer a holistic approach to the study of makerspace culture that enable the exploration of student learning experiences as they unfold overtime in a naturally occurring context [8]. Specifically, ethnographic methodologies enable us to forward a narrative understanding of learning that recognizes the cultural contexts of both engineering education and makerspaces, the longitudinal processes of learning in such contexts, and the processual manner in which identities and expertise are developed as social processes.

Ethnographic methods have been shown to be useful in offering descriptive and explanatory insights into processes of learning and expertise development [9-11] particularly in understanding how tacit knowledge is developed. In short, learning is a social process and ethnographic methodologies are well-suited to offer insight into those processes. This study, therefore, uses ethnographic approaches of participant observation, ethnographic interviews, and semi-structured interviews to further investigate how these spaces are being used, what activities are occurring, who uses the space, what motivates someone to use the space, how one gets involved in the space, and how the learning culture of these spaces develops.

Ethnographic observations enable us to identify common themes regarding the students' use and experiences of makerspaces, and associated behavioral patterns related to learning, expertise development, and creativity. These social processes of learning and expertise development can be understood through both observations and interactions with students in naturally occurring contexts, such as makerspaces. Traianou argues that ethnographic methodologies are important to sociocultural approaches of cognition "that stress the ways in which expertise is defined in practice" (p. 211) [12]. Therefore, this research offers explanations of the interplay between expertise development, learning, and creativity through rich descriptions of the individual and social practices of making and the manner in which the spaces produce, or sometimes fail to produce, a dynamic and welcoming culture.

Specifically, this project seeks to answer the following research questions:

- RQ1: How and what are students *learning* in makerspaces?
- RQ2: How are students being formed in their *identity* as an engineer in these spaces?

- RQ3: How is *creativity* expressed and understood in makerspaces?
RQ4: How does a student gain *expertise* in a makerspace?

Using ethnographic methodologies, we examine how expertise is acquired through social processes of collaborative learning in formal and informal interactions in makerspaces. Examining communication practices such as advising, mentoring, and storytelling, among others, can reveal the interplay between expertise, learning, and creativity in makerspaces

2.3 Makerspace Facilities Studied. The making spaces include a digital manufacturing studio with a workspace area, a general fabrication studio, and a machining center, open collaboration spaces, design studios (designated for freshman, sophomore, and junior/senior capstone), multimedia labs, design testing facilities, and faculty, administrative, and staff offices. The new engineering making spaces have been purposely designed to support an engineering culture and curriculum centered around sustainable design, making, and creating value.

The makerspaces are a part of the Department of Engineering at James Madison University. The ABET-accredited engineering program offers a single degree Bachelor of Science with an emphasis of engineering design, systems analysis, and sustainable decision making.

Each of the three making spaces are general purpose spaces (i.e., their use is not associated with a single course in the curriculum, but instead they are used by many courses, independent studies, research projects, and passion projects). Both the digital manufacturing studio and the general fabrication studio have open hours in the afternoon and evening which are staffed with either an undergraduate Teaching Assistant (TA) or a full-time lab manager. Equipment training occurs through the first and second year of the engineering curriculum.

Specific details on the spaces in the engineering program follow.

Machining Center



- 5 Sharp Manual Vertical Knee Mills
- 4 Sharp Manual Lathe
- 2 Vertical Band Saws (one for Aluminum and one for Steel)
- 1 Belt/Disc Sanders

Digital Manufacturing Studio



2 MakerBot Replicator 2
2 Up!+ Desktop Printers
1 Stratasys Dimension Elite
1 Stratasys Dimension sst1200
1 Objet 30 Pro
1 NextEngine 3D Scanner
1 HandyScan Handheld 3D Scanner
1 MakerBot Digitizer
5 Dell Precision Workstations
1 Universal 40W Laser Cutter

1 Rolland Vinyl Cutter
5 Collaborative Workstations
1 Formlabs 3D Printer
1 MarkForged 3D Printer
1 Coherent 1000W Laser Cutter
1 Angle Iron Bender
1 Slip Roller
1 Tormach Personal CNC 1100 Mill
1 Mitutoyo Optical Comparat

General Fabrication Studio



2 Clausing Drill Presses
2 Belt/Disc Sanders
1 Horizontal Double Mitre Band Saw
1 Panel saw
1 12" Single-bevel Compound Mitre Saw
5 3'X6' Metal top Workstations with Vise
1 Box and Pan Breaks
1 Shear
1 10" ShopFox Table Saw

1 Tube Bender
1 Router
1 ShopBot CNC Router
1 Downdraft welding station
1 MIG & 1 TIG welder
1 Plasma cutter
Assorted hand tools including JigSaws,
Grinders, Drill/Drivers, Wrenches, Files,
Hacksaws, Tap and Die Sets

In addition to the above described making spaces, the newly renovated engineering spaces include three design studios: a freshman design studio, a sophomore design studio, and a shared junior/senior capstone studio. These studio spaces include reconfigurable storage cabinets, whiteboards, large monitors with wireless connections, movable tables, and stackable chairs.

The use of makerspaces within the engineering program at James Madison University has a strong curricular connection. During students first semester, they learn to use the general fabrication studio through a hands-on tools training assignment, and students each leave the assignment with a wooden catapult. These trainings are scheduled by the students outside of class times, and once complete, students receive swipe access to the general fabrication studio during the hours in which the fabrication studio is staffed. Also, during students first year, students learn to use SolidWorks and MatLab, and they are introduced to using the digital fabrication studio through their second semester, Introduction to Engineering, course project: *MADE to Reach: Building an Environmental Sensor Package for a Tethered Weather Balloon*. Once students complete the online trainings for the Digital Fabrication Studio, swipe access during staffed hours is similarly granted. During students second year, students complete mill and lathe trainings during the sophomore design course sequence; completion of mill and lathe trainings allows students to opt into the advancing machining training and the apprentice program. All machine shop trainings are one-on-one with an engineering student that has completed at least 250 hours on the equipment OR a professional machinist. Students who enter the apprentice program work on paid engineering and university machining work under the direct supervision of the University machinist, and once students complete 250 hours on both the mill and lathe, they are granted swipe access to the machine shop. Sophomore design projects all require the use of the machine shop, fabrication studio, and digital manufacturing studio, and students can opt into additional trainings to use equipment such as for welding, pipe bending, laser cutting, etc. Junior/senior capstone project all have variable makerspace requirements, but as students have completed all trainings by their junior year, needs and makerspace use is left to each student team's discretion.

3. Overall Site Methodology

This project describes the first 18-months of a three-year longitudinal ethnographic study of learning across engineering makerspaces. The following section describes the researchers, the participants and field sites, the timeline and forms of data collected, and the iterative processes of data analysis at this stage in the research project.

3.1 Ethnographers. Guided by a faculty team with expertise in engineering education and communication studies and qualitative methodologies, four undergraduate junior engineering students and one graduate communication student are collecting autoethnographic, ethnographic, and interviewing data of design teams working in makerspaces over the course of two years.

The undergraduate engineering students joined the research team as sophomores and participated in year-long training in methods of autoethnographic writing and ethnographic methods of participant observation the year prior to the onset of data collection. As part of that methodological preparation, student researchers spent considerable time reflecting on their own identities as nascent engineers, critically interrogating what brought them to the engineering major and what aspects of engineering most interest them. This early reflective process prepares students to understand and situate their identities within the maker communities that they observe. Each of the students had quite different pathways into the study of engineering, ranging from early childhood experiences tinkering in their parent's workshop, outstanding skills in math and science, to idealizations of the field of engineering itself and what it offers students.

The graduate student ethnographer has an undergraduate degree in sociology and is currently in a graduate program in communication and advocacy. As part of her training she took an advanced coursework in qualitative research methods during the first semester of the project with one of the faculty researchers.

3.2 Courses and Field Sites. Two sets of field sites are studied as a part of this longitudinal ethnographic study. First are studios associated with the sophomore engineering design course sequence, and second are the studios associated with the junior/senior capstone teams. Descriptions of the courses, project, and design studios follow.

- ***Sophomore Design Teams.*** During students' sophomore year, students work to design, build, and deliver a human-powered vehicle for a client in the local community with some type of disability that makes riding a traditional bicycle or tricycle prohibitively challenging. This project spans two semesters with the first semester focusing on the first two phases of the engineering design process: planning and conceptualization and the second semesters focusing on later phases: preliminary design, detailed design, and design communication. During conceptualization, students construct mock-up prototypes to aid with communication of their ideas to the end user. During preliminary design, students construct proof-of-concept prototypes to aid with learning about feasibility, design interfaces, and design appropriateness for the end user. Finally, during detailed design, students construct alpha and beta prototypes; beta prototypes must pass a rigorous safety inspection and are trialed by the end user. Alpha and beta prototypes rely heavily on the digital fabrication studio, fabrication studio, and machine shop for construction as well as a custom sophomore design studio.

The sophomore design studio is an open space with assigned work stations, bike stands, lockers with team assigned hand-tools, bike mechanics tools, and general storage. Supplies are recycled from year-to-year and are stored in a closet off the sophomore design studio for student use. Students participate in an in-class workshop to learn how to use the bike mechanics tools during the Fall semester, and following the completion of an online quiz, receive access to a locker with tools and a workstation.

- ***Junior/Senior Capstone Teams.*** During students' junior year, students form two-year capstone projects. Many projects have external sponsors – some of which are identified by students, others faculty, and others yet friends or alumni of the University. During the first semester of this four-semester project, students focus on planning and understanding their project as well as formulating design requirements. During the second semester, students work through conceptual design and begin to work through preliminary design. Preliminary design and detailed design tend to continue through the Fall and early Spring of students' senior year, and students transition into design communication mid-way through their Spring senior year. These phases, though, are fluid and change team-to-team as student teams all start their projects at different locations with varying levels of pre-defined project clarity.

Course work during the junior and senior year focuses generally on the design phases in which students are expected to be working, and the material covered builds on the material learned during the sophomore year. For example, during students' sophomore year, students learn to generate functional models to represent a physical system, and during students' junior year, students learn to generate process models to represent the environment and processes in which they might be working. This flexibility is important as projects tend to come from a variety of disciplines: mechanical, electrical, environmental, chemical, etc.

3.3 Data Collection Timeline. The data collection timeline for the sophomore and junior/senior capstone projects begins during the second year of this NSF-sponsored project. Sophomore data collection progresses through the second year of this project, and junior/senior data collection will progress through the second and third year of this project.

- ***Sophomore Design Teams Semester One.*** In order to share the working vocabulary and experiences of the sophomore students enrolled in Sophomore Design I, the ethnographer rotated attendance among the four course sections throughout the semester. During that time period, the ethnographer also engaged in participant observation by participating in the same tool training experiences that are required of the sophomore students, such as the lathe training session. Further, she conducted field work, observing interactions and conducting ethnographic interviews, with the sophomore teams when those teams were in the engineering makerspaces for their class projects and activities. By participating in the same activities as the sophomore design students the researcher was importantly socialized into the curriculum, culture, and expectations, all of which provide necessary context for understanding the learning process in which the students are engaged. Further, she was able to establish the rapport and presence necessary for building the foundation for the second semester fieldwork.

Sophomore Design Teams Semester Two. Continuing in the capacity of participant observer, the researcher attends Sophomore Design II with the Sophomore students, engaging in field work when the student teams are meeting informally and using the makerspaces and learning with the students in the classroom itself. In addition to participant observation, the researcher will conduct both informal and semi-structured interviews with sophomore team members to gain insights regarding student interactions with and within makerspaces using maximum variation sampling to acquire experiences across a wide range of sophomore experiences.

- ***Junior/Senior Capstone Teams.*** Junior/senior capstone projects unfold over a two-year period. Four different capstone projects will be followed from their inception to completion over four semesters. Each of the undergraduate researchers is a member of one of these four projects. During the course of the study, the researchers will utilize autoethnographic methodologies to track their own experiences of learning, ethnographic methods of participant observation and informal interviews when participating in making and in makerspaces on campus, and semi-structured interviews with members of the four teams, as well as members of other teams who rely heavily on engagement with makerspaces for their projects. In doing so, we will capture links between both formal curricular structure (e.g., assignments related to the senior capstone and complementary coursework) and the informal choices of the students who are making decisions at each phase of their capstone project. As we cannot predict at the outset of the projects which will be heavily invested in engaging makerspaces and those which will only use them tangentially, we couple participant observation with semi-structured interviews to capture the full range of experiences, and thus choices, of the students completing the capstone projects.

3.4 Data Analysis. Data are analyzed in phases using iterative processes of grounded theory development [13]. Both field notes and autoethnographic journal entries are shared among all members of the research team on a secured file sharing platform approved by the university Institutional Review Board. Researchers post their field notes and journals to the shared site so that all team members can review data as it is collected; therefore, the data immersion phase [8] is ongoing, rather than a single point in time. Since data are collected from five researchers observing different student teams across a variety of makerspaces, analysis and interpretation of data in this first phase of the study cycle back and forth between individual researcher's initial analysis and team-based discussion of emerging themes and analytical categories. At the close of the first semester, researchers each constructed analytic memos that identified emerging themes related to learning in both their field notes and journals and those of at least one other researcher. Importantly, these analytic memos note *initial* interpretations of recurring dispositions, thoughts, and behaviors and what those might mean to the experience of learning. Those analytic memos were shared with the team to discuss their presence across the capstone teams and their connection to the observations of behaviors among the sophomore design teams. Discussions of these analytic memos led to the

identification of emergent questions that will guide the next iteration of observations across the sophomore and senior teams. Those initial observations are presented below.

4. Initial Interpretations: Scaffolding Mindsets to Learning

Initial observations point to the value of studying learning in situ over time across an engineering curriculum. Even early analysis of data point to the maturation of students over time between their sophomore and junior years in their ability to (1) identify what a student should have prioritized as important to learning as a sophomore, (2) what they failed to prioritize in learning, and (3) how that failure impacted their later ability to progress in team making environments. The learning that happens (and does not happen) in the sophomore design teams is referenced directly to the realizations of learning of students in the senior capstone teams. The initial data collected point to learning as a “mindset,” as student-centered, and developmental. Perhaps most importantly, students in both the sophomore design and senior capstone teams drew distinctions between valuable learning and “busy-work.” Valuable learning involved technical activities related to practicing and developing their skills in math and science, and “busy work” was those related tasks and activities that were related to communication, stakeholder research, and team dynamics. Yet, the failure to view communication and relationship-oriented activities with the same weight as technical skills in the sophomore design classes, were pointed to by the seniors as the primary sets of obstacles in the progression of the capstone projects. The following briefly describes initial themes related to learning across the sophomore and senior teams.

Learning to Learn. Researchers’ initial data collection point more to the processes of learning, than the contents of learning. Students reflections showcase how they are “learning to learn” through missteps and failures, cultural myths created by older students and faculty, and self-directed projects. Our study invites us to better understand the characteristics of the transition from being an uninformed decision maker to an informed decision making. In what ways, does making in the sophomore design teams prepare students to be informed decision makers in their senior capstone teams? What are the learning tasks that happen in the sophomore projects that prepare students to be informed decision makers in their capstone projects. In tracking future observations, the researchers will examine:

When and how do seniors reference earlier learning in the program in their decision making?

Tensions Between Structured and Unstructured Learning Activities. An important part of “learning to learn” for students is to understand and make connections between structured activities in the curriculum and unstructured activities that are necessary to the progress of their team projects. Classes such as Engineering Design and Engineering Project Management intentionally seek to tie capstone projects into the curriculum directly, and other core courses in the curriculum can indirectly accelerate or decelerate capstone progress as they may provide necessary technical knowledge.

In sophomore design, the researcher observed that students demonstrated an eagerness to come up with creative designs for their human powered vehicles. They were ready to “hit the ground running” and would discuss design ideas with one another in between other activities in class. However, they needed to do their work within the context of a design process that included team formation, discussions of ethical considerations, client persona creation, and stakeholder identification and communication. These sometimes-constraining parts of the process were emphasized by the professors. For example, the teams in one section of Sophomore Design I were instructed to completely redo their client persona’s because they had failed to grasp the importance of this step and had presented personas that failed to capture the client.

During junior and senior year, it is expected that these capstone classes will align with capstone projects and keep teams on track to meet reasonable deadlines for their project deliverables. However, the students in observed teams did not experience the classes in these ways. Instead, they often viewed course related

work as distracting them from the development of their capstone projects. As a result, only a select few on the teams were advancing an informed understanding of the project and the tasks necessary for its progression. For example, one student reflected, “[The] team seems to be in the mentality to just get everything done rather than really understand the weight this project can have....Every meeting the main objective is to just get the work that is due that week done....Instead I believe we should be trying to advance in the project.”

This frustration between advancing the project through self-directed learning and succeeding in the corresponding course through the completion of structured learning activities generated conflicts among teammates regarding prioritizing learning and completing requirements for classes and the projects. In tracking future observations, researchers will examine:

*How does conflict showcase the learning that is unfolding differently for team members?
How does self-directed learning develop differently among engineering students?*

Developing Trust and Learning. Trust was characterized by a variety of meanings for students across the capstone teams observed. Students referenced trust in team members completing tasks on time, completing them competently, and in contributing equitably to the project. The aspect of trust that took primacy was related to perceptions of team members’ competency in relationship of delegating tasks, as delegation of tasks was perceived as critical to meeting benchmarks. When delegation occurs, team members begin to assess each other’s degrees of competency to complete those tasks.

One student’s reflection points to trust as socially constructed through relationships with one another on the team, “Not only did I not trust the ability of my team, but I didn’t trust the ability of myself...Each individual timidly gave each other reassurance that this team had the ability to be great.” This student later reflected on how one’s own confidence in a task was connected to how others perceive them. Thus, we seek to examine how group expectations impact one’s learning over time. In tracking future observations, researchers will examine:

*How is a culture of trust/mistrust created through behaviors and relationships between teammates?
How does that culture of trust/mistrust impact references to learning?
What kinds of learning happen when tasks are delegated to team members?*

Leadership, Role Development, and Learning. The forming phase [14] of group development immediately begins once the capstone teams are assigned. These first few weeks of the capstone project is formative in setting the stage for the team dynamic and culture over the following two years. Assignments for the capstone class provide a structure through which students learn how to intentionally create a working group. These assignments include the creation of a team contract, stakeholder analysis, and weekly blog updates on team progress. Despite the learning objectives of these assignments, students often instead focused on “getting them done,” rather than understanding the long term influence they can have on the team and project should they be considered thoughtfully. This includes the implications for the role development of team members.

Across all of the capstone teams observed, student members grappled with the distinctions between perceptions of “ownership” of the project, official role designations and responsibilities, and leadership development processes. One student reflected, “From the early stages, this project was labeled as mine, something I never wanted. I spent the first few critical weeks of team formation trying to shy away from the possession of the project I was given and push that possession onto the entire team. My efforts seemed to fall short every time, which put a lot of the extra work load on my shoulders. For the success of the team, I internalized these feelings, hoping they would just go away.” In this student’s case, we begin to see the

impacts of perceptions, real or imagined, on a team members sense of empowerment and actuation of learning. Thus, in future observations, researchers will examine:

How does leadership development in teams contribute to learning?
How do different role designations in teams contribute to learning?

5. Discussion

This research relies on ethnographic research methods of participant observation, ethnographic interviews, and semi-structured interviews to understand the learning that happens in and around makerspaces. It is a necessarily student experience centered methodology that allows the researchers to operate *in situ* to understand learning processes and expertise development. Another benefit of these methods is that they reveal student perceptions of the learning processes in which they are engaged, offering insights into how students are acclimating to a program that is intentionally different from other, traditional engineering programs.

The existence of makerspaces in the engineering department is predicated on the understanding that usage of those spaces encourages the development of creativity and innovation in engineering students. The use of these spaces has been carefully integrated into the curriculum in order to achieve the stated goal of equipping students with skills needed to navigate an evolving world of engineering. The design-heavy curriculum extends far beyond technical skills to include a variety of skills that are necessary for design. These skills include stakeholder identification, communicating with clients, and team formation.

Early findings suggest a reluctance on the part of students to embrace non-technical skills needed for design. Students have regarded assignments that require them to develop these non-technical skills as busy work. There is a notion that non-technical skills aren't "real" engineering work. This suggests that while the program is designed to approach engineering in new ways, it must do so against the tide of cultural understandings of what it means to be an engineer. However, the necessity of these skills becomes increasingly apparent to students as they proceed through the program. Senior students have reflected how they viewed non-technical assignments negatively in their Sophomore year but that they now wish they had taken more time to develop those skills which they find to be crucial to the successful completion of their capstone projects.

This an example of a mindset shift that occurs in engineering students between the Freshman and Senior years. This shift in understanding is facilitated by the design projects that are a part of the curriculum and position students within makerspaces. As a community of practice and place of situated learning, culture plays an integral role in the learning that happens in makerspaces. Our early findings highlight issues of cultural significance among engineering students and demonstrate how they are navigated in the process of developing expertise. Senior observations regarding the effort required to operate as a functional design team reflect how developing expertise in makerspaces is a social process. As this research proceeds, we will continue to explore the interplay between design projects, development of expertise, and cultural contexts in engineering makerspaces. Additionally, questions arising from Senior experiences regarding leadership, teamwork, trust, and learning will be explored.

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References

- [1] K. Handley, A. Sturdy, R. Fincham, and T. Clark, "Within and Beyond Communities of Practice: Making Sense of Learning Through Participation, Identity and Practice," *Journal of Management Studies*, vol. 43, pp. 641-653, 2006.
- [2] J. Lave and E. Wenger, *Situated learning: Legitimate peripheral participation*, 1st ed. Cambridge: Cambridge University Press, 1991.
- [3] P. L. Berger and T. Luckmann, *The social construction of reality: A treatise in the sociology of knowledge*. New York: Doubleday, 1966.
- [4] F. Blackler, "Knowledge, knowledge work and organizations: An overview and interpretation," *Organization Studies*, vol. 16, pp. 1021-1046, November 1, 1995 1995.
- [5] B. A. Kriner, K. A. Coffman, A. C. Adkisson, P. G. Putman, and C. H. Monaghan, "From students to scholars: The transformative power of communities of practice," *Adult Learning*, vol. 26, pp. 73-80, 2015.
- [6] E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*, 1st ed.: Cambridge University Press, 1998.
- [7] V. Farnsworth, I. Kleanthous, and E. Wenger-Trayner, "Communities of practice as a social theory of learning: A conversation with Etienne Wenger," *British Journal of Educational Studies*, vol. 64, pp. 139-160, 2016/04/02 2016.
- [8] S. J. Tracy, *Qualitative research methods: Collecting evidence, crafting analysis, communicating impact*. Hoboken, NJ: Wiley-Blackwell, 2013.
- [9] L. A. Bricker and P. Bell, "'What comes to mind when you think of science? The perfumery!': Documenting science-related cultural learning pathways across contexts and timescales.," *Journal of Research in Science Teaching*, vol. 51, pp. 260-285, 2014.
- [10] I. Rodriguez, R. M. Goertzen, E. Brewster, and L. Kramer, "Communicating scientific ideas: One element of physics expertise," in *AIP Conference*, 2011, pp. 319-322.
- [11] V. Sawtelle and C. Turpen, "Leveraging a relationship with biology to expand a relationship with physics," *Physical Review Physics Education Research*, vol. 12, 2016.
- [12] A. Traianou, "Ethnography and the perils of the single case: an example from the sociocultural analysis of primary science expertise," *Ethnography and Education*, vol. 2, pp. 209-220, 2007/06/01 2007.
- [13] K. Charmez, *Constructing grounded theory*, 2nd ed. Thousand Oaks, CA: Sage, 2014.
- [14] B. W. Tuckman, "Developmental Sequence in Small Groups," *Psychological Bulletin*, vol. 63, pp. 384-399, 1965.