Student Autonomy: Implications of Design-Based Informal Learning Experiences in Engineering

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Abstract

As part of their college-based undergraduate degree experience, a large portion of engineering students are involved in different informal learning experiences, such as co-curricular design teams, student organizations, and undergraduate research. The purpose of this qualitative study was to better understand engineering students' learning experiences in informal learning sites, particularly their sense of autonomy, which emerged as a major theme in initial data analysis. Specifically, this study investigates a hands-on design and manufacturing laboratory for engineering students in a large research and state institution, which is home to student engineering design teams, such as a Formula design team. We found that these experiences enhanced students' self-directed autonomy and allowed them to take control of their learning trajectory. We discuss implications for future research and educational practices.

Introduction

It has been estimated that over a human lifespan about 90% of a person's learning occurs in non-formal environments, that is, people learn through informal experiences.[1] As part of their college-based undergraduate degree experience, a large portion of engineering students are involved in different informal learning experiences, such as co-curricular design teams, student organizations, undergraduate research, or studio-based environments. However, the learning outcomes of engineering students' are typically measured by assessing outcomes of formal instruction, and little research has been conducted to understand students' outcomes of informal learning experiences.[3]

The purpose of this study was to better understand engineering students' learning experiences in informal learning sites, particularly their sense of autonomy, which emerged as a major theme in our initial data analysis. Specifically, this study investigates a hands-on design and manufacturing laboratory for engineering students in a large research and state institution, which is home to student engineering design teams, such as a Formula design team. We present a qualitative study that investigated and compared engineering students' experiences in a non-curricular hands-on manufacturing laboratory focused on design. Research questions that guided our study were:

> **RQ1:** How do students describe their experiences with design in non-traditional engineering learning sites?
> **RQ2:** What are salient characteristics of these learning environments in terms of support for learning practices?

Our goal in exploring these particular research questions is to shed light on the salient influences that non-traditional engineering learning sites, such as Formula design experiences, have on engineering students educational and professional development. Specifically, we strive to understand the student perspective of such experiences, as well as to identify salient influential features and barriers of informal engineering learning sites.

Informal Engineering Design Experiences

Engineering programs in the U.S. have worked towards improving engineering education to better meet the demands of the modern engineering student and the future engineering professional.[3] A recent approach toward improving engineering education has been to move emphasis away from theory-driven standardized education, characterized by traditional lecture-based pedagogies, and toward more design experiences, characterized by collaborative, creative, active, and informal learning approaches.[4,5,6] Of the different non-obligatory learning experiences in which engineering students engage, design experiences are one of the most sought after.[7] This is not surprising given the centrality of 'design thinking' to engineering practice and because of the opportunity for hands-on learning experiences.[8]

Engineering design experiences, in comparison to more traditional classroom learning experiences, are not without their limitations. A distinguishing characteristic of less successful design experiences is that they often involve junior and senior-level students, implying that suddenly asking students to change their educational habits might be too much to ask of students.[9,10,11] This indicates that novel or unfamiliar pedagogies should be introduced early and consistently through engineering curricula.[4,9,12,13,14] In regards to informal learning environments, this implies that the students should have the opportunity, and be encouraged to participate in informal activities during the entirety of their engineering education, because despite the limitations, design experiences have unique and valuable benefits to engineering students. The most notable benefits that literature has illustrated include improved student retention, student engagement, multidisciplinary skills, communication skills, and student self-efficacy.[4,5,6,7,8,15,16,17] Although not necessary, this same literature implies that design experiences can be effective in informal learning environments. A common characteristic of successful design experiences described in the literature is that they are primarily nontraditional academic settings (i.e. studios, informal, service learning) and are offered to all undergraduate students, not just upperclassmen. Less successful examples described in the literature are typically set in traditional classroom settings, and are usually offered to only junior and senior level students who were more likely to have already established traditional learning habits.

The insight provided by design literature is that design experiences, including informal learning environments, should strive to enhance existing curricular opportunities, filling in academic gaps that traditional curricular activities do not have the time or resources to address. Additionally, it is already known that many students participate in out-of-classroom learning experiences, and that these experiences have a significantly positive influence on students' educational and professional development.[18,19] Closely investigating out-of-classroom experiences can help paint a more holistic picture of the student experience as a whole, providing a more situational understanding of engineering students' educational experiences.[20]

Research Study

To investigate informal engineering learning sites we observed students on a SAE Formula design team that works in a manufacturing facility offered by students' university. We chose the Formula design team because it is one of the more common and recognizable engineering design experiences that represent a more informal engineering learning environment that is offered by many different engineering programs in the United States. The following sections will describe the research study design in more detail

Research Site

The manufacturing laboratory is home to student engineering design teams, e.g. a Formula design team, from a large research and state institution. The study site and experience were non-mandatory for students to receive their degrees, and students self-selected to participate in these experiences. The Formula design team was chosen because it is representative of co-curricular activities that many engineering students join. Also, although considered as a non-traditional learning site, the Formula design team is bounded by an annual design competition. This limited, yet defined structure permitted reasonable investigation of learning outcomes and student experiences.

Methodology

Our research followed an open-ended grounded theory inspired methodology. However, during preliminary analysis, students' 'sense of autonomy' emerged as a major theme in the data; consequently we narrowed our focus to that framework, as we discuss later.

The Formula design team consists of over 100 engineering students from various engineering sub-disciplines (e.g. mechanical engineering, industrial and systems engineering, computer engineering, electrical engineering, etc.). Semi-structured interviews were conducted with participating students and administrative personnel. Eight Formula students were interviewed; six team members and two student leaders. Interviewed students were either third or fourth year students from a variety of engineering departments, including mechanical engineering, industrial and systems engineering, and electrical engineering. The interview protocol for the student interviews focused on the students' choice to join the Formula team, their experiences on the team, and their general experiences and perceptions of their education as engineering students. Sub-team leaders were asked a couple of questions regarding his/her experience as a student leader in addition to the general student interview protocol. Additionally, two non-student interviews were conducted; an administrative member of the student manufacturing lab, and the Formula faculty advisor. Interview protocols used to guide administrative interviews focused on asking participants about his/her experience with the student-manufacturing lab, his/her perceptions of what students do and learn in the lab, and about the future directions of the lab that he/she hopes to see.

In order to supplement the interview data, naturalistic observations were conducted, detailed field notes were documented for all observations, and archival data was collected. The observer attempted to remain as an external observer as much as possible, with minimal interactions with participants. To ensure trustworthiness of observations and analysis, triangulation, reflexivity external audits, and peer examination were used.[21] Observation protocol focused primarily on conversation topics, student behavior, student actions, student interactions, and student-faculty interactions. Also, observation data from the research site somewhat informed the student interview protocol. For example, if an interview participant discussed a particular event that the researchers had also observed, the interviewer would bring up that observed instance as a clarifying example. Formula team observations included observations of typical weekdays in the manufacturing lab. Additional observations were conducted during the Formula team's different student meetings: student leadership meetings, sub-team meetings, and the independent study meeting. In addition to the observations, some archival data from both research sites was collected to further supplement the interview data. Specifically, information packets, brochures, DVDs, and summary reports regarding the lab were collected. This information was used to better familiarize and contextualize the type of environment that the lab creates for students.

The learning site was investigated through two phases of analysis. The first phase of data analysis employed an open-coding procedure on interview transcriptions to allow emerging themes to take precedence. After discovering student autonomy (e.g. project ownership, intentional self-education, self-regulated goal-making) as a salient theme from both learning sites, a self-directed learner autonomy framework guided the second phase of data analysis. Since students self-selected to participate in these learning sites, some level of student autonomy was expected. However, it was surprising how little the students relied on or expected faculty guidance as well as the level of self-accountability demonstrated by the students.

It should be noted that this study is limited by its small sample size. However, the scope of this study is that of a pilot study, and the results will be informing a full-scale study with additional non-curricular engineering learning sites and additional interviews with students.

Guiding Theory for Secondary Data Analysis and Interpretation

As previously described, student autonomy emerged as a major emerging theme after the first phase of data analysis. A secondary data analysis was then performed guided by a self-directed learning framework informed by Candy and Littlewood.[22,23] Self-directed learning is a broad theory, with many domains relevant to adult education research.[22,24,25] Specifically for this study, self-directed learning from the autodidaxy domain, i.e. "intentional self-education", has implications towards students pursuing co-curricular activities that are worth exploring.[22] Littlewood's framework for learner autonomy also has implications towards students participating in non-traditional learning sites.[23] The primary components of the learner autonomy framework are a "willingness and ability" to learn, where willingness derives from a learner's "motivation and confidence", and ability derives from a learner's "knowledge and skills". [23] Merging these two theoretical frameworks, a self-directed learner autonomy framework, shown in Figure 1, guided the secondary data analysis for the study.

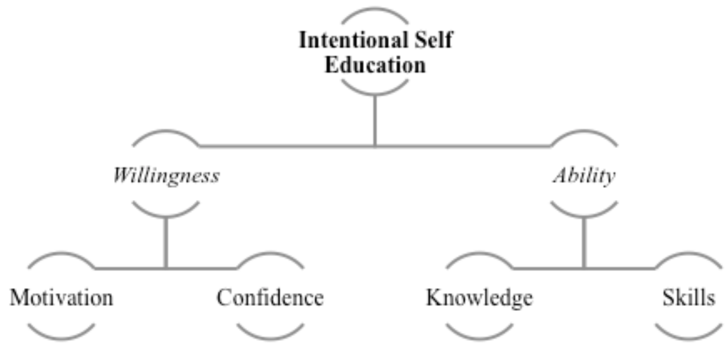

Figure 1. Self-Directed Learner Autonomy framework informed by Candy and Littlewood[22,23]

Research Findings

This section uses interview data to demonstrate the elements of self-directed learner autonomy exhibited by the interviewed and observed students. Please note that pseudonyms are used throughout to protect the identity of study participants.

Most of the interviewed participants indicated a disinterest in their formal coursework, but enthusiastically spoke of their Formula team experience. When asked about their reason for joining the Formula team students responded with:

> *[Angelina]: And at that point, I was kind of tired of engineering, so I was like, I need something else to keep me motivated to do this…I think everybody should do [a design competition team]. It just teaches you a lot. And it's a lot of fun. And even though I don't want to maybe do engineering in the future, but I think like it just motivates you so much to do what you're doing, keep doing it, and not just sit in classes and hate it. That's it. I just really like it. And I'm really passionate about it. I mean I get up every day for it.*

> *[Ernie]: It's fun. I like cars. I like that it's also, being able to put what I learn in classes to like an actual physical use.*

Responses such as those shown above, particularly Ernie's, are expected of students who are stereotypically labeled as "grease-monkeys" by their academically-inclined peers or instructors. Most students' responses when asked why they joined the Formula team were similar to Angelina's and Ernie's. However, this does not mean that all students are the stereotypical "grease monkey". For example, Angelina, who happened to be one of the sub-team leaders, never had experience, or a particular interest for working with cars. Another student, Michael, mentioned his preference for more conceptual work versus hands-on work.

> *[Michael]: I feel like there are areas to learn in research, pretty much, you would learn things about design like you would with manufacturing. But I like researching better, because I feel like conceptually it's more interesting to me. Manufacturing is kind of more hands-on, learn by doing. I like to learn that way sometimes, but most of the time I like to just sit and think.*

Although students like Michael pursue participation in hands-on design teams, it does not necessarily identify these students as less academically driven students. That said, even the seemingly academically disinterested students demonstrated an appreciation for the value of formal coursework, particularly for technical coursework (i.e. fluid dynamics, statics, thermodynamics, etc.). Along with an understanding of the value of formal coursework, students indicated that technical coursework informed their Formula design experience, and vice versa, in some form.

> *[Interviewer]: And what has helped you the most to learn the skills that you need for formula?*
> *[Angelina]: Well, classes. Once I joined formula, that's why I was so motivated to stay [in engineering], because I've been taking those classes, and I had no idea why I need to take those, why do I have to learn all this, and it just didn't make sense. And then it just like clicked that I need dynamics to do this and this, and then, I need fluids to do this and this, and then it just kind of combines… so I like that a lot about formula, that like, the way the classes, like come together, you're not just studying and doing problems. Um, so yeah, classes prepare you a lot.*

It was evident that the Formula design team experience provided a sense of *motivation* and *confidence* as engineers-in-training that was otherwise missing for students prior to joining the team. Although acquired through the Formula design experience, this sense of motivation and confidence extended beyond the out-of-curricular learning experience and into students' curricular learning experiences. This was also supported by observations of students often asking each other about formal coursework assignments and working together on course homework during Formula "down times".

One of the most striking themes that emerged from this study was the level of autonomy by the students on the Formula team. Frequently mentioned by the students as "ownership" over their design work and learning, this sense of autonomy is something that interviewed students do not recognize in formal courses. For example, one student described how he views his formal course work in comparison to his Formula design team experience:

> *[Ernie]: In formal classes, professors are] giving a problem where someone already knows the answer, or what they want you to get to, and how they want you to do. I like that [Formula faculty advisor] kind of like, he guides us and gives us plenty of great ideas, but it's very much, it's, it's our design.*

Although this sense of ownership seems to only be perceived in the Formula design team experience, interviewed students identified the "ownership" that the Formula design experience offers as a reason for their motivation to learn and succeed in both curricular and out-of-curricular learning experiences. It was evident that students' desire to succeed is primarily driven by the design competitions, however there is a very present sense of learner autonomy among the students when considering their *knowledge* and *skills*. For example, many students discussed their specifically assigned tasks as their "responsibility", and they acknowledged that the rest of the team depended on their ability to complete their tasks.

[Michael]: ...it's my job to make sure that the suspension moves in a predictable way, so that we can tune the suspension, so that when we go on the race track it's predictable.

When it comes to developing these knowledge and skills, students brought up a variety of resources including more experienced peers, past team reports and documentation, or specifically chosen formal courses. Learning from more experienced was the most cited resource used by the Formula students.

[Ernie]: Just being able to ask someone. Because if there's something I'm having a problem with, odds are one of the seniors on the team has had that problem somewhere down the road, or somewhere in the past, so it's likely I can just ask someone and they'll be able to point me in the direction towards someone who's you know been down the same path, so.

The key here is that, regardless of the resource, students would intentionally seek knowledge and skills in a self-directed manner.

[Angelina]: I just feel like I want to know it so that I can apply it, that I want to learn it more… you kind of have to kind of balance the point of research and then just doing it, even though you're never going to know exactly what you're doing, you're just kind of doing it. So, I guess you're just learning how to, not just theoretically learn it, but then actually do it. And then… just design it, and then hopefully you'll manufacture it and everything works out.

Along with the student interviews, observations also indicated that students often independently identify a knowledge or skill gap, and then they would seek any and all available resources to fill that gap. Most often older peers and student mentors were used as resources during observations, but there were also instances of students perusing the Formula team's archival server.

Discussion

As discussed in the previous section, aspects of self-directed learner autonomy were observed in the field study site. Table 1 presents a few sample observations from the study to help demonstrate aspects of self-direct learner autonomy that emerged from the researching findings. Motivation and confidence were key characteristics of students' behavior for the Formula design team. These characteristics demonstrate a *willingness* to learn, which is a component of self-directed learner autonomy.[22,23] Formula students very readily discussed their current work and on-going goals. There was little hesitance regarding what they were doing, and what they planned to do in terms of the Formula team. Because of this drive to succeed on the team, students appreciated the benefits of also succeeding in formal classes. This willingness to learn demonstrated by students indicates that non-traditional learning sites provide many opportunities for student autonomy that might not be present in traditional curricular learning sites.

Table 1. Sample observations from across sites that demonstrated self-direct learner autonomy.

Sample observations of non-traditional learning sites	***Demonstrated aspects of self-directed learner autonomy***	***Sample Quote***
Appreciation for the value of formal coursework	Motivation & knowledge	[Interviewer]: And what has helped you the most to learn the skills that you need for formula? [Angelina]: Well, classes. Once I joined formula, that's why I was so motivated to stay [in engineering], because I've been taking those classes, and I had no idea why I need to take those, why do I have to learn all this, and it just didn't make sense. *And then it just like clicked that I need dynamics to do this and this, and then, I need fluids to do this and this, and then it just kind of combines… so I like that a lot about formula, that like, the way the classes, like come together*, you're not just studying and doing problems. Um, so yeah, classes prepare you a lot.
"Ownership" of design work and learning	Motivation & confidence	[Ernie]: In formal classes, professors are] giving a problem where someone already knows the answer, or what they want you to get to, and how they want you to do. I like that [Formula faculty advisor] kind of like, he guides us and gives us plenty of great ideas, but *it's very much, it's, it's our design.*
Assigned tasks as their "responsibility"	Confidence & skills	[Michael]: *...it's my job* to make sure that the suspension moves in a predictable way, so that we can tune the suspension, so that when we go on the race track it's predictable.
Intentional development knowledge and skills	Knowledge & skills	[Angelina]: I just feel like *I want to know it so that I can apply it, that I want to learn it more… even though you're never going to know exactly what you're doing, you're just kind of doing it.* So, I guess you're just learning how to, not just theoretically learn it, but then actually do it. And then… just design it, and then hopefully you'll manufacture it and everything works out.

More than just a willingness to learn, self-directed learner autonomy should also include an *ability* to learn what one is willing to learn.[22,23] Formula students also demonstrated that they have this ability to learn what they are willing to learn. Students often cited numerous resources that they seek when they are unsure of a particular concept, skills, or tool. Formula students typically used their peers, more experienced team members, archived team documents, and even their formal engineering classes to some extent. The ability for students to readily list the variety of resources available indicates that students are not only able to identify when there is a gap in their knowledge or skills, but also to identify ways to fill that gap. This ability to learn what they are willing to learn demonstrates again that non-traditional learning sites can provide multiple opportunities for student autonomy.

Student autonomy was an expected theme, since students self-selected to participate in these learning sites. However, the observed students surpassed the expected levels of student autonomy. Students relied on or expected very little faculty guidance, demonstrating more of an employee-boss dynamic rather than a student-instructor dynamic. Since students had the space in these non-traditional learning sites to self-regulate their goals, they held themselves accountable for their achievements and learning as opposed to their faculty advisors. The loose structure and student-focused characteristics of these non-traditional learning sites fosters this student autonomy in a more viable way than traditional learning sites can offer.[26] Another explanation for the strength of observed student autonomy might be the authenticity of the engineering problems students work with, an authenticity that is typically missing in traditional learning sites.[1] These non-traditional learning experiences offers students "navigational flexibility" with an inflexible engineering curriculum, which in turn offers an opportunity for students to value the larger contributions and impact of their learning experiences beyond simply attaining a grade.[1]

Although it is evident that self-directed learner autonomy is a valuable feature of these non-traditional learning sites, often missing from formal learning sites, that does not necessarily demonstrate the actual value of self-directed learner autonomy to students' educational experiences.[27] Literature has indicated that student autonomy can be advantageous to students' experiences, under certain circumstances. In terms of effective learning practices, a dimension of learning is "using knowledge meaningfully", which requires students to have an opportunity to take ownership over an authentic and goal-focused problem.[28] Although student autonomy is not always advantageous, e.g. in formal well-structured coursework, it is valuable and influential on students' holistic educational experience.[29,30] More importantly, a key outcome desired of and by students is to be independent, confident, and critical thinkers, which we have shown can be attained via these non-traditional learning sites.[3,27,31,32]

Due to the "navigational flexibility" offered by co-curricular activities, and the role of non-traditional experiences in improving student persistence and retention in engineering, we see that experiences such as Formula played a very important role for individual students. They allow the students to take control of their learning trajectory and uncover personally meaningful activities that interest them and that can serve as a way for them to connect with disciplinary knowledge. Furthermore, non-traditional learning sites can facilitate students' maturation as independent critical thinkers, and can enhance the flexibility and ownership students have over their educational experiences in engineering curricula. In the same vein as Stevens' et al., rather than focusing on quantity measures about students' persistence, we have focused on "qualities of experiences that students have that stay, or leave, and the kinds of engineers they become (p. 365)," thus illustrating how design experiences outside of formal curriculum drive students' interest in engineering and allow students to discover a unique and personal trajectory to becoming an engineer.[1]

Conclusion

Informal learning environments, such as co-curricular design teams, are an understudied but important aspect of students' educational experiences. Student persistence with engineering can be facilitated by non-traditional learning experiences such as co-curricular design teams. We show how these experiences support persistence by providing support for disciplinary learning as well as student autonomy. Undergraduate engineering students from a Formula design team were observed and interviewed in order to gain a students' perspective of co-curricular engineering experiences. Self-directed learner autonomy was a salient feature in the non-traditional learning site, which students seldom identified in their formal course work. This study has implications for the design of non-traditional learning sites in engineering curricula, as well as the role of co-curricular activities and other non-traditional learning sites in engineering students' holistic educational experiences, specifically in enhancing students' sense of ownership and navigational flexibility over their educational experiences. Future work on this research should investigate other non-traditional engineering learning sites, as well as other unidentified influences of non-traditional learning environments.

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