The Engineering Learning Environment and its Role in the Attraction and Retention of Women in Engineering Programs

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Abstract – Previous engineering education studies have indicated that the engineering environment strongly influences attraction and retention within engineering programs. This research will aim to not only understand the learning environment, but also the connection between the learning environment and selection, attraction, and retention of women in engineering programs. A deeper understanding of this connection will lead to systemic ways to transform the engineering learning environment so that people from diverse backgrounds and interests will choose to study and practice engineering. A contextual model was developed to lead to a deeper understanding of the connection between the fit between the people and their environment and the relationship to the selection, attraction, and retention of women in engineering programs. An exploratory qualitative research study investigates the learning environment of engineering education through a set of interviews with undergraduate students and will be used to validate the contextual model.

Keywords: Learning environment, Attraction and retention, Competencies, Person-environment fit.

INTRODUCTION

Rather than focus on underrepresented minorities as the issue, this study is developing a deeper understanding of the engineering learning environment to gain insight as to why there is an underrepresentation of women and minorities within engineering. Previous engineering education studies have indicated that the culture or environment within engineering strongly influences attraction and retention within engineering programs [25][9][4][23][5]. Although some people learn in spite of the current learning environment, it cannot be assumed that the learning environment is acceptable [18]. "Male-normed classrooms, often dubbed 'chilly' climates for women, have generally been described in the literature as competitive, weed-out systems that are hierarchically structured with impersonal professors [25]." This description of the engineering classroom is representative of the engineering learning environment that many engineering students experience and that often lead to females having less self confidence or self-efficacy [28][3]. Additionally, within the learning environment research, the quality of the learning environment influences the learning that takes place in that environment [5]. The authors develop a preliminary understanding of the engineering learning environment through a systems perspective and propose a contextual model. This research will be the beginning of a series of studies that aim to not only understand the learning environment, but how to take a systemic approach to initiate change within the engineering education system.

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The relationship between the socio-cultural environment and student attraction and retention to engineering fields is a critical one that promises to lead to a better understanding of the engineering education system and ways to change that system so that its participants are more diverse in their outward appearance (more important initially, surface level diversity) and in their backgrounds and ways of thinking (more important over a longer time scale, deep level diversity) [17]. Currently, the type of student that graduates from engineering school has similar outward appearances in addition to similar ways of thinking and learning. Interventions to attract a more diverse set of students have been implemented with successes at a small, local scale, but little change to the larger, overall system (in 2002 21% of bachelor degrees were awarded to women in engineering [19]. Experts agree that the homogeneity of engineering graduates in the US is a major issue that will hinder the US from being an innovative leader of the coming years [27]. How can the system be changed so that a more diverse set of students will strive to be engineers? While 30% of all students entering college major in science and engineering, less than half graduate in these fields. The students that leave are typically the most qualified entrants into college and are disproportionately under-represented minorities. Some explain that the problem is not that the students are unable to handle the engineering school workload, but that it is not their choice to major in engineering [11]. How can the engineering education system be changed so that students choose to major in engineering? Jacobs et al. conducted a longitudinal study (children n=864, parents n=550, and teachers n=80) from 1987 to 2000 and found that the gendered home environment was to blame for the difference in interest in math-related endeavors. This paper attempts to develop an understanding of the larger engineering learning environment so that future studies can explore how a more complex learning environment will lead to a less gendered environment that empowers underrepresented minorities to pursue degrees in engineering.

LEARNING ENVIRONMENT

The meaning of learning environments varies across disciplines [12]. In this study, the learning environment is socio-ecological, including people and their multiple social fields. It is appropriately situated within a psychosocial context as student learning occurs within a person, not simply within the built environment.

In learning environment research the meaning of learning environment is based on Moo's three dimensions of human environments: Relationship, Personal Development, and System Maintenance and Change [18][5]. Learning environments include the "atmosphere, ambience, tone, or climate that pervades the particular setting [12]." The learning environment is the environment as perceived by the individual; therefore it is different for each person with their specific antecedents [22] or stream of life events [2]. Learning environments include the people and the relationships among the people, and they are dynamic and always changing. The people within a system have the ability to change the learning environment and the learning environment has the ability to change the relationships of the people. Different types of people thrive and deteriorate in different learning environments, and different people can tolerate certain learning environments [18]. If people can learn in spite of a learning environment that does not mean that the learning environment is acceptable [18]. Decision making skills and learning outcomes are different for different learning environments [5][1]. Research conducted in School Psychology indicates that students with positive emotion have better coping styles than those with negative emotion. Emotion is a product of the learning environment, which suggests that the learning environment can affect a student's coping or decision making skills, which is critical for engineering students [7].

This study attempts to address this gap in the diversity in engineering education literature in regards to the relationship between students and their learning environment. A systems approach to understanding this issue is needed, and the proposed conceptual model takes a systems approach to focus not on the learning environment alone, but the relationships between the learning environment and students and how students can be empowered to change their learning environment [8][13][14]. An ecological, systems approach has been taken in organizational research with the development of a demography, fit, and outcomes model to attempt to further understand diversity within organizations **Error! Reference source not found.**.

THEORETICAL BACKGROUND

This research is focused on the socio-cultural engineering learning environment and its effect on attraction and retention of women in engineering programs. This work is framed within the person environment (P-E) fit theory

[22] and Attraction Selection Attrition (ASA) theory [20][21] that have emerged from work in Psychology and Business. The person environment fit theory extends Lewin's field theory [15] in that it considers not only that the person and environment influences an individual's behavior, but that the fit between the person and the environment influences behavior. P-E fit theory focuses on the positive outcomes of having a close fit between a person and the environment. ASA theory differs in that it stresses the negative outcomes of having a close fit between a person and their environment. The resulting organization is homogeneous, rigid, and not innovative or creative. A lesser fit between a person and their environment results in a more diverse set of people within that organization.

CONTEXTUAL MODEL

The following contextual model emerged as a larger system perspective of the relationship between people within engineering education and their fit with the environment (see figure 1). This perspective demonstrates how the perceived fit of an individual person to their environment can have lasting effects on the attributes of the larger engineering education system. Students enter engineering with a unique set of motivations, self concepts, and traits. These students then assess their level of fit with the surrounding socio-cultural learning environment. If the students fit, they reinforce the system attributes and the engineering learning environment. This conceptual model closely mimics the ASA theory in which students are initially attracted to an organization (with their individual motivations, self concepts, and traits), are selected into that environment based on a level of fit between themselves and the environment, and leave the organization if there is not a good fit.

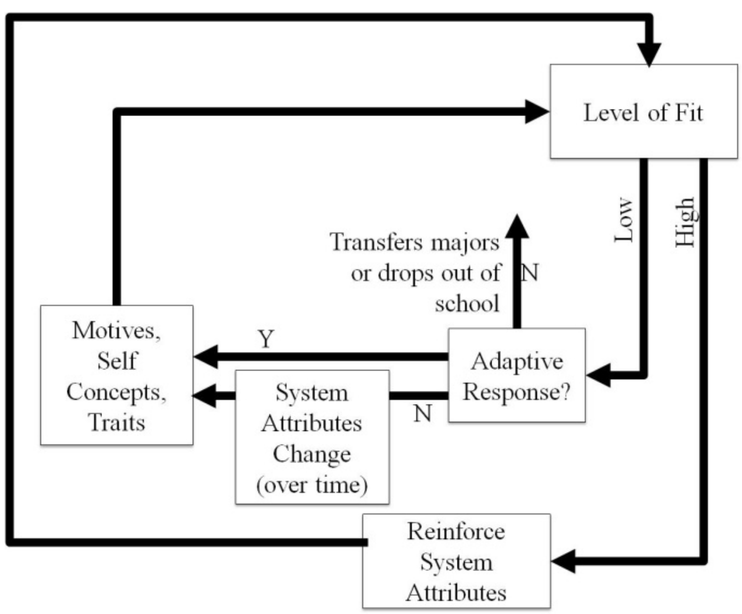

Figure 1-Contextual Model.

This model extends the ASA theory in the possibility of having an adaptive response and possibly continuing in the organization without adapting to better fit the environment. The outer loop of this contextual model corresponds with the negative outcomes that result from a high level of fit between people and their environment. A low level of fit and no adaptive response can become a positive outcome as the environment will change over time as people that do not fit the environment join the organization. The shaded areas of the contextual model in figure 2 correspond with negative outcomes that can result from a high or low level of fit between a person and their environment.

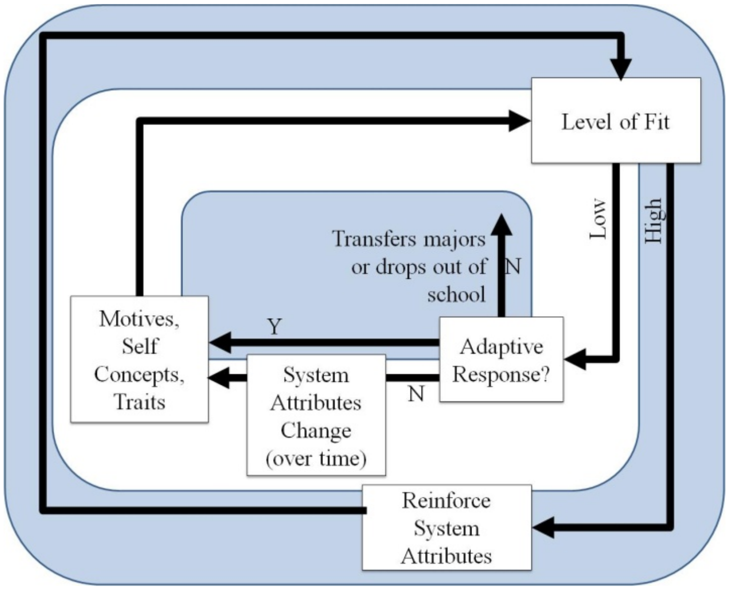

Figure 2-Contextual Model with Areas Shaded that Correspond with Negative Outcomes.

I. Motives, Self Concepts, Traits

Students enter engineering school with a set of hidden competencies that include motives, self concepts, and traits [24][26]. The motives, self concepts, and traits of the students may be influential in the decision to major in engineering, i.e. the attraction to engineering. Motives can range from getting a job upon graduation, making money, helping people, or even proving someone (or yourself) that you can be successful in engineering. Self concepts are the way that an individual views themselves. Traits are the characteristics or attributes of an individual. These hidden competencies typically go unnoticed as they are not as apparent as visible competencies of knowledge and skills. Additionally, these hidden competencies are difficult to empirically evaluate [26]. Motives, self concepts, and traits change in an individual at a longer time scale than competencies of knowledge and skills. In this model, these hidden competencies are what an individual benchmarks to their socio-cultural environment to determine whether or not a fit exists. In an attempt to fit better with the environment, a student may attempt to adapt to the environment by changing their motives, self concepts, or traits. As these competencies do not change quickly, it may be a slow process before the student actually changes enough to better fit their perceived environment. Some students do not attempt to change to ensure a better fit with the environment, but they choose to remain in the environment in spite of the bad fit. These students may graduate in spite of the learning environment, although it would not be appropriate to say that this environment is acceptable [18]. This can lead to a more heterogeneous environment, which eventually can lead to a more diverse set of people within engineering education, resulting in a better fit for a larger population of subsequent entering students.

II. Level of Fit

The level of fit of the person and the socio-cultural learning environment will determine whether the person needs to adapt, relocate, or be nonresponsive. In adapting, relocating (e.g. transferring majors), or being nonresponsive, the students are affecting the homogeneity of the engineering learning environment and are in turn affecting the surface or deep level diversity of the system [17]. Surface level diversity is diversity of people according to their outward appearances. Deep level diversity is diversity of backgrounds and/ or thoughts. Historically, many engineering educators have been supportive of 'weed-out classes' that determine whether a student's knowledge and skills fit within the rigor of the major. These 'chilly' climates have encouraged those with a low level of fit to relocate from engineering [25]. Systemically, this has resulted in a homogeneous, rigid, and nonresponsive educational system.

III. Adaptive Response

An individual that adapts to better fit the environment are perpetuating the motives, self concepts, and traits that are already present in the engineering educational system. However, in changing themselves they are allowing a more seamless transition into the engineering learning environment. An indirect effect of this adaptation is that a person that is diverse on a surface level (in appearance or background) may not actually contribute to a deeper level of diversity. In conforming to the current learning environment, they are actually helping keep the environment homogeneous.

A student that does not adapt to better fit the environment has a few options including transferring out of the engineering program, dropping out of school, or continuing in engineering education in spite of the bad fit. The students that choose to leave engineering because of the bad fit and because they understandably do not want to change themselves to better fit the environment are inadvertently encouraging a more homogeneous environment with little surface or deep diversity.

A student that chooses to 'tough it out' in engineering in spite of a bad fit between themselves and their environment is harboring a more heterogeneous, responsive, and flexible engineering educational system. These students may have different motivations than the ones that move easily to another major. For example they may be the daughter of an engineer, or they may want to have job security when they graduate. Over time this choice to stay in engineering in spite of the bad fit with the environment will result in a more heterogeneous environment with surface and deep level diversity. Students in this program will be more innovative and creative and over time students that previously did not fit with the engineering learning environment will. This is due to the change in the makeup of the engineering learning environment because of the 'pioneers' that did not let a bad fit cause them to move out of engineering education. This goes against the common belief among engineering faculty that it is necessary to 'weed out' students that do not have the knowledge and skills that it takes to become an engineer [25]. Should students that do not fit the environment be encouraged to stay within engineering? Will this eventually lead to a more heterogeneous environment with deep diversity and innovative, creative thinking?

IV. System Attributes

An adaptive response can also be found at a larger-scale, systems level. If the people that make up the engineering learning environment continue to attract similar people, the engineering education system will also become rigid and inflexible. This rigid and inflexible system will not be responsive to changes within the social, global, and environmental scale. However, if the individuals that make up the engineering education learning environment begin to change, there will be a larger scale, systems change to the engineering education system within the department, the college, and eventually across universities. This is critical in a time when engineers are increasingly needed to solve the complex issues that are currently facing people throughout the world today.

The attributes of the engineering education system are potentially dynamic. However, if the system remains homogeneous and nonresponsive, there will be little opportunity for the system attributes to change and it will become or already is stagnant and rigid.

EXPLORATORY STUDY

This research consisted of interviews with seven female undergraduate students. The transcribed interviews were coded according to scales that were common in literature reviews of diversity in engineering education research and learning environment research. The original codes included the following: competition/ cooperation, cohesiveness, involvement, relevance, critical voice, physical space, uncertainty, confidence, and support. While coding the transcripts an additional theme of work-focused emerged and a category was added to accommodate this theme. The following examples from the interviews illustrate the learning environment from the student's perspective.

I. Work-Focused

"I think that it just makes you appear as it is all business... It's just all work and it seems like it is very focused, like this is why we are in this building, to do work, and that's it."

"I guess geared toward school would be the best way to put it [relationship with other engineering students]; we have the same things to work on."

In these observations, a junior, female, engineering student explains the motivation within the engineering learning environment. It is a very limited, linear description of the interrelationships between people and their surroundings with a single goal of work. This keeps the social fields of an individual student severed from one another, i.e. social fields of friends, family, and engineering colleagues do not overlap. An overlap of these social fields would provide a more connected learning environment in which antecedents and stream of life events would be valuable and a constructivist approach to learning would be more suitable.

"I do [spend time in the engineering building] because I have gaps in between, so I spend it usually doing homework, but there's a little courtyard, but no one really goes out there, and there's not much of. Like on North Campus, you can lie out on the grass, and just kind of relax and do that. We don't really have as much of that."

In this observation, the junior, female, engineering student is further explaining the physical environment and how the physical environment supports the working culture. The physical environment on North Campus where the liberal arts buildings are located is different according to this student because there are spaces for the students to relax and decompress while reflecting on classes and schoolwork. The contrast that she notices is that although there are courtyards in the engineering building, students are constantly work focused with no time left for reflection and decompression. It is during these times that the students would begin to overlap their social fields and build a more robust, flexible, dynamic learning environment. The engineering learning environment according to this student is very ends-oriented with the goal being working hard so that each student can earn an engineering degree and get a job.

II. Cohesiveness

"No, at that point I was just going to class and sitting through the lectures and going home and working on it. …I wasn't taking advantage of the fact that there are other people in the study lounge that had the same problems. And I think if it had it would have been a lot smoother of a transition."

In this recollection of her first semester as an engineering major, a junior student explains that she was not interacting with other students in her classes or in the department. She approached these classes as she approached other classes with minimal interaction and later discovered that there was a support group of other students working through similar issues. This realization of the importance of working with other students is an important one, although she later explains that it is a working relationship with a goal of graduation in minimal time.

"I think engineering students are pretty social around each other. At least when we're in classes, everybody that's in the same class works on a lot of stuff together, helps each other out if that's possible, or they, when everyone's struggling, everybody talks about it and is in it together.

In this observation, a senior, female explains that engineering students do interact with each other, especially when they are in classes together and they need to overcome a specific obstacle. This still has the underlying theme of being work oriented.

III. Relevance

Half of the students interviewed either had a minor or seriously considered a second major. This may be an indicator that these students would like more meaning from their classes. This may be a coping mechanism for being in an environment with a poor fit. A double major or minor in humanities or social sciences would help the students get through their engineering degree in spite of a bad fit, because they would have a better fit elsewhere in another social field.

"And, a lot of times, if we're talking about building something and I don't really care about, you know, making structures and architectural things. But I see how learning that will help me learn something else. I kind of understand how learning problem solving skills is pretty universal and that's what you do in every single engineering class. So maybe some people don't, can't make that connection and that disengages them."

This observation illustrates how this student copes with working on assignments and in classes that are not explicitly relevant to her professional goals. She speculates that some students do not see how all of the engineering classes have a common theme of problem solving and that these skills will be transferable to other contexts in work and in life. Although she admits to not enjoying tinkering and building, she copes with this by seeing the relevance of the work.

CONCLUSION

Previous diversity in engineering education research has empirically determined that the learning environment and culture has influenced retention and attrition in engineering educational programs [25][9][4][23][16]. This research extends this research to take a systems approach to understanding the underrepresentation of women and minorities in engineering education by extending the P-E fit theory and the ASA theory. In particular this research involved an exploratory set of interviews with female undergraduate engineering students and the development of a contextual model to further understand the system drivers and impediments to increasing the surface and deep level diversity of engineering students.

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