AC 2007-148: IN HER SHOES: HOW TEAM INTERACTIONS AFFECT ENGINEERING SELF-EFFICACY

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In Her Shoes: How Team Interactions Affect Engineering Self-Efficacy

Abstract

Engineering is one of the few professional fields that has a disproportionately small fraction of female practitioners. One major reason for low female interest and retention in engineering is low engineering self-efficacy. In this study, learning within the freshman engineering culture was explored through a case study. One researcher, Sherry (a pseudonym), took part in this study as a full participant-observer by joining the freshman engineering culture as a student. The researcher was embedded in the freshman engineering classroom for one year. Class activities involved two team-based design projects. With the goal of investigating the context and process of learning engineering, Sherry recorded her learning progress, self-efficacy, and observations in a journal and discussed her experiences with other researchers involved in this project. Data were examined through the lens of Bandura's self-efficacy model. At the beginning of the class, Sherry started with moderately high self-efficacy; however, poor team communication and failure in her first design project significantly decreased her perceived self-efficacy. She also had tool phobia due to unfamiliarity with using power tools, which created an additional barrier to her making contributions to the project. In this study, Sherry's self-efficacy was improved as well as hindered by the mastery experiences relating to engineering skills and project success, by social persuasion from her team members, by the vicarious experiences she gained by observing students similar to herself, and by her physiological reactions. This study provides insights into how self-efficacy, perhaps more than ability, can be an important factor and a powerful motivator influencing the learning of engineering concepts and skills as well as retention in engineering. It also highlights the need to create a community of engineering learners that values professionalism in the transfer of knowledge and skills from one to another. Recommendations are made for team-based classroom activities that would promote positive engineering self-efficacy.

Introduction

The disproportionately low representation of female practitioners in the field of engineering is still an issue[1]. Engineering is one of the few fields where women representation is as low as eleven percent[2]. Recent studies show that women are more likely to drop out of engineering because of the social and affective factors and the environment that they perceive as unwelcoming[3,4]. In addition, female students have lower confidence in their engineering skills compared to their male peers, causing women to believe that they cannot do engineering[5, 6].

There is some evidence that self-efficacy has a significant effect on engineering students' continuation in the field of engineering. In 1997, Besterfield-Sacre, Atman, and Shuman found that persistence in engineering was related to social and affective factors[7]. They stated that cognitive factors such as students' academic preparation were less influential in engineering self-efficacy. In another study, Hutchison, Follman, Sumpter, and Bodner asked first-year engineering students to list factors affecting their self-confidence in their ability to succeed in their engineering class[8]. Understanding of the course material, team interactions, computing skills, and problem solving abilities were significant factors that were related to students' self-efficacy. In our study, we investigated the factors that support or hinder female students' persistence in engineering and their confidence in becoming an engineer during the initial stages of their education. The conceptual framework for this research was Bandura's self-efficacy theory[9].

Bandura's Self-Efficacy Theory

According to Bandura, one's behavior in showing effort and persisting in the face of obstacles is dependent on one's belief about his or her own ability to perform a given task successfully. Bandura labeled this construct self-efficacy[9]. Self-efficacy is not a broad construct like self-esteem; rather, it is content and context specific and should be investigated in the context of the task concerned. Consequently, when defining engineering self-efficacy, it is important to identify the specific skills that are of interest. One might have low self-efficacy in one area of engineering, such as applying physics principles to design a mechanical system, but have high self-efficacy in another area such as using the engineering design process to design the same system. Studying self-efficacy is important because a student with high engineering self-efficacy will persist when faced with challenging problems and is more likely to be successful. There are four types of experiences that affect self-efficacy: enactive mastery experience, vicarious experience, verbal or social persuasion, and physiological and affective reaction. These factors are described in detail below based on two references[9, 10].

Enactive mastery experience refers to one's prior experience in mastering a task. Such experiences are the most critical factors impacting self-efficacy. Successful experiences strengthen self-efficacy while failures weaken it. Performance failures can be most influential when they happen before the establishment of a firm sense of self-efficacy. Perceived self-efficacy can also be affected by the biases in self-judgment about the quality of one's performances.

Vicarious experiences also influence self-efficacy. Such experiences are mediated through modeling activities such as observing someone perform a task. Performance judgments based on vicarious experiences can be derived from objective and clear criteria or subjective indicators and social comparisons. Modeling that conveys effective coping strategies can support self-efficacy. Vicarious experiences can be helpful when students observe other students who are similar to themselves persisting and succeeding in a task. Such experiences would provide the efficacy that "if they can do it, then I can do it as well". Self-efficacy appraisals are especially sensitive to vicarious information when the students are uncertain about their capabilities related to a task and have little prior knowledge to make accurate evaluations of their own capabilities.

Verbal or social persuasion is third source of self-efficacy information. Social persuasion can come from instructors, peers, or family through acknowledgment of successes and encouragement of persistence. Social persuasions would have the greatest impact on people who believe they can produce the intended results by their actions; however, unrealistic persuasions would not be helpful. Persuasory efficacy can be conveyed through verbal evaluative feedback or non-verbal behavior. Negative social persuasion can be subtle and hidden in social practices such as professors assigning unchallenging tasks, repeatedly offering unsolicited help, or giving less recognition.

Finally, physiological and affective reactions also impact self-efficacy. Such reactions appear during activities involving physical accomplishments. Physiological states positively impact students' persistence when the student is not nervous or scared of the task but actually enjoys the activity. Negative emotional reactions to subjective threats can be reduced by increased mastery experiences. Learning and using coping strategies also improves the emotional position of the performer.

Current studies on engineering self-efficacy employing quantitative survey methods and qualitative interview studies have established that self-efficacy theory provides a sound foundation to explain students' experiences when learning engineering concepts and skills[3, 8, 11]. However, we currently have limited information on how the four mediators of self-efficacy, as described above, occur in the context of engineering. In this study, we have used a case study method to gain a deeper understanding of a freshman engineering student's learning and experiences. The goal of this research was to understand the freshman engineering culture from the perspective of a female student and to identify the mastery experiences, social persuasion, vicarious experiences, and physiological states that influenced her engineering self-efficacy.

Research Question

This research started as an anthropological study using grounded theory as a basis to understand learning within the freshman engineering culture[12]. The initial goal of the study was to understand what the engineering culture and the learning process look like and feel like from the perspective of a female student. During the initial stages of this study, self-efficacy and peer interactions became a prevalent factor in the learning process. Therefore, data were examined through the lens of Bandura's self-efficacy theory to answer the following research question: *How do freshman engineering team interactions affect the learning and persistence of a female student?*

Methods

In this study, a case study methodology was used to gain a deeper understanding of engineering learning. The subject had dual roles in this study, as she was both the researcher and the research participant. The case, Sherry (a pseudonym), was fully immersed in the engineering culture to gain an insider's view of freshman engineering. The data were based on the researcher's experiences as a freshman engineering student. The researcher was embedded in a freshman engineering classroom for one year; however, this paper is based on her experiences during the first semester.

Sherry is a doctoral student in science education who had three years of experience working on research projects in engineering education. She was interested in understanding how students learn engineering. She was also familiar with research on diversity and retention issues in engineering. She was interested in a dissertation research on engineering learning and was planning to conduct a pilot study. One alternative was to study engineering learning by observing freshman classes. However, she believed that a deeper understanding would be achieved by full immersion into the culture.

In order to establish the validity of the research it is important to describe how Sherry was similar to, or different from, a “typical” female freshman engineering student. One difference was her age. While there were a couple of male students older than 24 years old, Sherry was the oldest female student in her class. Additionally, being an international student, she was culturally different than the other students. Of the two other female students in the class, one was Hispanic and the other was Caucasian.

Sherry was similar to the other students in terms of her content knowledge. The studio course in which she was enrolled required introductory physics and calculus skills. Her physics and math background was adequate to perform well with this type of content. She was interested in learning engineering skills and concepts. On the other hand, her goal in taking the course was to explore and learn more about the engineering learning environment without strong intentions to pursue an engineering degree. This reflected a “typical” freshman student’s uncertainty in choosing engineering as a career.

There were three sources of data for this study: 1) the researcher’s observations and journal entries, 2) the researcher’s assessment of her self-efficacy, and 3) the self-assessment papers she wrote as assignments for the class. Sherry recorded 23 journal entries during the fall semester. In these entries she described and reflected on her classroom experiences. She also discussed her findings and experiences several times with two other researchers. Sherry kept her role as a student and researcher separate. All of the instructors knew of her dual role. When in the class, she was a student and fully engaged in the class activities. She recorded her observations and reflections after the class meetings.

The journal entries were analyzed to retrieve patterns. Another data source was recordings of her self-efficacy. She used a scale of 0-5 (five was a high level of self-efficacy) to assess her self-efficacy. She defined her level of self-efficacy by rating the statement: “*I am confident that I can design and construct an artifact, pass the class successfully, and become a successful engineer.*” The final data source was the set of self-assessment papers she wrote for the class. All students in the course were required to write self-assessments of their learning after each design activity.

Classroom Context

The curriculum in the department where she took courses included project-based design activities that focused on learning through hands-on design activities. The department was small and the engineering faculty was responsive to students’ questions and needs.

The class activities included two team design projects: a bridge project and a robot project. Each design project was completed in different teams. The course content covered the engineering design process, the subject of statics during the bridge project, and basic programming during the robot project.

First Design Project: Bridge - The goal of this project was to build a prototype bridge that would hold a minimum 14 lb weight. Sherry's team included four members, three male students and Sherry. This project lasted two months.

Second Design Project: Robot - The goal of this project was to design and construct a robot that would follow another robot. Sherry's robot team included two male and two female members. The duration of the robot project was one month.

Results and Discussion

Sherry started the semester with a moderately high level of self-efficacy. Her self-efficacy started to drop during the first design project and then reached its lowest point during the initial stages of her second project. It was at this point that she started to use strategies to improve her self-efficacy. These strategies were helpful and her self-efficacy increased significantly by the end of her second design project. Figure 1 shows the changes in her self-efficacy over time.

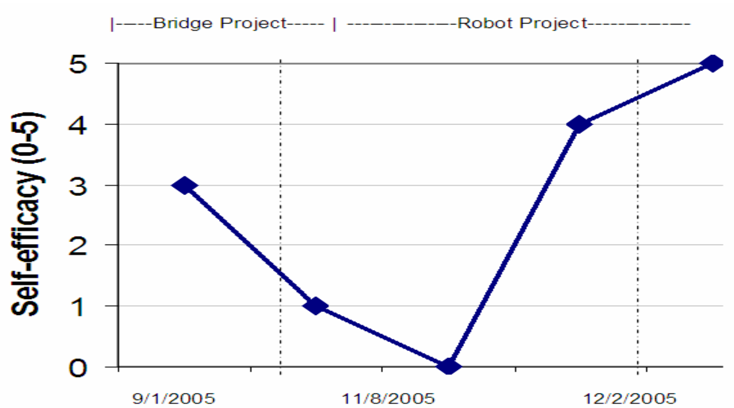

Figure 1. Changes in Sherry's self-efficacy during a semester

Sherry's experiences are examined using Bandura's self-efficacy theory to identify team-based engineering design activities that support or hinder self-efficacy. According to Bandura, there are four sources of self-efficacy: mastery experiences, vicarious experiences, social persuasions, and emotional states. Sherry's experiences are classified based on these factors.

Factors that Decreased Sherry's Self-Efficacy

A) Negative Emotional States

One factor that affects self-efficacy is the emotional and physiological states of the student when completing a task. While the engineering curriculum was not designed to be competitive, most of the students perceived the project to be competitive.

Sherry's initial reflections on the bridge project were: "The first week of September, we were assigned to our project teams and our goal was to design and build a prototype bridge. For this project, we were asked to define our own constraints and criteria for our design. Our bridge would be graded based on the criteria we determined (9/6/2005)."

In Sherry's team two team members wanted the bridge to hold the maximum weight and two wanted the bridge to be designed to be aesthetically pleasing. In order to reach a consensus, her team chose maximum weight as the main criterion and aesthetics as the secondary one.

"I was concerned about the selection of maximum weight as the main criterion but I was also glad that my team came to an agreement on the design criteria. Unfortunately this criterion required our bridge to be competitive. Men liked and wanted the competitive edge so that 'we can blow away the competition'. (9/6/2005)"

Sherry became worried during this project because communication in her team was poor and nobody assumed the team management role. She believed that the criterion they had chosen was a challenging one for their design that required effective team collaboration and planning.

Sherry also describes the bridge project testing day as an embarrassing experience because she says "we built a bridge that could hardly hold itself and was not at all aesthetically pleasing."

B) Lack of Social Persuasions

During the bridge project, Sherry experienced participation in a team that was unsuccessful. The team communication continued to be poor throughout the design project. Nobody in her team took the leadership and management role. She did not want to take the team leadership role herself because, being the researcher, she wanted to take a participant role in her team rather than managing and influencing the team.

The lack of team communication prevented possible positive social persuasions they could have exchanged during this project. Her team received some verbal persuasion from the instructors stating that failure was a critical aspect of learning. However, these experiences were not as powerful as the negative mastery experience related to the success of the design project. This design project was a powerful learning experience on the importance of team communication and team management; however, a positive team environment that allows the exchange of social persuasions did not exist to support her self-efficacy.

The second design project involved the design and construction of a robot and was completed with a new group of team members. During the robot project Sherry received negative verbal persuasion when her team members rejected her ideas without much discussion.

"Before we started the construction of our robot, I suggested that we build a physical model. Mark (pseudonym) rejected this idea immediately saying that we had the CAD model and did not need a second one. Ben (pseudonym) on the other hand was worried about time. Later on Mark made a calculation error in his CAD design of the robot. When we put it together, it was much bigger than planned. A physical model could have prevented this problem and saved us time in the long run."

C) Negative Mastery Experiences

Sherry perceived her bridge project as a failure. There were a total of seven other project teams in the class. Five of these teams built bridges that met all of their constraints. Several of them exceeded their constraints. One team could not complete their bridge on time. Sherry's design project was completed barely on time and was able to pass the competency criterion that required the bridge to carry 14 pounds. However, it did not meet either the maximum weight or the aesthetics criteria.

Although the class instructors stated that their project was successful because it was completed on time and passed the competency criterion, Sherry perceived this project as a failure because it did not meet the criteria her team had established. After this experience Sherry's self-efficacy dropped from 3 to 1. This was her first mastery experience in engineering design, and it was not successful.

D) Lack of Vicarious Experiences
After the bridge project, new teams were formed for the robot project. Sherry started the second project with low self-efficacy. The bridge project experience taught her how important team communication and management were for the success of a team. Consequently, she was very sensitive to this issue and did not want to have another poor team experience that would lead to another failure.

"When I arrived to class on Thursday October 27th, Mark was there. He didn't say anything to me at that time but then I learned that he put together the circuit by himself. I was angry that we didn't do it as a team. But I also knew this would save us time in the process. I don't want this project to fail like the bridge project but I want to learn as well."

Sherry was frustrated at this time, following an unsuccessful teaming experience where no individuals contributed to the team as a whole. From this, she went to another form of negative team experience where she felt she was not given the opportunity to participate. Her self-efficacy was at its lowest point at this stage. And it was also about this time, she noticed Mary (pseudonym), the other female member in her team, was not responding to the emails and not coming to the class anymore.

"When I learned Mary dropped out, I realized how similar we were. She also had a negative mastery experience during the bridge project. She was in the bridge project team that could not finish their design on time. She also did not know much about robots. She was also sitting next to me watching the other two team members when they were programming the robot (11/20/2005)."

Factors that Increased Sherry's Self-Efficacy

A) Positive Social Persuasions
Mary left engineering in the middle of the semester. At this time Sherry recognized that her self-efficacy had also significantly dropped, and she started to identify and implement strategies to support her self-efficacy. Her first strategy was to get social persuasion from an instructor. She approached an instructor to ask what was expected from an effective team and discussed ways to improve the communication in her team.

The team communication in her robot team increased during the final stages of the robot project. She contributed to the robot project and received acknowledgment from her team members. The exchange of positive reinforcement and recognition supported her self-efficacy.

"We had a team meeting on a Saturday. The goal of the meeting was to make physical modifications on the robot because it did not meet the size constraint given by the instructors. In my opinion the robot also needed some aesthetic improvements. I bought materials from a crafts store and brought them to that meeting. We adjusted the size of the robot and decorated the robot like a puppy. My team member, Bob (pseudonym), loved the new look of our robot and thought it was the coolest idea. He also thanked me for initiating the Saturday meeting to make improvements on our robot."

The robot project also involved several contests (beauty, speed, size) and the winners received extra credit. The winning teams were defined by the votes of the faculty and the students. Hearing other students' and the instructors' positive comments about their robot provided verbal persuasion further supporting her self-efficacy.

"Our robot passed all of the design criteria and won the second place in the beauty and the speed contests. It performed all the tasks required. It was fun to watch it move. It wobbled and made noises like a puppy. Some of my classmates stated that it was the most original and the cutest robot."

Interestingly, while this project clearly involved contests, Sherry and her team members were not concerned about the competition. Sherry's robot team did not choose competitive, norm-based design criteria. Their goal was to meet the required design constraints and criteria provided by the instructors. While the design testing day provided a negative social persuasion during the bridge project, the results of the robot testing and contests created positive persuasions.

B) Positive Vicarious Experiences

During the robot project, Sherry reinforced her team's communication by asking questions of her team members about the design and the robot programming and by observing them very carefully.

"I started to carefully observe my teammates when they were using the studio equipment. I noticed how they were dealing with obstacles such as not knowing how to use a power tool. I recognized they were not more knowledgeable than I was but they were not hesitant to try. They were usually using the trial and error strategy. Sometimes they would ask someone else for help. I started doing the same (11/17/2005)."

The vicarious experiences helped her correct her perceptions of herself compared to the other students. She also learned coping methods by observing the strategies other students were using to accomplish the tasks that required the use of power tools.

C) Positive Mastery Experiences

Sherry was concerned that she was not learning the computer programming skills through her robot team. One of the male members in her team took the programming responsibility and the other one took the design responsibility. She was assigned the role of team facilitation. She noticed that with this strategy they could produce a good robot but that she would not be able to learn any programming skills. Consequently, she started to study the concepts by herself. She then discussed her questions with her team member who was in charge of programming and with her instructor.

"In order to make sense of programming, I created a table, listing several basic observable behaviors of the robot and then the corresponding algorithms. Next, I wrote the programming that will cause the corresponding behavior. I shared my table with my team member who was working on the programming. Later, we even used this table in our report (11/15/2005)."

This learning experience helped her understand basic programming and supported her self-efficacy. She did not approach the programming problem with the goal of documenting it for their team report; however, her individual effort not only supported her own learning but also became a contribution to her team's design report. Building a working artifact was important for the success of the project because the failure of her bridge project had a negative impact on her self-efficacy. However, just building a successful design was not enough to increase Sherry's self-efficacy. The mastery experience was more powerful when she learned new concepts and skills such as programming. With an increased self-efficacy, she became more confident in sharing and defending her ideas.

D) Positive Emotional States

Initially, Sherry was not confident using the studio equipment. However, when her team was constructing their robot she started to use power tools.

"I had tool phobia. I did not have much experience using power tools and I did not know how they worked. I was not afraid of hurting myself but I was afraid that I would damage our design if I make a mistake."

Her self-efficacy increased as she learned how to use the power tools and started contributing to the project.

"It was a while ago when one of my classmates said 'it is amazing how weak we are, as humans, compared to machines'. I think it is amazing how knowing how to use the machines makes you stronger (9/17/2005)."

There were two additional affective factors that supported Sherry's self-efficacy. During the robot project, her team decorated their robot to look like a puppy. This design change surfaced a social impact and use of the robot as a possible children's toy. In addition, this design improvement, though a simple one, created an emotional attachment to and excitement about the project.

Another factor that lowered the anxiety during the robot project was effective time management. Her team set their team due dates two days before the actual due dates assigned by the instructors. This strategy, which was suggested by Mark, provided them with ample time to modify their design, revise their design reports, and rehearse their presentations.

Discussion & Conclusions

Self-efficacy is an important construct that can predict one's persistence and academic achievement[9]. Social and affective factors can significantly impact the self-efficacy of female students, especially during the early stages of engineering education. The freshman year is when students are uncertain about their career path and not knowledgeable about the skills needed to become an engineer. Therefore, self-efficacy can fluctuate rapidly during the freshman year as students form judgments about their skills based on their vicarious and mastery experiences.

Sherry's perceptions of design projects as a success or a failure impacted her perceptions of her own abilities. It should be noted that her assessment of project success was based on her own judgment and was not necessarily aligned with the instructors' judgment of her team's success. The vicarious experiences that supported her self-efficacy were based on her observations of the students who were similar to herself. These students did not know how to use the tools but they were not hesitant to use them. However, observing students who were experts on using the studio equipment was not supportive of her self-efficacy. Social persuasion from her team members was also very important. Her self-efficacy dropped when her team members rejected her ideas but increased when they appreciated and acknowledged her contributions. Finally, her being nervous in using studio equipment negatively affected her self-efficacy but this effect was positive when she took the initiative and learned how to use these tools. Another factor that influenced her self-efficacy was a change her team made in the design of their robot. Seeing the social relevance of the robot design as a possible children's toy improved her self-efficacy. Sherry's freshman engineering experience showed that self-efficacy impacts engineering learning and persistence in engineering. Table 1 provides a summary of the engineering experiences that supported or hindered Sherry's self-efficacy.

Table 1. Engineering Experiences that Increase or Decrease Self-Efficacy

Factors that Increase Self-Efficacy	Factors that Decrease Self-Efficacy
• Conceptual understanding of engineering concepts (ME) • Learning engineering skills (ME) • Effective project planning and time management (ES) • Team acknowledgement and reinforcement (SP)	• Unsuccessful project or successful project with limited opportunities to learn concepts (ME, ES) • Unfamiliarity in using studio equipment (ME, ES) • Limited knowledge transfer within the team (VE, SP, ME) • Competitive (norm-based) design criteria (ES)

Mastery Experiences (ME), Social Persuasions (SP), Emotional States (ES), Vicarious Experiences (VE)

In the context of team-based projects, learning mainly takes place within the team environment. Therefore, the quality of team communication plays a critical role in determining self-efficacy. Poor team communication influences self-efficacy because, in such an environment, there will be limited vicarious experiences to learn skills and limited social persuasion that motivates the team members. Poor team communication could also have other consequences by creating negative mastery experiences such as an unsuccessful design. In the case of Sherry, the bridge team environment, which had limited vicarious experiences, social persuasion, and a negative mastery experience, decreased her engineering self-efficacy.

In this study, Sherry persisted by employing strategies to obtain social persuasion, vicarious experiences, and mastery experiences so that she could increase her self-efficacy. She was able to contribute to the project by gaining skills in using studio equipment and gaining conceptual understanding of the programming. She learned how to use equipment vicariously by observing other students. These experiences increased her self-efficacy and her confidence in proposing and defending her ideas. It was after her self-efficacy increased that she significantly contributed to the project and received positive social persuasion from her team members who acknowledged her contributions.

This research has two key contributions to the current literature. First, it provides insights into the perceptions and experiences of a female freshman engineering student and identifies factors that affect self-efficacy in the context of engineering as presented in Table 1. Second, based on these findings, recommendations for further research and classroom implications are made to support students' engineering self-efficacy. It should be noted that the study of teams and capturing team interactions are challenging tasks. On one hand, this study is limited to one case and a doctoral student's experiences can partially represent the experiences of a freshman engineering student. On the other hand, this study helps uncover important relationships in a hard-to-research context and raises critical questions for future study.

Implications & Recommendations

Many engineering programs offer project-based team activities during the freshman year. The dilemma is that, while the social team context can be encouraging for women, these experiences might also have negative outcomes. Based on the results of this study, recommendations are made for engineering educators. These recommendations are specific to team-based design activities and are made based on the four sources of self-efficacy (social persuasion, vicarious experiences, mastery experiences, and emotional factors).

Female engineering students can be provided with positive social persuasions through effective team collaboration. Freshman students generally do not have the skills necessary for working in teams. Therefore, when they work in teams they usually have teaming problems or work toward completing the final product. Explicit team building activities should be used to support social persuasion and acknowledgement within teams. For example, asking students to identify the strengths of their team members and share them with the team could be helpful. However, when it comes to identifying weaknesses, students should be asked to judge their own weaknesses and identify their personal goals, along with the strategies they would use to improve their skills. Persuasions from the instructors also play an important role in supporting students' self-efficacy. The focus of this study was on student team interactions; however, we think it would be appropriate to discuss ways faculty can provide positive persuasions. For example, when instructors meet with teams, they should make eye contact with all team members, and avoid limiting their conversation with the student who might have the highest self-efficacy in the team.

Team context can be a powerful approach to learning skills and concepts supporting vicarious experiences. On the other hand, students do not naturally attempt to help their peers learn skills. Even senior engineering students do not consider team collaboration and peer teaching as critical factors when defining good teams[13]. Good team management enables the team to work effectively and also promotes the learning of all of the team members. Students should be required to create a project management plan such as identifying tasks and subtasks and allocating responsibilities. Extra credit can be given to the teams that use a collaborative teaming approach that encourage team members to exchange skills and knowledge. Instructors can observe student team meetings using a rubric designed to capture the level of team collaboration. Students can also be asked to evaluate themselves and each other based on the degree of support they receive from, or give to, the other team members.

This study also highlights the role of mastery experiences in relation to self-efficacy. It is generally believed that failure can be a powerful learning experience; however, caution must be made because self-efficacy can be lowered by negative mastery experiences. Rotating roles within the team would support positive mastery experiences. When students are given the freedom to select their team leaders, women would usually take or be given this responsibility. This is usually because women are perceived as better in planning and time management while men are given more technical responsibilities such as prototype design or programming. Such an allocation of team roles is effective in completing the project but does not allow room for new learning. Therefore, team roles should be rotated to support different types of learning experiences for all members. For example, during the construction of the designed artifact, the team member who is skilled at using tools and has the manufacturing role can take the leadership and supervision role. Such a rotation of the roles would allow other team members to improve their manufacturing skills while the person who already has this skill can improve his/her leadership skills.

Vicarious experiences can also be supported by modeling activities. Social learning environments provide modeling opportunities for women to get to know the skills of other students in order to judge accurately their own strengths through social comparison. Role models who would help female students recognize their own strengths, suggest coping strategies, and serve as a sounding board for problems would support self-efficacy. Another modeling strategy is showing female students videotapes of role models who face challenges, use coping strategies, and succeed in achieving their goals. Observing oneself successfully performing a task is another powerful tool for supporting self-efficacy. Watching edited videotape recordings or subsequent replays of one's successes have been found to be effective methods increasing self-efficacy[9].

Emotional states of female students can be supported by non-competitive and socially relevant activities. The design experiences should be collaborative because competitive projects force students to focus on norm-based design criteria rather than realistic customer needs. Furthermore, extrinsic motivation through competitive projects puts an emphasis on the completion of the final product rather than on the learning process. Socially relevant design projects would motivate students, especially females, intrinsically[3] and increase female students' self-efficacy. Examples of such activities are rescue devices, artificial hips that take into consideration differences in male and female pelvises rather than making surgeons use a male designed hip for women, and kitchens that are designed to meet the needs of women[14]. In addition, explicit connections between the design project and the science and engineering concepts students are learning should be made. When a project is socially-relevant and the content is contextualized, women would be more motivated, have more opportunities to use their prior experiences, and contribute more to the project. Consequently, they will learn more and gain positive mastery experiences at early stages of their education.

Self-efficacy, being a good predictor of academic performance and persistence, can support the learning of not only the female students but all students as they learn how to collaborate and work in teams. Recognizing and assessing self-efficacy are not easy but as critical as assessing students' learning. The most powerful assessment tool of an instructor is classroom observations and interviews. These observations and interviews can be done by addressing the following questions: Do students exchange positive or negative verbal persuasions with each other during their team meetings? Do students teach concepts to or learn skills from each other? Do teams spend time on team building and team management? Do all team members have access to learning? Do all team members learn the key concepts and skills required to design and build their artifact? Instructors can also employ the methods used in this study, and ask students keep journals reflecting on their learning, self-efficacy, and team interactions. In these journals, students should write about the strategies they would use to support their learning and solve teaming problems.

Engineering self-efficacy instruments should also be developed and used to capture the changes in students' self-efficacy at various stages of a team project. However, Bandura's guidelines should be followed when designing self-efficacy instruments[15]. We should restate that self-efficacy is a context specific construct and the validity of a self-efficacy instrument depends on its alignment with the course objectives. Therefore, an instrument developed and used for one course might not be appropriate for another course.

Summary

This study contributes to the current literature by providing examples of classroom experiences that support and hinder the self-efficacy of a female student. The recommended activities that would promote engineering self-efficacy, engineering learning, and persistence in engineering are based on authentic data. Further research should explore if these strategies would support self-efficacy and learning with larger populations. We hope this study will bring a new perspective to discussions in identifying ways to support learning through team design projects. We are confident that further studies on self-efficacy would have a significant impact in increasing persistence and success of the students in engineering.

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