AC 2008-654: TINKERING INTERACTIONS ON FRESHMAN ENGINEERING DESIGN TEAMS

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Tinkering Self-Efficacy and Team Interaction on Freshman Engineering Design Teams

Introduction

In the book *Talking about Leaving*, Seymour and Hewitt interviewed hundreds of college students whose high-school SAT math scores were at least 650 and who started their college careers in natural science, mathematics or engineering. The interviewees were selected randomly by the participating colleges and universities. Approximately half of those interviewed had switched majors out of science-math-engineering (SME) programs by their senior years. The other half of those interviewed were still SME majors as seniors and planned to graduate with a degree in natural science, mathematics or engineering. They found that the greatest contribution to the loss of students in Science, Math and Engineering fields was due to problems associated with the structure of the educational experience and the culture of the disciplines. They also found that SME academic programs had a more significant negative impact on female and male students of color and white women [32]. Henes, Bland, Darby, and McDonald reported that the results of a University of California Davis survey of 419 male and female engineering students indicated five major reasons why women leave or become discouraged with engineering: (1) Isolation, (2) not seeing relevance of highly theoretical basic courses, (3) negative experiences in laboratory courses, (4) the "cold classroom climate" and (5) lack of role models [17].

The first-year of engineering curriculum is critical in students' decision to persist in engineering. A six-year longitudinal study of undergraduate female engineering students at the University of Washington found that woman entered engineering programs as high academic achievers with confidence in their abilities. However, among women who left engineering by their sophomore year, their confidence declined during the first year of study [9]. Vivian Anderson interviewed 40 female students enrolled in their third or fourth year of an undergraduate engineering program and found that loss of self esteem was the biggest problem facing female engineering students [3].

The course and curriculum structure of many engineering programs result in a sense of isolation for the female students. The first and second years of college for engineering students consist of required basic mathematics, chemistry and physics courses that have numerous course sections, and engineering students are scattered. Due to the challenging workload, students rarely get involved with student engineering organizations and do not form the social network that is important for survival in engineering. The experience of isolation was even more pronounced for female students than the experience of male engineering students since there are so few female engineering students [17]. Additionally, the engineering courses often lack context, especially in the first year. Because many of these preliminary courses are large and impersonal, students often do not get the connection with the engineering, and the educational approach does not accommodate diverse learning styles [28].

Engineering education is moving towards a more team-oriented curriculum that not only focuses on content but also emphasizes the importance of developing communication and collaborative skills[24]. Engineering organizations focus on teamwork because of its ability to help spark innovative ideas and allow participants to produce higher quality projects [18, 23]. As a result, interdisciplinary or cross-functional teams are a required part of an accredited undergraduate engineering curriculum. The teams are typically involved in a range of functions that include design, development and manufacturing. This move to a curriculum that includes teamwork skills is in response to the engineering industry need for engineers who are prepared to work in a more global market, where diverse ideas, knowledge and skills are utilized to generate creative solutions to tough engineering problems. This implementation of a more team-oriented curriculum could have a potentially positive impact on female engineering students who have traditionally experienced what many researches call a "chilly" classroom climate[33]. If implemented properly, group work can create a learning environment that is less competitive and more attractive to female students. The team-based curriculum in the freshman engineering design class offers students the opportunity to work as a team to develop solutions to various projects, while gaining valuable hands-on design experience.

It is important to understand the complexities of cooperative learning group work in order to adequately provide an equitable access for all students. Critical parameters involved in setting up successful groups include preparation to work as a group; group size, student abilities, race, gender and previous experience [30]. Teams should engage in teambuilding exercises before the cooperative learning exercise. Research studies have shown that teaching students cooperative behaviors such as task-related interaction skills, sharing of ideas and information, staying on task and helping others to understand what was being taught has a significant impact on improving the learning experience for everyone in the group [25,35]. Some research has found that student teams should consist of three to six members [19]. However, it has been reported that groups larger than four may encounter problems with scheduling meeting times and lack of participation by one or more group members. Ideal group size varies according to the nature of the task or project and class size [30]. In general, it is best to utilize mixed ability grouping to minimize the difference in group progress and performance. Differences in social status such as gender, race or ethnicity can effect group interaction, can result in inequitable interaction and unequal learning outcomes. The group selection process becomes more complicated and context dependent when considering the factors of race and sex. Developing groups that consists of more than one person of a particular sex or races reduces the isolation of that person [30]. These are just some of the challenges and factors that should be considered when composing a team.

Group work is not a magical solution to improving science education. It is an instructional approach that is more effective with appropriate curriculum materials, effective instructional methods and teacher training [8]. It should be clear that simply assigning students to groups and telling them to work together does not necessarily result in cooperative efforts. It can result in competition within the group or individual student efforts with talking among members. Some studies have showed that collaborative work or teamwork is not always a positive experience, and in some cases can be counterproductive to creating an effective and equitable learning environment. For example, there is often a tendency of some women to take a less active part on the team and some men devalue women's contribution, which causes a problem for the women [13]. Gender bias on teams often undermines the equity potential of the team and even the course. Guzzetti and Williams showed that gender inequities are most evident during group work in laboratory assignments, which is consistent with Tobin's observation that females are less likely to be involved in operating lab equipment [16].

Developing Engineering teams has been based on the assumption that an increase in female proportion helps. Gender integration problems may be a function of the number and proportion of females in the organization. When a minority member is the only minority member of group, the minority member status may be identified as a "token", which affect the group dynamics in a negative way [21]. However, Cohen and Swim found that when seeking equity in cooperative groups, increasing the number of females in a group will not necessarily have beneficial effects [11].
According to Steele, increasing the number of females in a group only makes the minority status more salient, which results in an increase in stereotype threat. This would create a hostile environment and increase the females' level of anxiety [34]. Examining the impact of gender and team gender composition within engineering student design teams, Laeser, Moskal, Knecht, and Lasich, revealed that balanced gender teams performed the lowest as compared to majority female or majority male [22].

In the engineering culture, engineers are typically viewed as "tinkerers", who are inclined to tinker with gadgets, equipment and tools in order to understand, create or improve something. McIlwee and Robinson reported that many female engineering students have low "tinkering" confidence, skills or experience, which may limit the roles they assume on their engineering design teams. This low self-confidence in tinkering could also contribute to females leaving the engineering field or never fully actualizing their potential as a professional engineer. According to McIlwee and Robinson, 57% of the men they interviewed reported that the reason for entering an engineering field was because of their tinkering experiences as a child. Only 16% of the women interviewed reported their tinkering experience as a reason. For women the most often reported reason for entering an engineering career was because they were good in math and science[26]. In a study to identify women's experiences in engineering education, out of forty women interviewed only one admitted to "tinkering" experiences and decided to major in engineering based on these experiences [2].

Throughout various studies, many researchers consistently refer to an engineering culture that is not associated with the math and science undergraduate experience. Research on engineers and engineering by social scientists and engineers confirms that engineers believe in a uniform engineering culture. The engineering culture is a persistent concept; across a wide variety of literatures, similar values and practices of engineering culture are identified [24]. The engineering culture carries a strong image of an engineer as being a "tinkerer". The insecurity felt by most female engineering students and engineers were related to their technical abilities. Despite the fact that many engineering positions will not require any tinkering skills. Most students do not have a clear idea of what engineers do on the job, and they are unable to make a connection between what they are learning in college and what they will do as a practicing engineer. Most women do not learn the skills or the vocabulary associated with tinkering even though they are preparing for a career that is strongly identified with tinkerers. However, for most women their academic success will offset any insecure feelings about technical ability [26].

A contextual curriculum is a common theme for making the science and engineering classroom more inclusive. This allows students the opportunity to connect what they are learning in the classroom to events outside the classroom. Learning is enhanced if students understand the relationship between abstract ideas and real-world applications. This can be achieved through interdisciplinary, multi-disciplinary approaches to science curricula [29]. In the article, *Engineering A Warmer Welcome for Female Students*, Farrell points out that the challenge for undergraduate engineering programs is to show that math and science have social value and relevance. Engineering colleges are realizing the importance of engaging students in hand-on assignments using real-world projects [12].

Early collaborative design experiences have been promoted as another means of providing women with more positive experiences in engineering and serves as great preparation for engineering careers [28]. Anderson advocated implementing early design experience in the engineering curriculum, which is essential in developing a sense of basic engineering principles through application that can be reinforced later with theory. This early exposure to the practice of engineers also allows students, male and female, to decide early if this is a profession that they want to pursue. According to Anderson, most women were more satisfied later in their academic career when the engineering courses became more applied [2]. With early theory courses, women are introduced to a concept that they are unable to understand until it is presented later in their academic careers as a part of a specific project. Seldom do women bring to their engineering studies prior application experiences related to the theoretical concepts that they are learning. Anderson showed in her study that experience of successfully working out practical engineering problem can restore self-confidence that was lost during the course taking[2]. This is consistent with Bandura's self-efficacy theory where the most influential source of perceived self-efficacy is performance accomplishment.

A model of a person's approach toward and commitment to an endeavor can be represented by Albert Bandura's self efficacy model. Self-efficacy theory is concerned with an individual's beliefs about his or her personal capabilities to organize and execute a course of action to accomplish designated goals or performances. Self efficacy beliefs touch almost every aspect of a person's life based on whether the person thinks productively, pessimistically or optimistically; how well that person is capable of self-motivation and persevering in the face of adversities; their vulnerability to stress and depression and the life choices they make. The development and modification of a person's self-efficacy beliefs comes from fours sources of information listed in order of most influential to least influential: (1) performance accomplishment, (2) vicarious experiences, (3) verbal persuasion or encouragement from others, and (4) physiological or emotional arousal (i.e. anxiety) [3,4]. Bandura's theory of self efficacy provided the theoretical foundation of this study, which examined the development of tinkering skills while working on an engineering design team.

The most influential source of strengthening self-efficacy is through mastery experiences, also referred to as performance accomplishments. Successful experiences strengthen one's self-efficacy in a given area and experiences of failure can undermine one's self-efficacy. The second most influential source of self-efficacy is vicarious learning or modeling. Observing someone similar to oneself succeeding at a given behavior or task through sustained effort will increase the observer's self-efficacy. Whereas seeing someone fail despite their high efforts will undermine the observer's self-efficacy. The greater the observer perceives a similarity with the observed the more persuasive the observation. Verbal persuasion is the third way to influence self-efficacy beliefs. Encouragement and verbal support from others will increase one's effort and persistence to accomplish a task. People who have been persuaded that they lack the capabilities to accomplish a certain task will often avoid that task. It is more difficult to increase self-efficacy beliefs by verbal persuasion alone than it is to undermine it. The fourth and the least influential source of self-efficacy is physiological arousal, where people interpret their emotional states as a reflection of their capability to accomplishing a given task or goal [3].

Self-efficacy is domain-specific; it must be considered in terms of a specific situation. Therefore when referring to "tinkering" self-efficacy in an engineering design class, only the skills and challenges associated with "tinkering" in the context of engineering is considered. Bandura's self-efficacy model provides the framework to examine student team interactions and monitor the development of tinkering self efficacy. The four sources of self-efficacy provide a systematic way of monitoring group interactions and possible influences on individual team members tinkering self-efficacy beliefs.

Engineering design teams provide opportunities for Bandura's four sources of self-efficacy to prevail. Performance accomplishment is present through the various tinkering-related tasks necessary to accomplish a goal; modeling of tinkering behavior by team members, verbal persuasion to engage or not engage in tinkering by team members; and emotional state of team members and their perceived stress as related to the task. Thereby, providing some insight on how the freshman engineering design teams can be structured to provide students with more opportunities to increase their perceived tinkering self-efficacy beliefs. This is important for freshman engineering students who are making decisions about their engineering careers and their capability of completing the engineering degree.

Despite the various efforts that are in place to minimize gender differences in the math, science, and engineering classroom, female students working in teams still have a tendency to take on more stereotypical roles. This does not allow them to take advantage of the learning opportunities [4, 28, 30]. Studies have shown that female students have a lower tinkering and technical self-efficacy because of less prior experience. The team projects in freshman engineering design classes are meant to provide tinkering experiences early in the academic career [2, 28]. However, the sex composition of the group and group dynamics may influence the amount and kinds of opportunities to develop tinkering and technical skills. The purpose of this study was to examine the tinkering self-efficacy development of female students working within freshman engineering design teams of mixed sex composition and determined whether gender, team gender composition or prior tinkering experience had an impact on tinkering self-efficacy.

Research Questions

The basic question, "Does tinkering self-efficacy change for female students during the Freshman Engineering Design class while working on mixed sex teams?", was addressed by examining the following research questions:

- Is tinkering involvement affected by mixed-sex team composition?
- Is tinkering involvement affected by the Bandura's sources of self-efficacy displayed in group interaction?
- Is tinkering involvement increased or decreased as time progresses in the course and students gain more opportunities to engage in tinkering-based projects?

These research questions were approached by examining tinkering engagement within freshman engineering design teams through quantitative data collection and field observations. The quantitative aspect of the study consisted of a self-report on prior tinkering experience and self-reports on individual tinkering involvement during each team design project. The field observations of three targeted teams allowed for an understanding of participants' actions with respect to demonstrating or experiencing sources of tinkering self-efficacy. The observation data also addressed the social nature of group interactions within mixed-sex teams. The quantitative data combined with observations of specific teams provided a view of students' tinkering self-efficacy development during team work and issues of equity and access to materials.

Methodology

The research for this tinkering self-efficacy study was conducted at a university in a metropolitan area in the southwest. This is a 4-year public institution with an undergraduate enrollment of approximately 49,000 in 2005. The undergraduate enrollment consists of 48% men and 52% women. The school of engineering is ranked 41st in the nation for the undergraduate programs and is comprised of eight academic units: The School of Construction, Department of Bioengineering, Chemical and Materials Engineering, Civil and Environmental Engineering, School of Computing and Informatics, Electrical Engineering, Industrial Engineering, Mechanical and Aerospace Engineering. Approximately 9% (4,556) of the 2005 undergraduate population has declared engineering as their major, with 82%(3,752) male and 18% (804) female, which is comparable to the 2002 National Science Foundation statistics on undergraduate enrollments in engineering programs.

The Freshman Engineering Design class, ECE100, is a core interdisciplinary engineering course all engineering students are required to complete during their first year of study. The instructor was a young female doctoral graduate student in mechanical engineering. This class was her second time teaching the ECE100 course and she was very receptive to participating in this research project. The instructor was particularly interested in learning how to compose more effective student teams to create a more equitable classroom, where all students are involved with teamwork. Her teaching style was traditional lecture using power point presentations and some class discussion to share ideas. The class met two days a week with one day for lecture and the other day for lab. The lab class was conducted in a computer lab where students had access to a computer, shared with one or two other students. In this class the students worked with math modeling software MATLAB, excel spreadsheets and conducted internet-based research for their projects. MATLAB is a numerical computing environment and programming language that allows easy matrix manipulation, plotting of functions and data, implementation of algorithms and interfacing with programs in other languages. MATLAB was used in the class for modeling formulas. The lecture class was held in a traditional classroom, where the instructor used power point to present the course information. Most of the course management and class communication was done through blackboard, where the syllabus, assignments and lecture presentations were all posted.

According to the instructor's syllabus for this particular ECE100 section, the course was designed to emphasize the process of problem-solving, to prepare students to meet the general presentation requirements associated with technical work and to introduce them to the process of creating purposeful models. These skills and experiences will help them succeed with the discipline-specific problems to come later. The course objectives were achieved through various reading assignments, creative team work and technical problem solving opportunities associated with completing the team design projects. In addition to the design projects which included a written report and oral presentation, each team was required to complete a MATLAB modeling assignment. This assignment involved using MATLAB to determine the amount of Nitrogen needed to effectively dilute methane in a specific container. The students worked on the same team throughout the semester to complete three hands-on design projects in addition to one computer modeling project. There was no instruction or preparation on effective teamwork. The importance of teamwork was mentioned a few times in the lecture; however, there were no clear guidelines on how to work as a team. There were no measures or monitors in place to evaluate teamwork as the students worked on the design projects. The three hands-on design projects included: the design and launch of a matchstick rocket; design and build a robot to compete in a sumo robot competition; and design and build a catapult or trebuchet to successfully launch a ball into a designated target. Table 1 summarizes the three design projects.

Table 1.
Summary of the three design projects

Project	Description	Timeframe	Materials / Tools
Matchstick Rocket	Design the best matchstick rocket for mass production. Consider costs, ease of production and performance. Step-by –step instructions provided.	1/26 - 2/2	matches, Aluminum foil, scissors, straight pin, paper clip
SUMO Robot	Design a robot capable of defending itself by pushing other robots out of a mini sumo ring 30" in diameter. The robot should be no larger than 4" length by 4" width at the start. There is no limit to the height. The robot is not limited from deploying objects that make it wider or longer after the start. It should weigh no more than 1.25 lbs.	2/7 - 3/9	motor, IR sensors, programmable board and electronic parts, any materials could be use to design the body, wheels, and other as long as it fit the
Catapult	Build a catapult, a trebuchet or a ballista to launch a tennis ball at a target 3 ft in diameter 100ft or 200 ft away.	3/23 - 4/27	teams decided on materials and tools to use.

The ECE100 class selected for this study consisted of 44 students with 14% (6) females and 86% (38) males. The ethnic makeup of the class consisted of 59% (26) whites, 14% (6) Hispanics, 7% (3) Native Americans, 9% (4) Asians, 5% (2) African Americans and 6% (3) unknown. Although this was a freshman engineering design class, approximately 45% (20) of the students were freshmen and the other 55% (24) were classified as sophomores or higher. The class consisted of students majoring in various fields of engineering with six undeclared and one student pursuing a degree in the school of liberal arts and science. Table 2 provides a summary of the student teams and composition.

Table 2.
Summary of teams

team	# females	# males	# Freshmen
1	0	4	2
2	0	4	2
3	0	4	2
4	1	3	3
5	0	4	1
6	1	3	0
7	0	4	0
8	2	2	3
9	1	2	3
10	0	4	1
11	1	3	1
12	0	4	0

This freshman engineering design class was selected for this study based on the instructor's willingness to work within the parameters of this research project by composing groups of specific sex composition. In addition, the course curriculum consisted of at least three team hands-on design projects. In the context of this study, hands-on projects refer to projects that require the team to work with materials and equipment to create or modify a final product.

In order to view the team interactions with respect to tinkering in mixed sex teams, three teams were selected for observations. Ideally four teams would have been selected for observation based on the sex composition; two balanced teams, and two teams with only one female member, to provide a backup team in each category. However, there were two teams with one female and only one team with two female members. The students were first given the option to self-select their teams, and then the remaining students were assigned by the instructor. There were not enough unassigned female students for the instructor to compose two teams with two females. Two teams consisted of four students and one team had three students, therefore there were a total of eleven participants involved in the observation part of this study. A description of the three observed teams is detailed below with pseudonyms used for student names. Team 11 was a self-selected team that consisted of three males and one female. The female student, Tanya, was a freshman majoring in Chemical engineering. The male team members consisted of Tim a sophomore majoring in civil engineering, Tony a sophomore with an undeclared major and Terrence a junior with an undeclared major. Based on the members' classification, this team had the most academic experience combined. Another self-selected team, Team 9, consisted of two males and one female. The female member, Wendy was a freshman in the pre-professional mechanical engineering program. The male team members consisted of Wayne, a freshman majoring in Aerospace engineering, and Winston, a freshman pursuing a degree in the college of liberal arts & sciences. During the first project, there was an additional male member who dropped the course during the first two weeks of school. Based on academic level, this team had the least amount of experience with each team member classified as a freshman.

Team 8 was the team formed by the instructor to meet the sex composition requirement for this study. Team 8 consisted of two males and two females. Karl was a freshman in civil engineering and Ken, a sophomore in electrical engineering. Kim was a freshman in chemical engineering and Kathy a freshman in civil engineering. Karl and Kim were friends and requested that they be on the same team. Ken expressed that the team assignments did not make a difference to him because he does not like working on teams. Kathy a very quiet Native American student, did not express any preferences for team assignments.

The data collection tools consisted of self reports and observations. The self-reports were confidential questionnaires that the respondents completed based on their perspective of their prior tinkering experience and tinkering involvement during each team project. Since it was only their view, their responses were compared with observational data to gain an additional perspective. The prior tinkering experience self-report was administered one time at the beginning of the course. This self-report measured previous tinkering experience of all students in the course and established a baseline of student's prior tinkering experience. The self-report consisted of seven Likert scaled items that characterized the student's involvement with tinkering tasks closely related to tasks encountered in the engineering design course. The reliability of the self-report was measured using SPSS and resulted in a Cronbach's alpha of .84.

The prior tinkering self-report questions were designed to capture the students' prior tinkering experience in an everyday setting and in an academic setting. The questions are related to tinkering skills utilized in the context of the freshman engineering design course. Since Bandura's theory of self-efficacy is context related, the design of the prior tinkering experience questions were composed within the context of tinkering in the freshman engineering design course. Participants were asked to indicate how often they have been personally involved in various tinkering activities by identifying past experiences that would allow the opportunity for students to gain tinkering experience with tools and equipment used in the course. The complete prior tinkering self-report is shown in Table 3.

Table 3.
Prior tinkering experience self-report

Prior Tinkering Experience

Please indicate by marking an X underneath the number that you feel most accurately reflects how often you have been personally involved in each of the following statements prior to enrolling in this ECE100 course.

		Never	rarely	sometimes	very often	Always
1	Disassembled mechanical items (i.e. transistor radio, small kitchen appliances, etc.) just to see how they work	1	2	3	4	5
2	Attempted to repair mechanical items (i.e. computer, small kitchen appliances, etc.)	1	2	3	4	5
3	Assembled items such as furniture, toys or model plane according to instructions	1	2	3	4	5
4	Assembled items such as furniture, toys or model plane without instructions	1	2	3	4	5
5	Used common household tools such as screwdrivers, saw, hammer, drill, etc.	1	2	3	4	5
6	Created or modified an existing mechanical items to improve or change it's operation, (i.e. toy, small appliance, computer, cell phone, etc.)	1	2	3	4	5
7	Used common science laboratory equipment (i.e. voltmeter, caliper, oscilloscope, etc.) during high school Chemistry, Biology or Physics laboratory	1	2	3	4	5

Tinkering involvement self-reports provided the students with an opportunity to self assess their tinkering involvement and their team interaction during each design project. Each respondent indicated what they personally accomplished with respect to tinkering tasks and how frequently they got involved with tinkering related tasks. This provided some insight into the team interaction of each project with respect to Bandura's sources of self-efficacy. It also showed the impact of each project experience on the development of tinkering skills and gives an overall view of team interaction with respect to individual tinkering access. The complete tinkering involvement self-report is shown in Table 4.

Tinkering involvement self-reports, consisted of 11 items, with a 5-point Likert scale, to measure the respondents' view about their tinkering involvement. As in the prior tinkering self report, an odd number of steps were used for the scale to give the respondents an appropriate option when they feel neutral towards a statement with 1 (never) and 5 (always). Bandura's four sources of self-efficacy guided the development of the tinkering involvement self-report items

The reliability of the tinkering involvement self-reports was measured after combining the results for all self-reports from all three projects and reverse scoring the items that reflected a negative tinkering experience. The items included in the reverse scoring were items 1, 4, 6, 8 10 and 11. SPSS was used to determine the reliability, resulting in a Cronbach's alpha of standardized items .77.

Table 4.
Tinkering involvement during team interaction self-report.

Date: ____________ Your gender: _____ Indicate your Team gender composition:

all male	all female	equal male/female	one female	one male

Team Interaction Self-report

Please indicate by marking an X underneath the number that you feel most accurately reflects how often you personally experienced each of the following statements during the last team design project

		Never	rarely	sometimes	very often	always
1	Avoided any tasks that required tinkering with tools, equipment or materials	1	2	3	4	5
2	Approached any tasks that required tinkering with tools, equipment or materials	1	2	3	4	5
3	Successfully completed a task that required hands-on use of equipment	1	2	3	4	5
4	Abandoned a task that required hands-on use of equipment	1	2	3	4	5
5	Verbally encouraged team member/s to get involved with tinkering use of equipment, tools and materials	1	2	3	4	5
6	Verbally discouraged team member/s from getting involved with tinkering use of equipment, tools and materials	1	2	3	4	5
7	Received verbal encouragement from team member/s to get involved with tinkering tasks	1	2	3	4	5
8	Encountered verbal discouragement from team member/s about getting involved with tinkering tasks	1	2	3	4	5
9	Observed team member/s successfully completing tinkering tasks	1	2	3	4	5
10	Observed team member/s failing to complete tinkering tasks	1	2	3	4	5
11	Experienced anxiety while doing or the thought of doing any tinkering tasks	1	2	3	4	5

Participant observation of the three, mixed-gender teams provided the opportunity for 1) a contextualized view of group interactions, 2) tinkering involvement and 3) social environment of the classroom setting. The purpose of the observations was to find meaning in the participants' actions through the lens of Bandura's self-efficacy theory. An observational protocol based on Bandura's four sources of self-efficacy as related to tinkering and team interaction was used as a guide for collecting observation data. The observations were based only on the categories designated in the observation protocol sheet. The observation categories were created using Bandura's sources of self-efficacy. The categories included tinkering behaviors, verbal persuasion, vicarious learning and anxiety. The following provides a definition for tinkering and description of each observation category.

Tinkering in this study was defined as the manipulation of equipment, tools or materials using one's hands to change, create or better understand the inner workings of a gadget, small device, or to create a new gadget or device. Jones et al. found that male students engaged in more exploratory tinkering and female students handled laboratory equipment only as instructed. Exploratory tinkering was characterized as tinkering that is approached without any inhibitions or regard of instructions, rules or stated regulations. Regulatory tinkering was characterized as tinkering that is limited by the instructions, rules or regulations or as needed to fulfill the immediate goal, assignment or task. Regulatory tinkering did not involve looking at applications or modifications of equipment, tools or gadgets beyond the current goal or task. Simply handling materials in the process of gathering, cleaning, or preparing them for use was not considered tinkering.

The tinkering behaviors observed included avoiding, approaching, completing, and abandoning tinkering tasks. Bandura's source of self-efficacy, performance accomplishment, was reflected in a situation when a student successfully accomplished or did not accomplish a given tinkering task. The self-efficacy sources observed during team work included encouragement, discouragement, observation of team member success or failure and anxiety towards tinkering. Encouragement is the verbal encouragement or discouragement by team members to get involved with tinkering tasks. Modeling or observation in the context of this study refers to team members observing another team member engage in a tinkering task, without physically getting involved with tinkering. Anxiety experienced by a student when engaging or approached to engage in tinkering related tasks can be observed and interpreted in several ways. In the context of this study, anxiety was exhibited when a student displays a form of hesitance or obviously uncomfortable with performing tinkering tasks.

In this engineering design course tinkering tasks included but was not limited to successfully assembling a given part of a project such as a wheel assembly, the battery pack module as designed by the team, measuring and cutting specific parts, assembling the electrical circuit card or any tasks that requires the use of tinkering. As the observer, I rotated between the teams every few minutes to capture who was involved with tinkering tasks and behaviors listed on the observation protocol sheet. Therefore, if a student displayed avoidance of getting involved with tinkering tasks, then I would mark his or her initials in that box; however, if the same student later got involved with tinkering I would mark their initials in the corresponding box noting that this occurred later in the class. If the same student continued to avoid tinkering tasks, I would not mark their initials again. The observations did not keep count of how long or how many times each student displayed behaviors outlined in the observation protocol. It gives an indication of who was involved with certain tasks and if that involvement changed any throughout the course of the task.

During the observations, in addition to behaviors, I looked for pre-defined statements and or actions that would demonstrate the sources or behaviors defined by Bandura (1997). These predefined statements and physical indicators were defined based research on women's experiences in science and engineering For the verbal encouragement, I looked and listened for verbal statements directed to team members that would include but not limited to the following statements:

"you should assemble the…."
"rebuild this ….."
"measure and cut the ….."
"You would be good at assembling…"
"Why don't you try to use the …."
"I can show you how to use the…."

Discouraging verbal statements directed to team members would not promote the involvement with tinkering tasks. Such statements could be implicit and include redirecting team members to non-tinkering tasks such as gathering materials' taking notes, writing reports and completing written assignments. Verbal discouragement may be very explicit and include the following statements:

"You can't operate that equipment"
"You don't know what you're doing"
"You're taking too long to …."

For the modeling category, the participant's observation of the team member must be a direct and attentive observation and does not include casual glances. The modeling can be either of successful completion or failure to complete tinkering tasks. According to Bandura's (1997) self-efficacy theory, if the modeling is observed by someone who identifies with the person engaging in the task then the influence on self-efficacy is greater. In this case if the modeling is observed by someone who shares the same gender or ethnic background as the person performing the tinkering task, it was be noted.

To observe anxiety in the participants, I used the following predefined verbal and physical indicators of anxiety.

"Working with tools makes me nervous"
"I am uncomfortable working with tools, equipment, etc….."
"I prefer to write the report, compile the presentation, etc…."

Physical indicators include backing away from the work table area where tinkering is being done and obviously avoiding any tinkering tasks by not going in the equipment lab area or near the equipment and materials

The observation data were tabulated to represent who demonstrated a particular tinkering behavior specified on the protocol sheet. The team member's initials were used to indicate when he or she engaged in a particular behavior listed on the observation protocol. In order to get an indication of how male and female students were involved, the initials were replaced with the sex of that particular person, "M" for male and "F" for female.

Teams often met outside of class time, especially for the robot and catapult projects; therefore, it was not possible to meet with them to conduct observations. All three teams were asked to include me on their communication list to inform me of any meeting dates and times outside the normal class meetings. Since I was not informed of the team meetings outside of the normal class hours, my observations were limited to times within the designated class period. Seven team observations were conducted lasting from half an hour to one hour per observation session. For team 9, I was able to make 7 observations totaling 5 hours and 40 minutes. For team 8, 5 observations were completed totaling 4 hours and 40 minutes. Finally, team 11 completed most of their tinkering work outside the normal class hours. Therefore, only 4 observations were made totaling 3 hours and 40 minutes.

The first self report administered to the whole class was the prior tinkering self report which was administered during the second week of the course. Forty-one students completed the prior tinkering experience self-report given at the beginning of the semester. This questionnaire was administered one time before the teams engaged in any design projects. The tinkering involvement self-reports were completed by all students at the end of each hands-on design project, after the final project presentations.

The data were analyzed using non-parametric tests on SPSS because the population sample for this study was small and very little was known about the distribution of the variables. Non-parametric tests made fewer assumptions about the data and accomplished the same task of parametric tests by comparing the rank values between groups. These rank values assisted in determining which group tended to have larger values than the others. The Mann-Whitney *U* is the non-parametric equivalent of an independent samples t-test. The Kruskal Wallis *H* test is the non-parametric parallel to a one-way ANOVA. It is used in this study to compare the responses of more than two groups, i.e. teams. Each research question is addressed below using the data from self-reports and observations.

Results

I addressed the research question, "Is tinkering involvement affected by mixed-sex team composition?" by comparing the responses by the number of females on a team. Using the self-tinkering involvement reports, where each respondent indicated the number of females on their team, an overall summary of tinkering involvement was determined by calculating a sum for each respondent of the self-report responses for all the projects. Tinkering involvement self report items 1, 4, 8, 10 and 11 were transposed before the sum was calculated. These items captured the lack of tinkering involvement. Therefore, a high sum represents more tinkering involvement. Reponses of those with one or more female team members were compared to the response of those with zero female team members. The Mann-Whitney U test, the non-parametric equivalent of an independent samples t-test, was used to compare the responses by number of females on a team. The comparison of overall tinkering involvement responses by number of females on a team shows no significant difference ($U=864.50$, $p= .644$). The observation data of the three mixed-sex teams provided another perspective of the impact of mixed sex teams. The observations included two teams with one female member and one team with two female team members. The observation data shown in Tables 7, 8 and 9 is summarized and tabulated to indicate the tinkering involvement by the sex of each team member. The "M" represents a male and "F" represents a female. This type of tabulation provides an overall view of how each sex was involved with tinkering during the specified project.

Team 8 was the only balanced team, composed of two females and two males. It was also the only team that a female student visibly had negative experiences. I completed a total of 4 hours and 40 minutes of observations covering all three design projects. The summary of the observation data is shown in Table 5. The two female students on Team 8 avoided and or reluctantly approached tinkering tasks. In the first two observations one female student avoided tinkering tasks and later approached tinkering tasks that she eventually she abandoned. This same female student withdrew from the course during the second team project. The other female team member reluctantly approached tinkering tasks and was observed being engaged in tinkering tasks as they worked on the first and second design projects. However, by the third project, she no longer engaged in tinkering and only observed. One of the two male students built the last two design projects on his own, while the other team members completed the reports and presentations. Based on these observations, the tinkering involvement within Team 8 appears to have nothing to do with the number of females on the team.

Table 5.
Team 8 observation data– 2 males, 2 females

	Matchstick Rocket		Sumo Robot		Catapult
Observation Category	Obsv 1	Obsv 2	Obsv 3	Obsv 4	Obsv 5
Avoided tinkering tasks	F	F			
Approached tinkering tasks	F,M,M,F	M,M,F,F		M,F,M	M
Exploratory tinkering	M	M		M	M
Regulatory tinkering	F,F	F,F		F,M	
Handling		M			
Accomplished tinkering tasks	M		M	M	
Abandoned tinkering tasks	F	F,M			
Discouraged team member/s			M		
Received discouragement			M,F,F		
Observed success				F,M,F	M,F
Tinkering anxiety physically exhibited	F				

Team 9 was composed of three males and one female for the first project. However for subsequent projects the team was composed of two males and one female because one male member dropped the course due to scheduling conflicts. The 5 hours and 40 minutes of observation data for Team 9 is summarized in Table 6. The female team member was observed being involved with tinkering tasks throughout all observations. There was one male member who avoided tinkering tasks or reluctantly approached the tinkering tasks limited to handling equipment and materials. This was observed once during the matchstick rocket project and during all three observations of the sumo robot project. During the catapult project, this same student was observed approaching and accomplishing tinkering tasks.

Table 6.
Team 9 observation data– 3 males, 1 female

	Matchstick Rocket		Sumo Robot			Catapult	
Observation Category	Obsv 1	Obsv 2	Obsv 3	Obsv 4	Obsv 5	Obsv 6	Obsv 7
Avoided tinkering tasks	M		M	M			
Approached tinkering tasks	M,M,F	F,M,M	M,F	M	M,M,F	F,M,M	M,M
Exploratory tinkering	F	F, M	M	M	M,F	M	M
Regulatory tinkering	M	M	F		M,F	M,F	M
Handling	M				M		
Accomplished tinkering tasks						F,M,M	
Encouraged team member/s	M,M	F,M,M	M	M		F,M,M	
Discouraged team member/s							
Received encouragement	F	F,M,M	F	M,F		F,M	
Received discouragement							
Observed success				M,F	M		F

The observations for Team 11, summarized in Table 7, were limited and only consisted of four observations, totaling 3 hours and 40 minutes. This team appeared to be very efficient and worked well together. They completed most of their projects outside the normal class meetings, therefore during class they seldom worked on their projects. Team 11 was composed of one female and three males, all members were observed being engaged with exploratory type tinkering tasks during the first project. There was one incident where the female team member avoided tinkering tasks during the sumo robot competition. There was one male team member who engaged in the tinkering tasks related to making last minute modifications for the robot competition. There was only one observation of Team 11 during the catapult competition. During this observation only the male team members were involved with tinkering tasks. It is possible that the female student was more involved with tinkering during team meetings that I did not observe.

Table 7.
Team 11 observation data – 3 males, 1 female

Observation Category	Matchstick Rocket Obsv 1	Sumo Robot Obsv 2	Sumo Robot Obsv 3	Catapult Obsv 4
Avoided tinkering tasks			F	
Approached tinkering tasks	F, M, M, M			M, M ,M
Exploratory tinkering	F, M, M, M	M	M	M, M, M
Regulatory tinkering				
Handling				
Accomplished tinkering tasks	F			
Encouraged team member/s		M		
Discouraged team member/s				
Received encouragement		F,M		
Received discouragement				
Observed success		F,M, M	F, M, M	F

There were some differences in tinkering involvement by teams. However, there was no evidence that this difference was due to the sex composition of the team. Comparison of the tinkering involvement responses by number of females on a team showed no significant difference on any of the projects. The observation data of the three mixed-sex teams showed no definite trends with respect to the number of females on a team. All three teams observed consisted of one female and the tinkering involvement was different for each team. There were separate incidences of a male and a female student avoiding and reluctantly approaching tinkering tasks. I was unable to conclude that the participants' tinkering behavior was due to the number of females on the team.

The research question, "Is tinkering involvement affected by the Bandura's sources of self-efficacy displayed in group interaction?" was addressed by using Pearson's correlation to examine the relationship between sources of tinkering self-efficacy with tinkering behaviors.

The correlation analysis provided a general indication of the relationship between self-efficacy sources and behaviors based on prior tinkering and tinkering involvement self reports. It also provided an indication of performance accomplishment with respect to tinkering tasks. According to Bandura's theory, performance accomplishment is the most influential source of self-efficacy. The prior tinkering experience self-report responses were added to obtain a sum value for each respondent. The overall prior tinkering sum and the overall tinkering involvement sum are correlated (r = .312, p= .002, N=93) this indicates that with more prior tinkering experience there is more tinkering involvement.

Correlation between prior tinkering experience self-report responses and tinkering involvement self–reports responses provided an indication of the relationship between the two reports. The correlation data for each item in the self reports are summarized in Table 8. The prior tinkering self-report item 1, disassembled an item just to see how it works, was the most influential prior tinkering item on tinkering involvement. It correlated with 6 of the 11 tinkering involvement self-report items, 2 correlations at a level of .01 and 4 correlations at a level of .05. Prior tinkering item 6, modified a mechanical item to improve it, correlated with 5 of the 11 tinkering involvement self-reports, 4 correlations at a level of .01 and 1 correlation at a level of .05. The least influential prior tinkering experience was assembling items according to instructions, item 3. It correlated at .05 level with only 1 of the 11 tinkering involvement self-report items. In general, the more prior tinkering experience a student reported having generally results in less avoidance, observation of failure and abandonment of tinkering tasks and more approaching and observation of success tinkering tasks.

Table 8.
Correlation of prior tinkering and tinkering involvement self reports

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11
pt1	-.351(**)	.229(*)	.234(*)	-.081	.046	.048	.088	.004	.224(*)	-.297(**)	-.230(*)
N	93	93	93	92	93	93	93	93	93	93	93
pt2	-.316(**)	.323(**)	.223(*)	-.174	.106	.095	-.025	.049	.226(*)	-.163	-.125
N	93	93	93	92	93	93	93	93	93	93	93
pt3	-.203	.139	.167	-.216(*)	.088	-.069	.147	.034	.185	-.128	-.094
N	93	93	93	92	93	93	93	93	93	93	93
pt4	-.158	.203	.209(*)	.118	.132	.202	.034	.273(**)	.115	-.140	-.129
N	93	93	93	92	93	93	93	93	93	93	93
pt5	-.266(*)	.388(**)	.225(*)	-.408(**)	.023	-.219(*)	-.034	-.184	.200	-.125	-.168
N	90	90	90	89	90	90	90	90	90	90	90
pt6	-.315(**)	.384(**)	.325(**)	-.224(*)	.167	-.089	-.016	.134	.266(**)	-.198	-.112
N	93	93	93	92	93	93	93	93	93	93	93
pt7	-.298(**)	.259(*)	.106	-.211(*)	.115	-.032	.062	-.095	.174	-.125	-.024
N	93	93	93	92	93	93	93	93	93	93	93

Note.

Pearson correlation with missing values excluded cases pairwise. ** correlation is significant at the p=.01 level (2 tailed) * correlation is significant at the p= .05 level (2 tailed).

The prior tinkering responses of freshman students were compared to students classified as sophomore, juniors to determine if more academic experience had an impact on prior tinkering experience. There is a significant difference in the responses by academic classification ($X^2(2) = 35.55$, $p = .000$). Table 9 shows that Freshmen ranked lower than Sophomores and Juniors in prior tinkering experiences. The ranking value increases with academic classification. This trend suggests that with more academic experience there are more tinkering experiences.

Table 9.
Ranks of prior tinkering sum by classification

Classification	N	Mean Rank
Freshmen	48	30.22
Sophomores	24	62.19
Juniors	18	64.00

The overall prior tinkering data were analyzed by teams to determine if the prior tinkering experience was significantly different by teams. There was a significant difference in prior tinkering experience by team ($X^2(11) = 41.21$, $p = .000$). The team prior tinkering experience ranks in Table 10 reveal that teams with no freshmen were ranked the highest in prior tinkering experience and teams with two or three freshmen were ranked lower.

Table 10.
Team ranks of prior tinkering experience sum

Team	N	Mean Rank	# of Freshmen
12	3	9.50	2
4	6	10.25	3
2	12	28.25	2
8	9	45.00	3
1	9	46.50	2
3	9	49.00	2
9	9	49.50	3
10	6	50.00	1
11	9	52.00	1
5	9	59.00	1
6	9	75.50	0
7	3	84.50	0

Prior tinkering experience influences tinkering involvement. According to the correlation data of prior tinkering self-report response to the tinkering involvement self report responses, specific tinkering experiences correlate more with tinkering involvement. The data suggests that tinkering experience is gained through time in school. Freshmen ranked lower than the upperclassmen in prior tinkering experiences. This is confirmed by comparing the tinkering involvement of each team. Teams with fewer freshmen ranked higher in tinkering involvement.

An additional correlation analysis analyzed the relationship of the tinkering involvement items within the tinkering involvement self report items. Tinkering involvement self report items that represent the sources of tinkering self-efficacy were compared to the self-report items that reflect tinkering behaviors. This provided an indication of the relationship between the other sources of self-efficacy, besides prior tinkering experience, and tinkering behavior. The correlation data are summarized in Table 11. According to the correlation results, the most influential source of tinkering self-efficacy is tinkering involvement self-report item 9, observed team members successfully complete a tinkering task. Item 9 correlated at a level of .01 with 5 of the 6 tinkering self efficacy behaviors. Item 10, observed team members fail to complete tinkering tasks, is the next influential source. It correlated at a level of .01 with 3 of the 6 tinkering self efficacy behaviors. The least influential tinkering self efficacy source was item 7, received verbal encouragement to get involved with tinkering tasks. It correlated with only 1 of 6 self efficacy behaviors included in the tinkering involvement self report.

Table 11.
Correlation of tinkering self-report items, self-efficacy sources with behaviors

	Behaviors					
	Item 1	Item 2	Item 3	Item 4[a]	Item 5	Item 6
Sources						
Item 7	-.074	.047	.099	.108	.356(**)	.164
Item 8	.193	-.205(*)	-.150	.343(**)	.061	.318(**)
Item 9	-.317(**)	.341(**)	.322(**)	-.268(**)	.369(**)	-.098
Item 10	.266(*)	-.262(*)	-.427(**)	.305(**)	-.301(**)	.114
Item 11	.142	-.173	-.274(**)	.231(*)	-.254(*)	.312(**)

Note. Pearson correlation with missing values excluded cases pairwise, N=93, N[a]=92, ** correlation is significant at the .01 level (2 tailed) * correlation is significant at the .05 level (2 tailed).

The tinkering involvement self- report responses were analyzed by sex, academic classification and teams to obtain an indication of any difference that may exists. There was no significant difference between the male and female overall tinkering involvement (U=451.00, p =.161) and no significant difference by classification (X^2 (2) = 5.418, p = .067). There was, however, a significant difference by team (X^2 (11) = 39.234, p = .000). The team rankings are shown in Table 12. There is no trend in the team ranking with respect to classification or number of females on a team.

Table 12.
Tinkering involvement team ranks

Team	N	Mean Rank	# females	# freshman
4	6	9.67	1	3
1	9	29.89	0	2
3	9	30.56	0	2
10	6	34.08	0	1
8	9	40.11	2	3
5	9	46.06	0	1
9	9	54.61	1	3
6	9	58.56	1	0
2	12	58.67	0	2
11	9	62.89	1	1
7	3	82.67	0	0
12	3	84.17	0	2

The correlation of prior tinkering responses to tinkering involvement responses identified specific prior tinkering experiences that correlated with tinkering involvement. Although all students reported having some prior tinkering experience, not all tinkering experiences influence tinkering involvement. The prior tinkering experience of modifying an object to improve the function correlated well with tinkering behaviors. While the experience of assembling an object according to instructions correlated negatively with abandoning tinkering tasks. The correlation results corresponded well with Bandura's theory of self-efficacy. The prior tinkering experience, observation of others, verbal persuasion and anxiety were sources of tinkering self-efficacy that correlated with tinkering behaviors. However, unlike Bandura's ranking of influence, in this study anxiety was more influential than verbal persuasion based on the correlation results. Based on the analysis of the participants' responses on the prior tinkering and tinkering involvement self reports, the males and upperclassmen had the prior tinkering experience that correlated with tinkering involvement behaviors.

The research question, “Is tinkering involvement increased or decreased as time progresses in the course and students gain more opportunities to engage in tinkering-based projects?” was addressed by completing a Kruskal Wallis, non-parametric ANOVA. The Kruskal Wallis compared the tinkering involvement self-report responses of all participants by project. The analysis compared the mean ranks of each self report item across each project using the non parametric Kruskal Wallis test. In addition, the observation data were examined for patterns or trends in tinkering involvement. The results provided an indication of how tinkering involvement changed as time progressed in the course.

The results of the overall tinkering involvement self-report responses compared by project did not reveal a pattern of tinkering involvement with progression through the design projects (X^2 (2) = 9.723, p=.008). The corresponding ranks of each project are shown in Table 13 show that there was less tinkering involvement during project 2.

Table 13.
Tinkering involvement project ranks

Project	N	Mean Rank
1	31	52.47
2	31	34.71
3	31	53.82

The ranking of projects is shown in Table 13, reveal that project 2 ranked the lowest in approaching and accomplishing tinkering tasks. Project 2 also ranked the highest in avoiding project and team members observing each other failing at tinkering projects. Shown below in Table 14 is a summary of the tinkering involvement self report items that were significantly different by project.

Table 14.
Tinkering involvement items by Project

	Item 1	Item 2	Item 3	Item 10
Chi-Square	15.450	8.876	7.868	6.802
Asymp. Sig.	.000	.012	.020	.033

Item 1 Avoided any tasks that required tinkering with tools, equipment, or materials
Item 2 Approached any tasks that required tinkering with tools, equipment or materials
Item 3 Successfully completed a task that required hands-on use of equipment
Item 10 Observed team member/s failing to complete tinkering tasks

Note: Kruskal Wallis Test, grouping by project, df = 2

Table 15.
Project ranks for self-report items.

	Project	Mean Rank
Item 1 Avoided any tasks that required tinkering with tools	1	41.52
	2	60.16
	3	39.32
Item 2 Approached any tasks that required tinkering with tools	1	53.95
	2	36.23
	3	50.82
Item 3 Successfully completed a task that required hands-on use of equipment	1	52.27
	2	36.76
	3	51.97
Item 10 Observed team member/s failing to complete tinkering tasks	1	46.24
	2	55.66
	3	39.10

Note: N = 31 for each project with a total of 93. [a] N=30, total of 92.

To examine if tinkering involvement across projects differed between male and female students, the tinkering involvement across projects for male and female participants was analyzed with a Kruskal Wallis test. Table 16 shows the comparison of the tinkering involvement self-reports across projects for the male and female respondents. A difference between projects in tinkering involvement responses was calculated for the male respondents.

The female responses showed no significant difference in tinkering involvement between projects. Their tinkering involvement responses remained consistent throughout the three projects. However, according to the observation data reported earlier, there is an indication that the female tinkering involvement decreased as the time progressed.

Table 16.
Comparison of tinkering involvement self-reports by project for males & females

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11
						Males					
Chi-Square	14.154	8.782	5.235	2.448	1.270	.653	1.365	.319	6.244	6.964	1.408
Asymp. Sig.	.001	.012	.073	.294	.530	.721	.505	.852	.044	.031	.494
						Females					
Chi-Square	1.633	.526	3.326	1.260	.792	.322	1.000	2.985	.700	3.524	.901
Asymp. Sig.	.442	.769	.190	.532	.673	.851	.606	.225	.705	.172	.637

Note. Kruskal Wallis Test, Grouping Variable: project, males only, df=2

Table 17 summarizes the ranking of each project by self report item based only on the male responses. The male participants, avoided tinkering tasks more and approached tinkering tasks less during project 2 (robot). They also observed team members failing at tinkering tasks more during project 2.

Table 17.
Project ranks of self-report item for males

	Project	Mean Rank
Item 1	1	34.46
	2	50.98
	3	33.06
Item 2	1	45.37
	2	29.62
	3	43.52
Item 9	1	41.15
	2	31.54
	3	45.81
Item 10	1	41.15
	2	46.27
	3	31.08

Note: N = 26 for each project with a total of 78.

According to the tinkering involvement self reports, the factor of time in the course did not appear to have an impact on tinkering involvement. The observation data of the three teams provided another perspective on the impact of time on tinkering involvement. Despite the overall trend in the self reports, the observations revealed two incidents where time did have an impact. The observation data for team 8 is summarized in Table 5. The two female students on Team 8 avoided and or reluctantly approached tinkering tasks. In the first project, matchstick rocket, all team members were involved with tinkering but not as a team. Each team member worked on their individual rockets with little input or assistance from each other. During the two observations of the matchstick rocket project, one female student avoided tinkering tasks and later approached tinkering tasks that she eventually abandoned. This same female student withdrew from the course during the second team project. The other female student and one male team member reluctantly approached tinkering tasks. The other male student worked confidently alone and made it clear that he did not like working on teams. For the second and third projects, this male team member elected to do all the tinkering type work to complete the projects and the other team members completed supporting tasks and assignments. By announcing to his team members that he would complete the projects, he discouraged the other team members from getting involved with the tinkering tasks. As a result, the tinkering involvement for the other male and female student declined in subsequent projects. Time did not have a positive impact on female tinkering involvement with this team. One female student withdrew from the course and the other female student's tinkering involved decreased.

Team 9 observation data are summarized in Table 6. This team started with three males and one female. During the first project, matchstick rocket, one male team member dropped the course. The female team member was observed being involved with tinkering tasks throughout all observations. However, by the third project she was observed being engaged in more regulatory tinkering and less exploratory tinkering. During the catapult demonstration, observation 7, she did not engage in any tinkering type tasks. She retrieved the ball after it was shot toward the target and observed any tinkering done by team members and the operation of the catapult.

There was one male student who avoided and reluctantly got involved with tinkering tasks during the matchstick rocket project. However, during the second project, sumo robot, the same male student avoided tinkering tasks in all three observations. In observation 5, during the matchstick rocket project, he approached tinkering tasks at the level of handling materials and equipment. By the third project he was more involved with tinkering tasks and accomplishing tasks. He was observed approaching tinkering tasks in a regulatory manner, only as instructed, during both observations of the third project. During observation 7, the catapult competition the two male team members completed any last minute and intermittent tinkering tasks necessary. It appears that the tinkering involvement of the female student decreased while the one male student showed an increase in tinkering involvement.

The observation for team 11 is summarized in Table 7. All members of team 11 were observed being engaged with exploratory type tinkering tasks during the first project. During the second project, sumo robot, there was one male team member who engaged in the tinkering tasks related to making last minute modifications for the robot competition. The female student and other two male students were not observed being involved with tinkering tasks. There was one incident where the female team member avoided tinkering tasks during the sumo robot competition. There was only one observation of Team 11 during the demonstration of each team's catapult design. The female student was not involved with tinkering. Like the female student on Team 9, she retrieved the ball after it was thrown to the target by the catapult.

The observation data of the three teams provided some insight on the tinkering involvement for males and females. Team 8 had a female student who avoided and reluctantly approached tinkering tasks and dropped the course during the second project. This same team had a male team member who did all the tinkering tasks. On team 9 there was a male student who avoided tinkering tasks during the first project and got more involved with tinkering as the class progressed. The female student on team 9 was involved with tinkering throughout the course. However, by the last project, her tinkering had declined from exploratory to regulatory type tinkering. The few observations of team 11, show that the tinkering involvement of the female student declined after the first project. The male students' tinkering engagement declined during the second project and recovered during the catapult project, which is consistent with the self report responses.

Other Findings

This study was designed to address the research questions related to tinkering self-efficacy. During the course of the research project there were other notable findings and observations beyond the observation protocol related to team interaction. A female student informant stated that during the first project her team members worked well together. Everyone was involved with designing and building the matchstick rocket. However, after the first project, she experienced some bias. The male team members did not include her on team planning or discussions. She also mentioned that she had to force her way into the team discussions in order for her ideas to be considered. This type of behavior continued throughout the remaining of the course. She was very surprised by their behavior towards her but she did not allow their behavior to diminish her involvement with the team. She was even more motivated to be involved and actively contributed to the team's final design product. This finding could be attributed to the complexity and nature of the design project. The first project was very simple with step by step instructions provided. However, the subsequent projects were complex involving multiple technical skill sets and requiring creativity. She mentioned that she had to take a forceful approach in order to stay involved with not only the tinkering activities but also the team discussions and project planning.

The female team member on Team 8, who dropped the course right after the first project, was a very soft spoken Native American student who did not get involved with any activities within the team. She sat on the side, observed and eventually attempted to create a matchstick robot of her own, but with no success. Since this team did not engage each other in any type of communication, especially sharing ideas, it was extremely difficult for her to find her place. In the last tinkering involvement self-tinkering report, the other female team member entered a comment stating that their team worked better after the other female team member dropped the course. Basically, they found their role on the team. There are potentially several factors contributing to the dysfunction of this team; cultural differences, personality, experience, lack of communication and accountability. The fact that two females were paired on the team seems to have no impact in their team involvement.

The observations of Team 11, consisting of 3 males and 1 female were limited. During the first project, the female team members seemed determined to prove that she was the brains of the team. She was assertive and outspoken. However, as time progressed it was clear that everyone on the team was an active contributor and her enthusiasm appeared to decrease. As seen in the team observations her tinkering involvement by the final project was limited to retrieving balls thrown by the catapult. Throughout the course, however, she remained the self-appointed team spokesperson who confidently represented the team and took it upon herself to explain their progress or answer any questions concerning the team. Another interesting observation is that Team 11 did not design the catapult or the trebuchet they presented during the last project. Instead they ordered kits online that only required assembly according to the directions. The instructor approved this stating that as long as they worked on it as a team it was acceptable. This demonstrates the instructor's lack of emphasis on design.

Discussion

The self-report data collected in this study found that the number of females on a team made no difference in tinkering involvement. This result could be a reflection of the small sample size and the proportion of females in the sample. The 5:1 ratio of males to females made detection of sex effects in tinkering involvement difficult. The lack of female students in this class, as in most engineering programs, makes it challenging to study any effects related to sex. It is also possible that the number of females on a team had no impact on the tinkering involvement as reported in the self-report data. This is in agreement with the Mead et al. study, where engineering faculty members reported that team performance was influenced more by the engineering discipline than by sex or ethnicity [29].

The absence of a tinkering involvement difference based on the number of females on a team could be a reflection of the isolation of the lone female team member. Since all the mixed-sex teams in this study consisted of only one female, including the team where one female student dropped, it is possible that the students disregarded any impact or influence the female students had on their team. Therefore the participants reported that the number of females on a team had no impact in tinkering involvement.

Bandura's sources of self-efficacy, previous experience (performance accomplishment), verbal persuasion, vicarious learning and anxiety, when placed in the context of engineering are typically manifested in a negative manner, especially for women. There are so few female students and faculty members for the female students to gain vicarious learning experiences. McIlwee and Robinson reported that the female engineering students typically have less prior tinkering experience, which creates a level of anxiety for them regarding their technical abilities. They also reported that the engineering curriculum does not compensate for female engineering students' lack of mechanical experience [26].

The correlation data reported in this study suggest that the Bandura's sources of self efficacy apply to "tinkering" skills in a freshman engineering design course. Bandura ranks the sources of self efficacy with performance accomplishment as the most influential, observation of others as the next influential source, then verbal persuasion and the least influential self efficacy source being anxiety [3, 4]. Unlike Bandura's ranking of influence, verbal persuasion was shown to correlate with more tinkering behaviors than the observation of others. This difference could be due to the hands-on nature of tinkering where verbal persuasion to get involved is more effective than observation. Since Bandura's theory of self efficacy is context dependent, the various sources may have a different influence ranking depending on the context.

The observation data revealed two separate incidents where time and perhaps Bandura's sources of self-efficacy were a factor in tinkering involvement. In the observation data of Team 9, one male student's tinkering involvement increased from avoidance to approaching tinkering as the class progressed. However, a female student, on Team 8, started with similar avoidance responses to tinkering, instead of increased tinkering she eventually dropped the course. In addition to time, these two incidents are a demonstration of Bandura's Self efficacy theory and how the sources of self efficacy impact tinkering behaviors. In one case, the male student on Team 9 had positive experiences. His teammates encouraged him to participate and modeled successful tinkering. This student's tinkering involvement increased with each project. In the other case, the female student on Team 8 had negative experiences with tinkering; she did not receive any encouragement from her team members. Since one student did all the tinkering type work at home, she did not have any opportunities to observe successful tinkering. She dropped the course sometime during the second project.

The difference in these two students' responses to their lack of tinkering experience could be the result of the self-efficacy sources demonstrated in the team interactions. The difference can also be related to one of the findings in the Hene et al. study, which suggests female students often feel inadequate and marginally included in the laboratory activity. This feeling of inadequacy leads them to question their ability to complete the engineering degree; however, men do not see lack of hands-on experience as a weakness [17]. Anderson pointed out that many women experience a loss of self esteem and self confidence in engineering, which leads them to drop out [2]. There was no indication that the female student in this study dropped out of engineering. However, the fact that she dropped out of this freshmen level engineering design course was an indication that she may have experienced a loss of self-confidence and feelings of inadequacy.

The competitive nature and complexity of the projects were factors that possibly had an impact on tinkering involvement. The drop in tinkering involvement during the second design project may be due to the competitive nature of the project. The pressure of competition could have influenced the team members to take on tasks that are more comfortable in order to get the project done. This division of tasks resulted in only select team members taking on the tinkering tasks. Barker's case study of students enrolled in a project-based undergraduate computer science course found when students perceived pressure to finish a project they often selected team roles based on expediency or familiarity [6]. In addition to expediency, students are influenced by getting good results. Tonso pointed out in her study of freshman engineering design teams, that when teams can figure out what needs to be done to get good results they will do that instead of focusing on the design or engineering [37]. Since the second project had a competitive component, getting good results and performing well was additional motivation for teams to figure out what needs to be done in order for their team to not only successfully complete the project but also win the competition.

The division of tasks within a team works against expanding the team members' skill set and widens the gap between male and female tinkering experience. It results in one or two team members completing the tinkering tasks while other team members complete organizational tasks related to scheduling, getting materials, writing reports and preparing presentations. In addition, all the female students in this study were the only female on their team, tokenism could have also contributed to female students taking on more female stereotypical roles [11]. Male and female students in the Mead et al. study agreed that women were less likely to be given responsibility for tinkering type tasks especially for the freshman and sophomore level female students [29].

Researchers have found a difference between actual performance and perceived competence of female students. However, this difference is usually high academic achievement and low perceived competence as a result of diminished self esteem and self confidence [31]. In this study, the female students reported having approximately the same tinkering involvement throughout all three projects. Yet the observations show that the quality of the female students tinkering involvement decreased with time. The following explanations may contribute to a reason that there was a difference in what the female students reported and what was observed. It is possible that the observation time was insufficient and did not include all the team interactions. The field observations during the second project were limited to three brief observations with the third observation being the competition. For Team 11 there were only two observations; with one being the competition.

The female students may not have perceived any difference in their performance and, therefore, did not report their diminished tinkering involvement in the self-report. The competitive engineering culture could have influenced the female students' perception of their performance. The female students in this study perhaps did not acknowledge that their tinkering involvement had diminished in an effort to maintain a competitive edge. In a study by Anderson, she found that the female engineering students were reluctant to discuss their negative classroom experiences [2]. The female students in this study may not have felt comfortable with reporting their lack of tinkering involvement because that could be a reflection of an inability to be an engineer.

An aspect of the engineering culture is competition among colleagues that is a result of the "weed out" practice of many engineering educators. This creates an environment where student learning is not necessarily the focus and students are reluctant to seek help. Murray et al. found that engineering students who seek help are not viewed as the "best and brightest" [28]. The female student informant in this study provided anecdotal evidence that a chilly climate existed for women in this freshmen engineering design class. The isolation she reported is consistent with the experience of lone female team members as reported by other research studies that reported the women's opinions and ideas were sometimes ignored and ridiculed [1, 29, 36]. Male and female students in the Mead et al. study agreed that female students have to be more aggressive to get attention and sometimes the respect of their classmates [29]. The influence of the engineering culture may have contributed to many of the results found in this study.

The engineering culture is the prefect condition for stereotype threat. Stereotype threat is a situation in which a person risks being judged negatively based on a commonly held devaluing stereotype that exists about one's group. This threat creates a sense of pressure that can degrade the person's performance [7]. There is evidence that there is a widely held belief that women are not good engineers and men are better engineers [28]. Garrod revealed that male students do not think that women can be a successful engineer, mother and wife [15]. In addition to the stereotype that women are less capable than men in engineering, there is a commonly held belief that female students tend not to be as tough as the male students [7]. The male-dominated field of engineering coupled with the stereotype of women not being good engineers could explain the female students diminished tinkering involvement and their reluctance to report that they are not performing as expected.

Implications

There have been many efforts in the improvement of the education process of engineers. The engineering design curriculum has expanded to include skills beyond content and subject matter. However, the changes have been slow and are not necessarily implemented effectively. Tonso found in her study that many of the efforts are well-meaning, however, they do not translate into successful practice in the classroom. She found that the emphasis on engineering design and effective teamwork was not practiced, although it was mentioned. In addition, what is presented in the classroom is not often translated into practice in the laboratory [37]. The freshmen engineering design course in this study employed two of the teaching approaches recommended to create an inclusive learning environment to prepare future engineers: active learning and collaborative work. However, as in the Tonso study, the efforts in implementation were not effectively practiced. The teamwork practices and engineering design process were presented in class and related readings were assigned. However, the execution of these practices on the individual teams were not emphasized or monitored. The findings of this study have several implications for the freshman engineering classroom including factors for team formation, team preparation, team management and curriculum to maximize the sources of tinkering self-efficacy and ensure that all students have an opportunity to gain positive tinkering experiences.

In addition to the critical parameters involved in setting up successful teams it is important to consider the factors that arise from Bandura's sources of tinkering self-efficacy. Creating a mixed ability team with respect to prior tinkering experience would allow team members with more tinkering experience to share with those with less tinkering experience. This also provides opportunities for modeling successful tinkering skills, which proved to be an influential source in tinkering involvement.

The negative effects of the lone female team member described by many researchers were not apparent in this study. Although there was evidence that sex bias did exist according to the participant informant, there was no indication that having more than one female on a team would make it more equitable. Therefore, when considering the team formation with respect to sex, perhaps employing a grouping strategy that does not involve selecting out the female and minority students and is based on skill would be more effective and reflective of the real engineering team.

Teamwork training and preparation exercises were not done for the freshmen engineering design class used in this study. Despite the lack of teaming preparation, several teams appeared to work well together. However, there were a few teams that did not work well and the concept of teamwork was not apparent. Investing the time to engage students in exercises and team skill-building activities that will prepare them for cooperation will also make them aware of their interpersonal skills and work process necessary for effective teamwork [10]. Team preparation should also include the integration Bandura's sources of tinkering self-efficacy. Such integration could include practices that encourage team members to get involved with tinkering tasks. This could be accomplished through team interaction practices that include team feedback and rotating role assignments giving each team member an opportunity to act as the team facilitator. Providing feedback gives team members an opportunity to encourage other team members as well as provide constructive feedback on areas of improvement.

It is important to foster team interactions that encourage all team members to get involved with all aspects of the design process including tinkering. Successful teamwork is slow and takes more time than individual work [14]. When teamwork is implemented as a means of saving time or when the students perceive that efficiency is the purpose of the assignment, they will divide the tasks or do whatever is necessary to complete the project. The group interaction shifts from dialog and discussion toward a division of labor based on expertise [6]. Assigning team roles may ensure that each student gets actively involved with tinkering. However, simply assigning roles can also result in a division of labor, therefore, rotating each student through the role of group facilitator may foster group interaction and participation [10]. The group facilitator can ensure that each student is participating, sharing, and contributing to all aspects of the group, including tinkering. The team should provide feedback to the group facilitator identifying areas where the facilitator is excelling and an area of improvement. This would provide an opportunity for everyone to participate actively and learn from the experience.

The freshman engineering design course curriculum should be organized so that all students have the opportunity to gain positive and effective tinkering experiences. Projects assigned to the teams should incorporate complexity, time restraints and a variety of skills so that teamwork is necessary for the successful completion of the project [30]. For example, the curriculum should include design projects that get more complex as the course progresses. Each project should build on the tinkering skills used in the previous project. The competition among teams should be eliminated. This will minimize the pressure of getting the project done and possibly avoid the division of tasks and unequal distribution of tinkering tasks. It is also important to manage the team interactions. The students will learn how to navigate the engineering design process, manage projects and work with others, while expanding their skill set.

The classroom implications listed above are directly related to creating a teaming environment that includes a well-organized curriculum and careful monitoring of the team interactions. This course should not only focus on the engineering and design process but also prepare students for teamwork and provide opportunities for positive tinkering experiences. Imbedding positive influences of Bandura's sources of self-efficacy in the team interactions will assist in increasing student tinkering engagement.

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