Gender Differences in Learning

by

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SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 1999

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ABSTRACT

A study was conducted in order to identify the gender differences in learning. Case studies were prepared on nine undergraduate students who were enrolled in Design and Manufacturing I. Through informal meetings with the students and their professors, information was collected on the learning styles of the students. The factors that affect these different learning styles were then evaluated. The conclusions drawn are specific to the students studied, but the recommendations made can be applied to most educational environments.

There is a large correlation between a student's experience and his/her ability to learn in a specific subject. The level of exposure that a student has had affects his/her confidence, which further affect his/her problem solving approaches. In order to be more effective, educators must continually evaluate the progress of their students, as individuals. Further, experimental teaching situations should be considered.

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Table of Contents

Introduction....................Page 4
Purpose of the study, methods used, and overview of final conclusions.

Description of the Course....................Page 7

The Participants....................Page 12
Summary of the students' backgrounds, gender-related perceptions, and progress in the course. Identification of the teaching styles of the students' professor..

Why Is This Course Important?....................Page 21
Perceptions of the purpose of and roles in the course from the students and the professors.

What Are We Learning?....................Page 23
Summary of the concepts and skills that the students learned in the course.

Getting Over the Hurdles....................Page 25
Comparative problem solving approaches of the students.

How Successful We Feel....................Page 27
Perceptions of success from the students and the professors.

Summary....................Page 29
Findings and recommendations.

Notes....................Page 32
Definitions and supplementary information on the study.

Introduction

Women represent 28% of the undergraduates in the Mechanical Engineering department at the Massachusetts Institute of Technology (Registrar, Fall 1998). Their academic credentials are comparable to their male counterparts', having the similar interests and abilities. There are few identifiable differences between the genders in terms of grades, performance, or recognition. Yet, there seems to be a hole in the women's education.

I present the argument that women are learning differently, even here at MIT. It is essential to recognize the factors affecting this difference and to consider ways to improve the learning experience of all students. As an educational society, we can no longer neglect those whose learning styles differ from the norm, regardless of their gender.

Goals

To define the extent to which gender differences affect learning. To identify and focus upon those differences that represent deficiencies in the education process.

Further, to make recommendations as to how to minimize the factors that lead to these learning deficiencies.

Methods

To learn about the learning differences between genders, I have carried out nine case studies, involving five men and four women who were enrolled in a sophomore design and manufacturing course during the study. To help in gauging their learning, I met with each student for nine one-hour sessions, assessing the following areas:

- Participant's background
- Weekly progress
- Validity of how ideas are formulated/influenced by others
- How designs change over the course of the semester
- Timeliness/planning
- Personal feelings about achievements/milestones
- Learning curve

Results

The results of this study have proven to be anecdotal. The observations and generalizations that are made are only applicable to the nine students studied. The recommendations, however, can be applied to most learning communities.

As the recommendations have followed from generalizations made about the students and their learning styles, it might be said that the factors that affected the learning of these nine students are some of the factors that affect all students. Therefore, I will try to present my generalizations and my recommendations so that they can be applied to all learning situations.

Why Is This Course Important?

The convergence of the education goals of a course and its professor with the learning level of the students is an essential part of effective education.

What Are We Learning?

Students who feel a sense of independence from their instructors and their peers often feel that they do not have much to learn. Although they can identify the concepts that others think are important, they do not value the absorption of new information. However, the inexperienced student, who is looking for guidance from his/her educators and peers, is much more open to learning the concepts that are presented to him/her as being important.

Getting Over the Hurdles

The key part of problem solving is the initial problem definition. While experience level seems to have little bearing a student's ability to actually solve problems, the students with the most experience are the most skilled at defining problems and at identifying starting points from which to find solutions.

How Successful We Feel

The largest boundary to overcome before beginning the learning process is evaluation of confidence level. Once a student in confident in his/her current abilities, he/she is most able to apply those abilities in order to gain new knowledge.

Summary

We must pursue many alternative styles of teaching to effectively accommodate the many different styles of learning represented by today's students.

The Course

2.007 Design and Manufacturing I

"Develops students' competence and self-confidence as designers. Emphasis on the creative design process bolstered by application of physical laws, and learning to complete projects on schedule by using standard project management tools. Synthesis, analysis, and robustness as complements. Subject relies on active learning through exercises in lecture and laboratory. A major design-and build project is featured. Lecture topics include idea generation, estimation, concept selection, visual thinking and communication, kinematics of mechanisms, design for manufacturing, and designer's professional responsibilities. Several manufacturing techniques featured in 2.008 are used in fabrication of designs."
(Course Description)

Course Objective

"To enable students through lecture and hands-on experience to:

- Learn the process of design.
- Combine creative thinking with engineering principles (physics) to turn ideas into robust reality.
- Discover and utilize basic mechanical components.
- Realize the importance of project management.
- Realize the importance of concurrent engineering.
- Complete 2.007 with the skills and confidence to take an unstructured problem and develop it into in a systematic manner a design that exhibits creativity and is well engineered by the use of principles learned in physics and 2.001."

(Course Material)

Technical Content

- "Identifying the problem and its functional requirements
- Generating potential design parameters to satisfy the functional requirements
- Identifying physical principles and their early application to select design parameters
- Generating creative concepts on paper and testing simple models
- Selecting concepts
- Creating a project schedule
- Embodiment of the design
- Bench-level prototypes of critical elements.
- Manufacturing and testing the design
- Reflecting on the results (closing the design loop)."

(Course Material)

Overall Goal of 2.007

"The overall goal of 2.007 is to help you learn to effectively execute the steps required to practice design in a systematic manner, which is vital if you are to become an effective design engineer. These steps define the process of design:

Define problem

- Strategy
- Functional requirements
- Design Parameters & Physics of the problem
- Schedule
- Resources available

Develop concepts

- Kinematics (motions, forces, and connections)
- Concept drawings (stick-figure sketches for Free-Body-Diagrams, isometric sketches, solid models)
- Sketch models
- Preliminary analytical models & identification of critical technologies
- Bench Level Prototypes (Bench-Level-Prototypes)
- Concept selection
- Preliminary hardware assessment & manufacturing review
- Update schedule to make sure design can be completed on-time and on-budget

Embodiment

- Final component selection
- Detailed layout drawings

- Set-up analytical optimization spreadsheets
- Preliminary hardware selection & manufacturing review

Details

- Final sizing of components and structures
- Part drawings & manufacturing review
- Update schedule

Prototype and test

Manufacture"

(Course Material)

The Contest

"The contest gives you a real design goal on which to focus.

- Learning is enhanced with a real-world focused problem.
- The contest is also a means to compare your design to other designs.
- In the real world, you will be judged and compared every day.
- History shows the contest is 50% designing and building, and 50% driving."

(Course Material)

Organization

There course has two 1 ½ hour lectures twice a week and one 3 hour lab per week. The lab sections are taught by one section professor and 1-3 Undergraduate Assistants (UA's) for every 15 students.

Grading

To the students:

"This is very much an interactive course, and you have a very low chance of passing the course if you do not attend lectures and labs. In lecture and lab, there will be a lot of information presented. You will not succeed if you just try to read the web. Substantial amounts of information will be discussed and illustrated blackboardically that will not be handed out. Your grade is also very dependent on the problem sets. Each problem set focuses on helping you create your 2.007 machine. There are no busy-work assignments. Everything is focused on the contest machine from Day 1.

There are also a whole series of active learning mini quizzes in lectures. If you turn in an attempt to solve the problems, they cannot harm your grade. If you do not turn them in, then your grade could be hurt if you are borderline.

You will be responsible for using the Rohrbach method for grading your problem sets. You will be part of a 4 person grading team. Each person will review and make comments on each other person's problem sets. Your section instructor will review the team's comments and will give the team a grade on how effective they are at providing constructive criticism. The instructor will then give each student a grade for their own problem set.

The key to earning an "A" is not putting in long hours, the key to earning an "A" is to relax, follow the schedule, come to class and lab, and to think creatively and deterministically (can you write a spreadsheet to justify and optimize major design decisions, such as the size of a motor?). The student's grade will be largely based by how well the students learn the design process taught in 2.007. This is reflected by how you do on the problem sets (80% of your grade), in addition to having a working machine the week before the final contest.

Real designers in countless companies use this process. Good designers get raises and responsibility and reflect well on themselves and their profession. Bad designers are of no use to anybody.

A bad designer:

- Has no respect for project management.
- Thinks he can just cut-&-fit on the fly.
- Can see it all in his head and does not need to sketch and test and plan.
- Works late hours the night before the contest and produces something.
- Enters the contest and then disappears from the class.
- Gets at best a "C" in 2.007.

2.007 is far more about learning the process of design, by designing and building your machine, than just building a machine to compete in the contest. Without knowing the process of design, you will not be able to compete on real design projects in the real world."

(Course Material)

The Participants

To preserve the privacy and integrity of the participants, their names will not be used. Instead, they will be identified with nicknames that will add clarity to the reader's understanding. Following the students' nicknames, their gender will be identified by (M/F). Both of the professors are male.

The Male Students

The Prover (M)

The Prover (M) has had no experience in design or machining outside of the required coursework, yet he has a good understanding of how things work and of general manufacturing methods. He recognizes the relevance of his coursework. He sees his own skills and successes through the eyes of his peers, often wanting to be successful to avoid embarrassment or to prove himself.

The Prover (M) feels that, in high school, women learned more easily and liked learning a lot more than men did. At MIT, he has observed that women do not learn as well as men.

Many of the design aspects of *The Prover (M)*'s machine came from advice from his peers, his friends, and the UA's. Having only three weeks left in the semester, he decided that he wanted to win the contest, and he made a major design change to his machine. Throughout the semester, he felt very behind in progress and in design, but finished the course feeling that he had gained a perspective on his abilities and had become braver in terms of machining. *The Prover (M)* went on to compete in seven rounds of the contest and placed second overall. He was very pleased with his success.

The Draftsman (M)

The Draftsman (M) had extensive experience with engineering drafting, designing and manufacturing during high school. At MIT, he addresses his coursework with confidence and realism about the amount of time and effort that he will need to put in.

The Draftsman (M) sees women as being more studious than men; they are more attentive in class and are better note-takers.

During the semester, *The Draftsman (M)* changed his design to make his machine more aggressive. He worked at a steady pace, following the personal schedule that he had set early in the semester. He remained confident through most of the semester, only panicking a bit while trouble-shooting. *The Draftsman (M)* lost in the third round of the contest.

The Younger Brother (M)

The Younger Brother (M) has had a very large amount of exposure to design and manufacturing; in addition to multiple high school projects, he uses machining equipment regularly at his part time job, and his parents have a small shop in their home. *The Younger Brother (M)* approaches his coursework with an attitude of over-confidence, often dismissing most of the material presented. *The Younger Brother (M)*'s older brother was the 2.007 Head Teaching Assistant last year.

The Younger Brother (M) has found men to be more skilled at hands-on, engineering-type activities, and women to be generally better at psychology, social sciences, foreign languages, and writing. Although he has no factual base for this conclusion, *The Younger Brother (M)* thinks that the average female GPA is lower than the average male GPA at

MIT. He attributes this to MIT being primarily a math, science, and engineering school, and he thinks that men are better than women in these three areas.

With little time left in the semester, *The Younger Brother (M)* simplified his machine drastically. At all points, having an impressive machine held priority over learning about the design process. He was worried about his personal progress throughout the entire semester. He was very nervous going into the contest because he felt that people had high expectations of him although he had already given up hope on the success of his machine. He lost in the first round of the contest.

The Questioner (M)

The Questioner (M) had no machining experience prior to his MIT coursework, but he seems to have intuition about the physics of mechanical design. If he becomes interested in a subject matter, he is able to learn very quickly. However, he constantly questions his abilities, his motivation, and even his choice of major.

The Questioner (M) claims to have no previously formed ideas about gender differences in learning.

The Questioner (M)'s main challenge was overcoming his feelings of inexperience. Through hard work and determination, he learned quite a bit about design and fulfilled his personal goal of learning. His self-confidence varied greatly through the semester - from feelings of independence to questioning his approach to design. He went into the contest feeling apathetic about success. He was eliminated in the first round.

The Farmer (M)

The Farmer (M) has great amounts of experience with precision machining, design, and heavy machinery; he spent a summer working in a machine shop. In addition, he grew up on a farm, working with and thoroughly understanding many types of farm machinery. He feels that his coursework teaches him how to calculate the physical principles that he already understands. *The Farmer (M)* is confident in his abilities, always striving to apply his technical knowledge.

The Farmer (M) claims to have no previously formed ideas about gender differences in learning.

The Farmer (M) approached the design process with extreme precision. He applied many of the principles that he has learned in his other courses to improve the quality of his machine through extensive technical analysis. He did not see the course as a competition with his peers, but as a chance to challenge himself. He continually reconsidered the minute details of his design in order to improve it. Since he built a machine that fulfilled his own goals rather than the course's requirements, his strategy did not allow him to score any points. *The Farmer (M)* lost in the first round of the contest.

The Female Students

The Bicyclist (F)

Aside from assembling a bicycle once, *The Bicyclist (F)* has had no experience with machining outside of her coursework at MIT. Yet she has gained a good understanding of mechanical systems from her engineering courses. She approaches her courses with enthusiasm and diligence, easily recognizing what she is learning. *The Bicyclist (F)* has a lot of self-confidence in her ideas, and can rarely be persuaded to accept defeat.

The Bicyclist (F) thinks that men know more about machines because they have had more experience. She sees society as the cause for men's higher exposure level. Despite their inexperience, *The Bicyclist (F)* feels that women are capable of learning about machines very quickly.

The Bicyclist (F) began the course with a very challenging design and a lofty strategy. She worked diligently to overcome many technical challenges and was very active in seeking guidance from professors, UA's, and peers. Throughout the course, she was proud of her learning and received much praise on her efforts from her professor. *The Bicyclist (F)* was very satisfied with her end product, but realized the difficulty of her strategy. Going into the contest, she was resigned to the possibility of losing, and was eliminated during the first round.

The Enthusiast (F)

The Enthusiast (F) has had extensive experience with machining; she is a member of MIT's Hobby Shop, she spent a summer working in MIT's Atomic Physics Department, and she cites a large amount of experience assembling LEGO structures and many pieces of household furniture. She truly enjoys solving engineering problems and has very good intuition about physical systems. She is very confident in her abilities.

The Enthusiast (F) attended an all-female high school and she thinks that a single-sex environment is more supportive for women. She does recognize that men are usually more technically-minded and that this often causes women to be overlooked in learning environments. *The Enthusiast (F)* feels that one's technical abilities are predominately due to his/her environment, and that his/her pre-determined capabilities play only a small role in determining this.

The Enthusiast (F) began and ended the semester with a relatively conservative design. She was successful in fulfilling all of her design goals due to constant reevaluation of her schedule and her manufacturing methods. *The Enthusiast (F)* made it to the second round of the contest.

The Learner (F)

The Learner (F) cites middle school and high school shop class as her only machining experience. *The Learner (F)* feels very unconfident in her design abilities and her technical knowledge, although she does seem to have some intuition about how things work. She approaches her lab courses with excitement about the prospect of learning something new.

The Learner (F) thinks that men are smarter than women. She sees the main cause of this being that women lack the confidence with respect to technical things that men have instilled in them at an early age. She thinks that while growing up, boys are encouraged to fix things and figure things out, while girls tend to shy away from mechanisms. *The Learner (F)* recognizes the benefits that might come out of having all-female sections in lab courses and of having more female role models in the shop.

The Learner (F) learned a substantial amount about design and manufacture through the course. As the semester progressed, she became more aggressive in asking questions and in solving problems. She learned to question her ideas less and to be more forward by following a personal plan. Her machine was built to be very robust and reliable. She lost in the fourth round to *The Prover (M)*.

The Planner (F)

With the exception of using her father's power drill and hand saw, *The Planner (F)* has had no machining experience outside of her coursework at MIT. She feels that she has a very poor sense of how things work. *The Planner (F)* thinks that the things she learns about manufacturing in her lab courses are much more concrete than the abstract concepts taught in the introductory Mechanical Engineering courses.

The Planner (F) feels that men are more technically knowledgeable because, when growing up, they are exposed to more mechanical systems. She sees this as a result of boys' tendencies to want to take things apart and figure them out.

The Planner (F)'s machine design remained constant throughout the semester. Lacking confidence in her design abilities, she followed the course recommendations and did a lot of work on paper before beginning to build. Having planned her machine, her manufacturing process, and her personal schedule in advance, she was very successful in completing a robust machine in a timely manner. *The Planner (F)* made it to the fourth round of the contest.

The Professors

The Young Professor

The Young Professor teaches with a "hands-on" approach. He feels that an essential part of teaching is having genuine concern for the students and their learning. He thinks that it is important to be supportive, but to also be realistic; he often plays devil's advocate. He tries to generate high expectation for his students.

In relation to success in this course, *The Young Professor* has seen that women are more conservative in their ideas, designing safe machines, while men design machines that are more complex and impressive. As far as learning styles go, he sees women as being shy and lacking the confidence that their male counterparts have.

The Young Professor's Students

The Younger Brother (M)
The Questioner (M)
The Farmer (M)
The Learner (F)
The Planner (F)

These five students make up one Rohrbach grading group. They all worked very closely, trading ideas and suggestions.

The Course 6 Professor

The Course 6 Professor tries to interact with his students very frequently, giving them continual feedback on their progress. He also encourages the students to give him feedback on his teaching. He tries to set a clear pathway for the students, defining all of the steps that must be followed in order to finish a project or to learn a subject.

The Course 6 Professor observes that women tend to be more deliberate in their designing and planning, choosing a design and sticking with it. The men are more likely to make radical changes to their machines. Also, very few of the women's machines were designed to be aggressive, while the men's machines are much more competitive. *The Course 6 Professor*'s idea about learning styles is that women work really hard at one method of solving a problem, while men try many different approaches until they find the best solution.

***The Course 6 Professor's* Students**

The Prover (M)
The Draftsman (M)
The Bicyclist (F)
The Enthusiast (F)

These students are not in the same grading groups. *The Enthusiast (F)* and *The Bicyclist (F)* seemed to work together quite often.

Why Is this Course Important?

The students were asked:

"As designed by the department, what do you think this class is supposed to teach you? What do you feel that you are learning from this class?
What do you see as the lecturer's role in the course? Your section professor? Your UA's? How well do you see these roles being carried out?
What responsibilities do you feel that you have as a student in contributing to your own learning? How well do you see yourself fulfilling these responsibilities?"

The professors were asked:

"What do you see as the section professor's role in 2.007? How well do you feel you fulfilled that role?
What do you see as the student's role in adding to his/her own learning? Did you see many of your students doing this?
What do you see as the department's goals for this course? What are student's supposed to learn? Do you whole-heartedly agree with these goals? What are your personal goals for how to teach this course?"

There is overwhelming agreement among the students and the professors about the purpose of the course, and the roles of the professors and the students. The only source of variance was the students' definitions of what they actually learned in the course.

The students and professors alike see the main goals of the course as matching the goals in the course material. The consensus was that the purpose of 2.007 is to expose undergraduates to machining and physical applications of their technical coursework while introducing the design process, instilling confidence in technical abilities, and teaching personal project management.

The section professor's role is seen as this: To take the broad ideas presented in lecture and scale them down into specific physical implementations. The students mostly all felt that the professor's main task is to give guidance on individual machines while keeping the students motivated. The professors agree, seeing their role as helping the students put theory into practice through the design process.

The Prover (M), *The Draftsman (M)*, *The Bicyclist (F)*, and *The Planner (F)* cite machining as their main take-away from the course, while *The Questioner (M)*, *The Enthusiast (F)*, *The Younger Brother (M)*, *The Farmer (M)* and *The Learner (F)* recognize issues such as time management, personal motivation, and process plans. So while the students accurately recognize the educational goals of the course, they can also recognize whether or not their actual learning coincides with the goals. Furthermore, it is the professor's responsibility to evaluate the course goals and to gauge the level of learning among the students in relation to these goals.

What Are We Learning?

The students were asked:

"There is much to be learned from 2.007, including technical, social, and strategic concepts. Please list the specific concepts to which you have been exposed, indicating those which you feel you understand."

The answers varied from simple machining and design concepts to general ideas about how to work with others effectively. The main division of responses can be linked to the progress of the students in the course, their feelings about their own abilities, and their prior experience with design and manufacture. The majority of the students answered with a combination of machining/design principles and general concepts that will help them get through this course and many other projects in the future.

The machining principles that were presented to me as being learned and understood were all relatively simple, showing that most of the learning was the result of the students' day-to-day work in lab. Only *The Draftsman (M)*, *The Farmer (M)*, and *The Questioner (M)* spoke of concepts that they have absorbed from the course but have not actually used in the building of their machines. They seem to be genuinely interested in learning about design; whereas the other six students are focused upon learning only those principles that will help them reach the goal of finishing their machines. It is unfortunate that so few of the students see the importance of all the concepts that are being presented in the course, as this approach to learning would help them the most in their futures as engineers.

The answers about general concepts were very different. While all of the students who have had limited prior experience with design have learned simple machining concepts, they cited the general problem solving and group interaction concepts as being the major things that they will take away from the course.

Among those students with prior experience in design and manufacturing, it seemed as though that didn't really feel that they had learned to apply any of the general concepts. Yet, they answered me with many "big picture" answers, as if they were identifying those things that they knew they were supposed to be learning and applying For example, *The Younger Brother (M)*, *The Farmer (M)*, and *The Enthusiast (F)* all seem to feel that they aren't applying many things that they are learning much from this course; they seem to be using the machining skills that they already had. Still, these three all proceeded to tell me that they were learning the importance of things like asking questions, planning ahead, and keeping their designs simple. I cannot say they have truly learned the importance of any of these concepts, but only that they know what learned concepts the professors think are important.

Getting Over the Hurdles

The students were asked:

"Please look at all details of each component that you have constructed. Identify any difficulties that you encountered in design or construction. Try to explain how you solved each problem." They were then given examples of explanations - brute force, the help of others, further calculations, etc.

The students identified many different ways in which they solved the problems with their machines. The responses varied between getting help from peers, UA's, and professors to mechanical intuition to still being without a solution. There was a wide separation between the students who felt that problem solving is a simple step in design and those who have difficulty in even identifying methods with which to approach their difficulties.

The Draftsman (M), *The Younger Brother (M)*, *The Farmer (M)* and *The Enthusiast (F)* all solve problems independently, while the other students state that they get most of their solutions from their peers. *The Questioner (M)* was the only one to identify lecture as a source of problem solving information. *The Prover (M)* went as far as saying that he often hits standstills when designing on his own, and *The Bicyclist (F)* identified self-intuition as an additional source for ideas. While they both admitted to knowing that it is not the best method of problem solving, both *The Learner (F)* and *The Planner (F)* cited brute force as their main method of problem solving.

The students with the most experience seem to have rational reasons for their problem solving methods. For example, *The Enthusiast (F)* prefers to solve problems on her own rather than asking different people and having to decide between their varied advice. Further, the students with the most experience seem to be the most independent in their problem solving - seeing most problems as simple and most solutions as requiring that they "just" do the obvious.

The students with the least experience are the most hesitant in their solutions. For example, *The Questioner (M)* thinks that he solves problems the wrong way, meaning that the complex solution is the wrong one. The inexperienced students do not recognize that through solving their design problems, they are learning about how to design elegantly.

Another factor in the problem solving process is the ability to recognize problems. For example, *The Planner (F)* states that because she planned her machine very well in advance, she is not encountering many problems. In direct contrast to this , *The Farmer (M)* feels that he has planned very well, but always comes up with new ideas for how to attack each design issue. It seems that *The Farmer (M)*'s exposure to and experience with mechanical design allows him to constantly redesign his machine through continual problem solving while *The Planner (F)* sees the design process as a precursor to problem solving.

How Successful We Feel

The students were asked:

"Looking back, would you have designed your machine differently? If yes, how so? What do you think you could have done differently to make 2.007 a better experience for you? What do you think your professor thought of your overall performance? Of your machine?"

The professors were asked:

"Please evaluate your interaction with each of the following students. Include comments on your satisfaction with their performance in the class and in the contest and your satisfaction with their individual learning."

Very few students achieved complete success in this course; this is because complete success involves the design process, the physical machine, the contest, and the learning process. All of the students, however, were successful in some area of the course. Their ideas for how they might have improved their experience in the course are indicative of what they see as their personal potential. Further, it is interesting to examine the evaluation of how each student thinks his/her professor viewed his/her success in comparison with the professors' actual views.

In reference to how the students think that they could have improved their experiences in the course, most of the answers referred to improvements in strategy and design, and in scheduling. *The Prover (M)*, *The Draftsman (M)*, *The Bicyclist (F)*, and *The Planner (F)* all think that they would have been more successful if they had started designing and/or building earlier. *The Younger Brother (M)* and *The Farmer (M)* would have re-evaluated their point-scoring strategies in order to have been more successful in the contest. Only *The Questioner (M)* and *The Enthusiast (F)* felt very satisfied with their work and would not change much in their personal learning process. Finally, *The Learner (F)* cited the desire to have more confidence throughout the learning process.

There is overwhelming agreement between what the students think their professors think about their success and what the professors actual say about each student's learning. By considering how a professor might view his/her progress, the students were able to speak about their work objectively. Yet, the students do not seem to realize how much they learned throughout the semester.

Considering that each student's learning was successful in some form of the definition, there are clear divisions between the types of learning that the professors identified. *The Younger Brother (M)*, *The Draftsman (M)*, *The Enthusiast (F)*, and *The Farmer (M)* entered the course with considerable design experience; they were all confident in their abilities and had little trouble in the course. According to their professors, each of them learned more about designing and manufacturing, but only *The Younger Brother (M)* and *The Farmer (M)* learned much about the iterative design process; thrc ugh their troubleshooting and design revisions they each learned of the importance of planning ahead.

According to their professors, each of the five less-experienced students learned much about the design process also. But more importantly, these five - *The Prover (M)*, *The Bicyclist (F)*, *The Questioner (M)*, *The Learner (F)*, and *The Planner (F)* - were most successful in gaining confidence in their technical abilities. Once they overcame the feelings of inexperience, each of these students excelled in the learning and implementation of the design process.

Summary

Having considered many of the factors that are indicative of a student's learning, the generalization can be made that experience is the single most influential factor. In addition, if a student has a lack of confidence in his/her abilities due to a lack of experience, his/her learning will be greatly hindered. Having identified and understood these factors, it is necessary to recommend changes to the education process that will account for their presence.

Through the correlation of experience with learned concepts and skills, problem solving approaches, and feelings of success, it is apparent that if we can compensate for a student's lack of experience, we will greatly improve his/her learning experience. In fact, the Mechanical Engineering curriculum attempts to do this by requiring a pre-requisite to this course that exposes the students to machining equipment and practices. Without the presence of the pre-requisite, the inexperienced students would be at an immeasurable disadvantage. However, there must be further action taken to increase students interests in mechanical systems as early as possible. Though the presence of seminars and workshops at the university will reach some of the students, society as a whole must encourage all students - young and old, male and female - to be inquisitive through continual exposure to new concepts.

Students can only learn when they feel comfortable with their current abilities. Often, a student's confidence in himself/herself is affected by many factors other than his/her actual abilities. Due to societal pressures, women are trained to question their abilities without cause. With this understood, it is very important to reinforce a student's feelings of confidence before expecting him/her to apply his/her knowledge. Through positive reinforcement, a student's confidence will become stronger, allowing him/her to pursue further learning. This responsibility falls upon teachers of every kind: educators, parents, and peers.

Through the study conducted, a key example of how the lack of self-confidence can affect the learning process was made apparent. When the students came upon problems in their designs, they had to spend considerable time redesigning, and often rebuilding parts of their machines. This process is an important part of the learning experience, forcing the students to question their design reasoning and to reevaluate their person scheduling. When faced with such design problems, though, the women with no previous design experience showed little confidence in their problem solving abilities. They were overcome with feelings of failure and they wanted to just give up on their projects. However, all of the men, regardless of their experience level, would work diligently when they were faced with such a problem. The inexperienced men did not question their abilities, but recognized their lack of knowledge and continued to work at the learning process.

It is essential that the education system begin to actively address the issues that hinder students' learning. Although education at MIT is of the highest caliber in the world, if the needs of just one student are neglected, we are failing as an educational institution. Information is only as valuable as the person who understands it; the quality of an education must be measured by the learning experience of the students.

To understand how a student learns, it is important to consider the source of his/her personal motivation to learn. The study of students enrolled in this course has proven to be very fruitful in this aspect; the students were either motivated by the competition factor of the course, by the pure satisfaction that they felt in themselves and in their design achievements, or by a combination of the two. In the case of these nine students, there was overwhelming proof that that men were motivated by the presence of the contest at the end of the course, while the women were motivated by the increased feeling of satisfaction in themselves and in their machines. Whenever possible, it is important to design and implement courses that will appeal to the different motivational factors within students.

Through experimentation with different learning environments, we might be able to find what works. "Hands-on" atmospheres have proven to be the most effective in teaching of students with all levels of experience, but we cannot stop here. To appeal to the many different learning styles represented by today's students, we must try different lecture styles, smaller groups, and new project ideas. We must pursue many alternative styles of teaching to effectively accommodate the many alternative styles of learning.

If professors continue to teach "at" students rather that "to" students, they are neglecting the needs of their customers - not a good practice for the education business. A mode of receiving continual feedback must be established. In order to adapt the teaching process to the students' needs, educators must evaluate the status of their students on a regular basis. The establishment of smaller, more dynamic teaching groups will allow for further communication between the students and their teachers. When the entire educational community's general awareness of the boundaries that students face rises and when a serious commitment is made to overcoming those boundaries, we will be able to begin to address the differences between the learning capabilities and styles of all students.

Notes

Course 2 - Department of Mechanical Engineering

Course 6 - Department of Electrical Engineering and Computer Science

Quality of Study

While every effort was made to make the results of this study reliable and complete, there are a few factors that were out of my control. My personal interaction with the participants and the limits of time are the major factors.

Having weekly meetings with the students, my presence might have affected their performance in some way. When asked about this possibility, a few said that my questioning made them more aware of their progress in the course and motivated them to work harder. A few said that the only effect that my study had on them was the introduction of the gender differences in learning, causing them to think about what changes could be made to the curriculum to enhance women's learning. The majority of the students cited no effect.

Also, each student's comfort-level with me may have affected his/her willingness to share his/her experiences with me. I had been associated with some of the students before the study began, and I feel that this allowed them to be more open with me. The students whom I did not know before the study initially told me less about their backgrounds and about their feelings of personal progress. By the end of the semester, though, I could see no difference in the amount of information that the students would tell me.

My very presence in lab affected the way that both of the professors behaved toward the students. When questioned about this, *The Young Professor* said that his knowledge of my study raised his awareness of gender differences in learning, but did not affect his teaching styles. *The Course 6 Professor* said that my study did not affect his perception or his behavior at all.

Pursuing this study presented me with many challenges. Working on this project alone limited my ability to address many of the minute details of each student's learning process; I was unable to spend enough time with the students to see every learning stage through which they went.