Engineering Education, Beyond the Books

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Abstract

This paper will focus on the process and benefits students receive through practical manufacturing experience. Included in the paper are two examples of small projects that can be completed in 1-2 hours, yet still provide a valuable introduction to the machining process. The Purdue hammer project, which is produced in a sophomore introduction to mechanical design course, is a brass hammer with a wood handle. Using hexagonal brass stock, the students learn drilling and milling, while they create the hole for the handle. The lathe is used to chamfer and to turn the work piece down to length. Other machines used are the grinder, polishing wheel, press, and a CNC mill. A more simplified project is the Purdue cardholder project. After milling a piece of aluminum bar stock into the shape of a cardholder, students learn different finishing techniques, pressing, and CNC milling. Once students completed the projects described in this paper, information was gathered in the form of a survey. The students' opinions of machining the projects were then consolidated and included in this paper. The results showed that working in the machine shop "help[ed] to remove the intimidation of the shop itself." Other results include: the students' fear of using the machines declined, the extent at which they knew the machines increased from 2.4 to 3.7 and 1.9 to 3.8 on a 5 point Likert Scale, they enjoyed the opportunity to get their hands dirty, and they saw the experience as a valuable learning tool. However, the thing the students liked best was "the fact that [they] had something material to bring home and say 'I made this in class'." The two things that they liked the least were "only get[ting] one day in the shop" and "leaving the shop."

I. Introduction

Since the practice of engineering began people qualified and willing were taught the skills needed to provide good engineering solutions. "In the past, most of the incoming students had considerable hands on experience, and it could be assumed that students had some experience with basic tools and common machinery. Today, however, students generally have little or no exposure to mechanical devices. Instead, students may have much more experience with computers," [1] leaving a knowledge gap that needs to be filled. University of Michigan conducted a survey of alumni, and the results clearly showed that the majority of the respondents do not feel the University prepares them well in the areas that are most important to them, manufacturing [1]. Not only do universities need to provide graduating engineers with analytical training and training in the design process, they need to teach all the tools required to complete a design. Students have difficulties designing parts that are inexpensive and easily produced because they lack hands-on manufacturing experience. Building manufacturing experiences into the core curriculum will provide engineers that are better equipped to make good design decisions. Purdue University has implemented many projects throughout the mechanical engineering curriculum that provide hands-on experiences. The current paper will discuss two machining projects that have been implemented on a large scale, resulting in numerous benefits for the students, focusing on the process and benefits students receive through practical manufacturing experience.

In this paper, a brief background of the two classes that have implemented manufacturing projects on a large scale is presented. Two specific examples of projects that have been implemented, the Purdue Hammer Project and the Purdue Cardholder Project, are discussed. The results of student surveys are presented, including the comments students shared.

II. Class Background

The introduction to manufacturing processes could be included in a variety of classes. The mechanical engineering curriculum at Purdue University includes a sophomore level design course, focused on an introduction to the design process. The ethnic data for this course can be seen in figure 1 (No African-American or Hispanic students were enrolled in the semester the data was collected). Due to the fact that the course is a requirement for graduation, roughly 120 students enroll in the course every semester, 88% of which are male and 12% female. In an effort to reinforce the lectures using hands-on experiences, a lab also accompanies the lectures. In the labs the students are provided with design problems that require they use material learned in lecture, such as Decision Matrices, Gantt Charts, and a variety of other tools. An integral part of design is understanding the manufacturing process. Therefore, the design course devotes a few lectures to show videos on the different manufacturing options. Following the goals of providing hands-on experiences, one lab is set aside to practice machining. The project chosen is the Purdue Hammer. The details will be described in Section III.

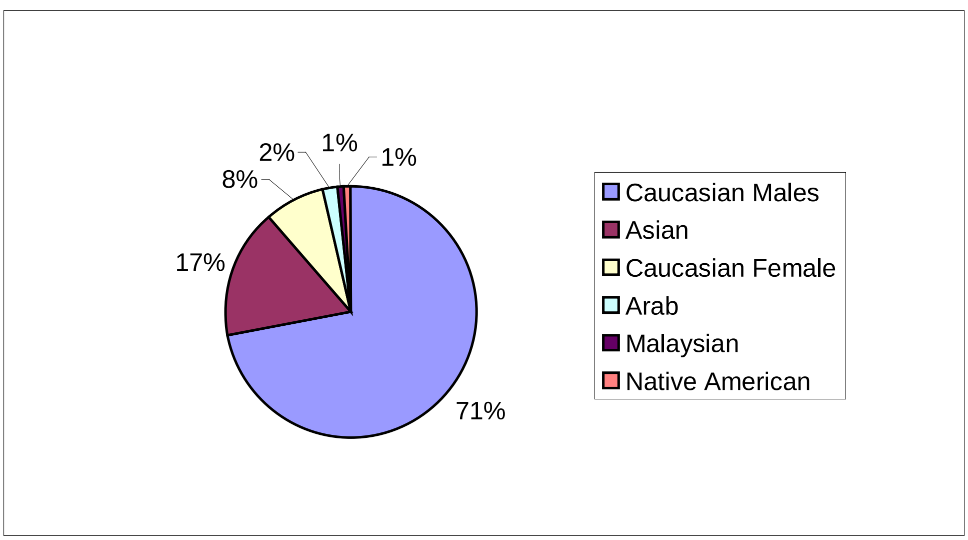

Figure 1. Ethnic Data

The two and a half hundred students enrolled in an interdisciplinary course titled, Engineering Projects In Community Services (EPICS), have the option of milling the second project discussed, the Purdue Cardholder. EPICS is a design course that brings together students of different disciplines to provide free engineering for community service agencies. The teams consist of approximately ten to fifteen students with majors ranging from education to various engineering disciplines. Accompanying the labs is a lecture. Due to the diversity of majors taking the course, it can be difficult to present material that is the same value to all students. For this reason, students are allowed to substitute workshops for lecture credit. One of the workshops offered to the students is the Milling Workshop. During this workshop, students will learn to use the mill while making a cardholder. Details will be described in Section IV.

Above are listed two classes that have incorporated practical manufacturing experiences into the course curriculum. At each university there are a variety of courses that relate to manufacturing. Whether the class requires students to create a prototype or a test setup, understanding different aspects of manufacturing is a definite asset to mechanical engineering students. All of these experiences will aid in their development as engineers. As can be imagined, there are plenty of opportunities throughout a standard curriculum to incorporate manufacturing experiences.

III. Purdue hammer

Included in the current paper are two examples of small projects that can be completed in 1-2 hours, yet still provide a valuable introduction to the machining process. A laboratory or machine shop should have the instrumentation and machines to provide significant hands-on experience for students. Machining is not an observer's sport [2] and needs the proper amount of supervision to provide a safe environment. The Purdue hammer project, which is introduced in a sophomore introduction to mechanical design course, discussed earlier, is a brass hammer with a wood handle. Using hexagonal brass stock, the students learn drilling and milling, while they create the hole for the handle. The exact dimensions can be seen on the drawing below (Figure 2).

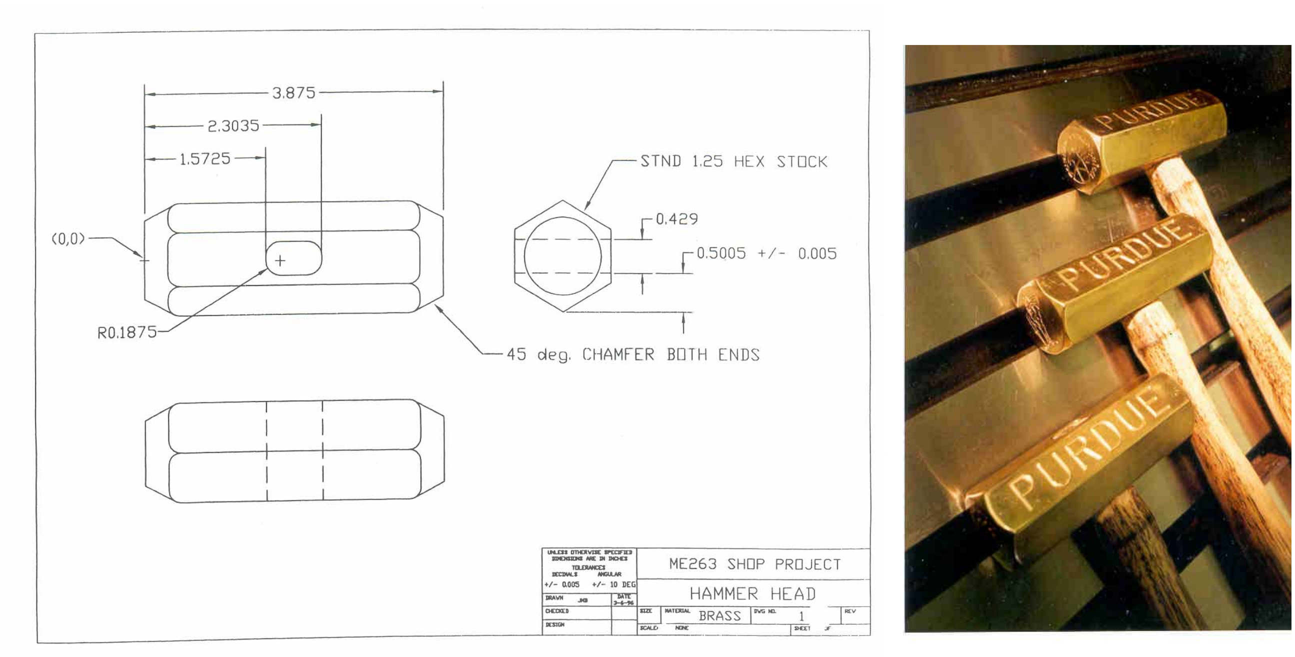

Figure 2. Purdue Hammer

Students learn the benefits of peck drilling and the correct direction to feed a cutter, as they remove material to form the hole for the handle. The lathe is used to turn the work piece down to length and to chamfer the edges. The project is set up so that either the milling or the lathe portion can be done first, preventing a backlog of students waiting on one machine. A CNC mill is used to write PURDUE on the side of the hammer, which could be substituted with a stamp if a CNC is not available. The final step is grinding and polishing. Students learn first hand that the smoothness of the finish is directly related to the amount of time spent on the grinding and polishing wheels, emphasizing that a fine finish takes time and money. Once completed the proud students have a hammer that they made and can take with them.

The cost of the material and cutters used in creating each hammer is $10.49. For a detailed break down of the cost for one hammer see below (Figure 3). Special end drill/mill cutters are used for milling the slot in the brass, and standard ball end mills are used to write PURDUE. However, standard cutters could be used, which would reduce the cost. For less then $10.50, each Purdue University mechanical engineering student has a memento of the time they spent working towards their undergraduate degree.

Brass Hex Stock	$4.87
Hammer Handle	$2.84
Cutters	+ $2.78
Total	$10.49

Figure 3. Cost of a Hammer

IV. Purdue cardholder

A cheaper more simplified project is the Purdue cardholder project. Again this project was developed with two criteria in mind. First, the project need to be easily accomplished in one to two hours, and second, the students should have something that they can be proud to take with them. This second criteria implies that the project be fairly cheep to complete. The entire cost of the cardholder is under $5.00 for each. A complete cost breakdown can be seen below (Figure 4). Three flute 5/8-inch cutters with extra long flute lengths were used. Standard cutters could be used and would be cheaper. Upon coming into the shop, students are given a piece of one and half by two inch bar aluminum stock. The stock is already cut to the four inch length the students need, and the students are informed of the processes and time it took to machine the piece to the proper length. If more time is available, students could be required to measure and cut the work piece to length. The following drawings (figure 5) are handed out and education on the mill begins.

Block Aluminum	$3.12
Cutters	+ $1.27
Total	$4.39

Figure 4. Cost of a Cardholder

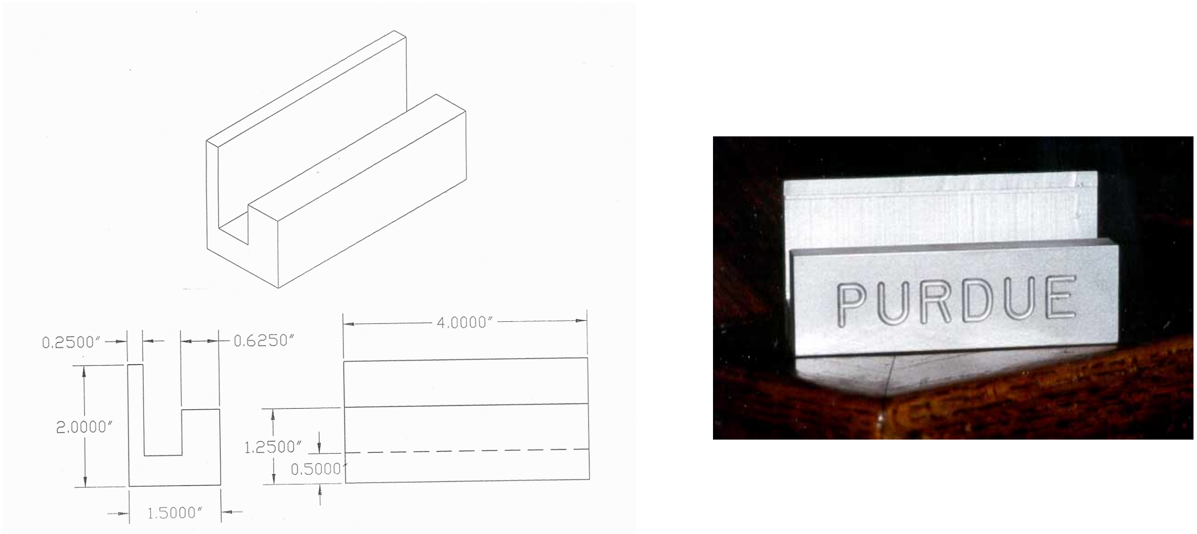

Figure 3. Purdue Cardholder

After instruction on safety, how the milling machines work, how to determine the correct feed rate, and the correct directions to machine, the students begin milling the piece of aluminum into the shape of a cardholder. Once the manual machining is completed, the students learn about the different finishing techniques available to them, as well as the benefits and drawbacks to finishing before using the press or CNC mill. The students are encouraged to make their own decision as to what order they would like to complete the process and which finishing technique to use. A CNC mill is used to write PURDUE on the front of the cardholder, which could also be completed with a stamp. The finishing is completed, resulting in a cardholder the students take with them.

V. Survey Results

Once students completed the projects described in Sections III and IV, information was gathered in the form of a survey. Using a 5 point Likert Scale, questions were asked to determine how well the students were instructed, their level of knowledge about the machines, as well as, how valuable they felt the experience was. Comments were encouraged, and the students' opinions of machining the projects were then consolidated.

The data collected was tallied into four headings. First, all of the data was totaled and averages were calculated for six questions: level of knowledge before, level of knowledge after, level of instruction, level of assistance, value of the experience, and the level of fear experienced during machining. The results for all the females were then separated from those of the males, added and averaged. These two groups will be compared later in the paper. The next two groups calculated were minorities and Caucasian males, which will also be discussed later in the paper. The results for all of the above mentioned groups are displayed on the chart below.

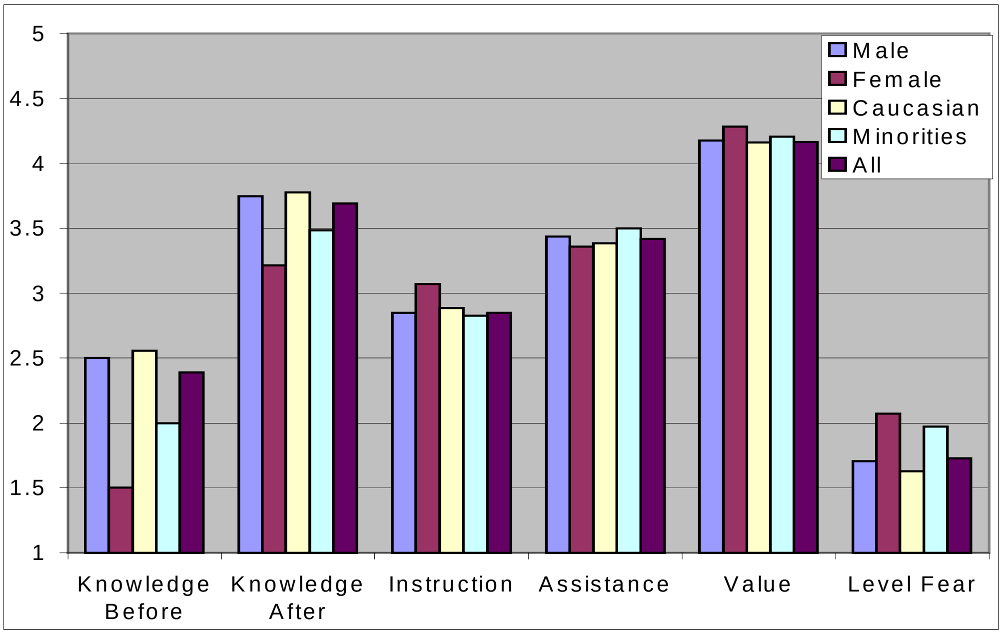

Figure 4. Data From All Groups

There were several areas where all of the groups had similar responses. The first two areas were instruction and assistance. A score of “one” corresponded to “Too Little,” while a score of “five” represented “Too Much.” Therefore, a score of three would represent the perfect level. The level of instruction was approximately a 2.8, while the level of assistance was a 3.4, suggesting that the balance of instruction and assistance was about right for the students. The final area that received similar responses from all groups was the value of the experience. All of the groups rated the experience as being very valuable with a score of approximately 4.2, indicating that students believe that the practical experience is important. To fully understand the rest of the data it becomes important to break it up into several charts.

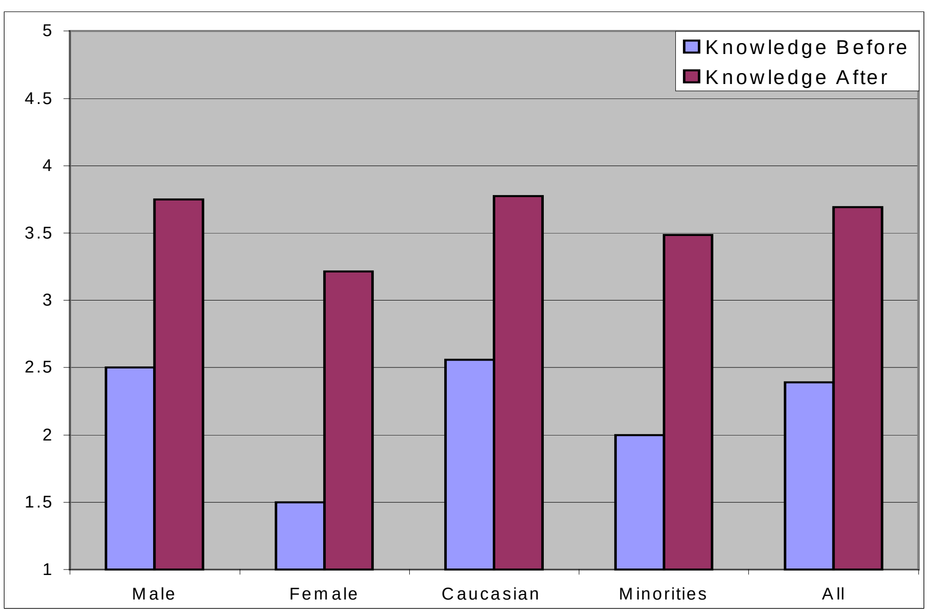

Figure 5. Increase in Knowledge

Figure 5 represents the amount students' knowledge increased over the course of the project. All of the different groups increase over an entire point. However, some groups increased more then others. The lowest increase was the Caucasian males, from 2.6 to 3.8. While the largest increase was that of the females, starting at only 1.5 and increasing to 3.2. Minorities also had substantial increases on over 1.5 points.

Throughout history people have emphasized the differences between males and females. Therefore it is only natural that any differences between genders be discussed. Below is a chart of the male and female responses to the six categories (Figure 6).

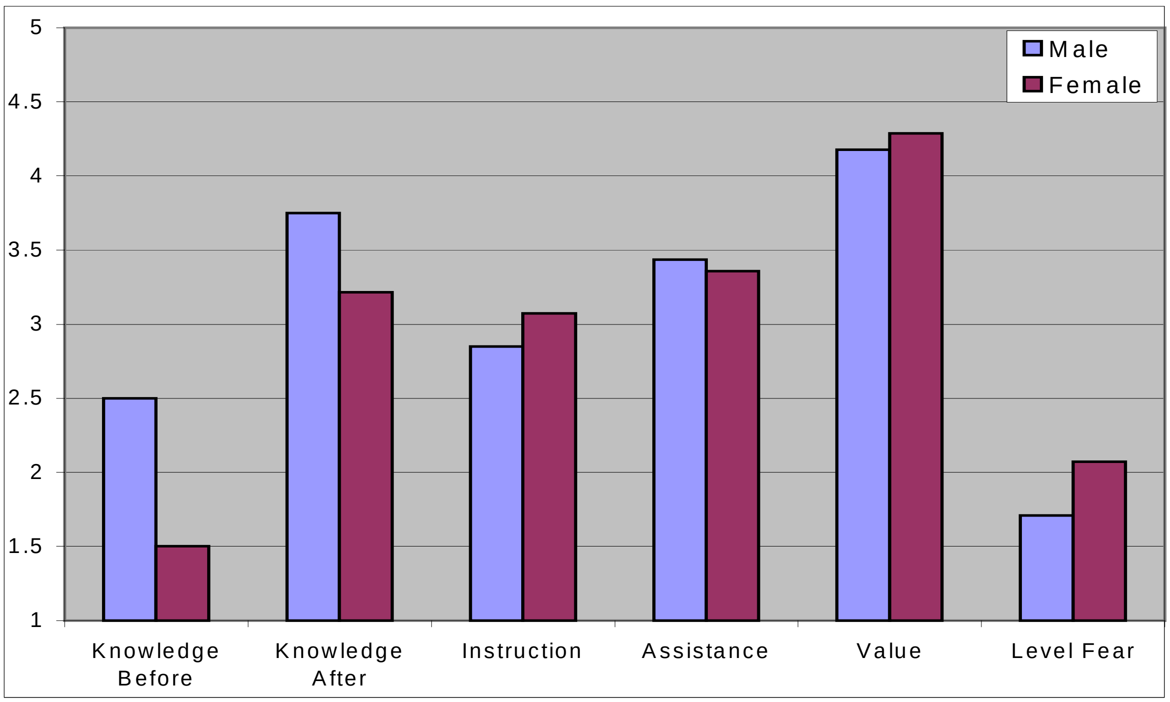

Figure 6. Male and Female

Looking at the data it becomes apparent that females believe they don't know as much as the males to start, 1.5 as opposed to 2.5. However, the females have a greater increase in knowledge, increasing to 3.2, while the males increase to 3.7. The other point worth mentioning is that the females have a higher level of fear while using the machines, approximately 2.1 as opposed to 1.7 (Figure 6).

Not only is it important to compare the female and males, but also the minorities and the Caucasian males. The Caucasian males make up over 70% of the class; therefore, it is important to see what the other 30% think. Below is a chart of the response given by both minorities and Caucasian males (Figure 7).

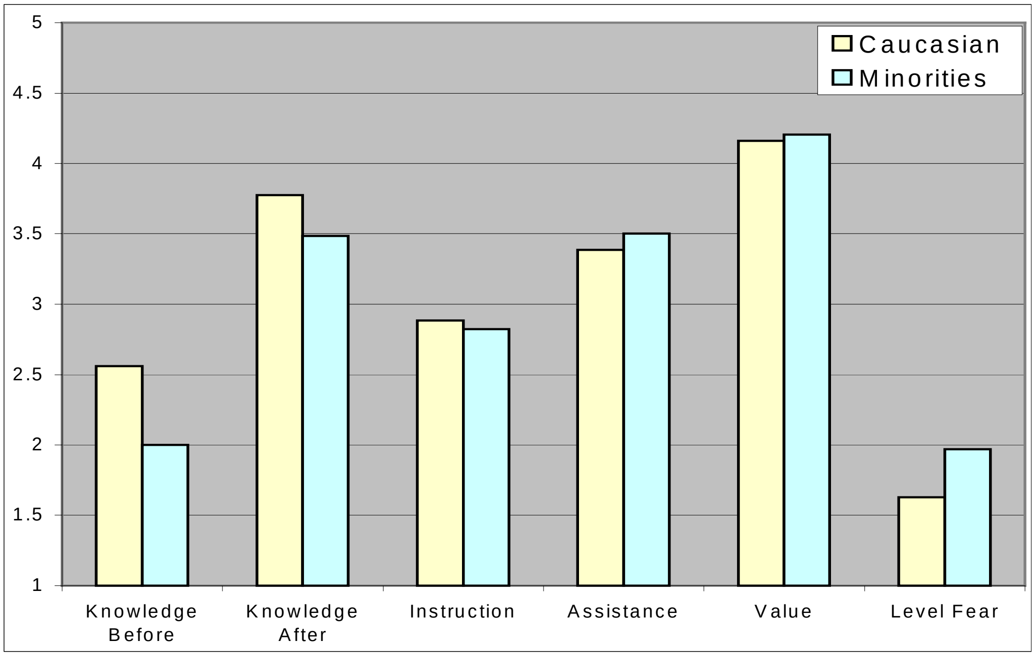

Figure 7. Caucasian and Minorities

The minorities are very consistent with the results seen by the females. They begin with a lower knowledge then the Caucasian males, 2 as opposed to 2.6, and also had a higher level of fear then the Caucasian males, 2.0 instead of 1.7 (Figure 7). However, the minorities had a higher knowledge after machining, approximately 3.5, which is higher then the females 3.1, but not as high as the Caucasian males of 3.8. The level of instruction, assistance, and value are all consistent with what was seen earlier.

VI. Students' Comments

The results showed that working in the machine shop "help[ed] to remove the intimidation of the shop itself." The students' fear of using the machines declined, and the extent at which they knew the machines increased substantially. They enjoyed the opportunity to get their hands dirty, and they saw the experience as a valuable learning tool. Below are some of the comments students wrote when asked:

What did you like best?

- finished product
- hands-on experience using common machines
- I was able to take the hammer with me
- getting to work on something real
- the impressiveness of the CHC being able to be programmed
- the experience - I've never used those machines before
- just building something was fun, in class we don't ever get to build things & it was a greatly appreciated change of pace
- I didn't really know anything, so it was a really good hands-on learning experience and it was fun.

- I really understand how it works after the workshop and it was really fun.
- doing something in practice not theory
- I would like to go into the shop a lot more often
- meeting [the people that run the shop] so I can get more experience with the machines outside of class
- This was a good project because we got a chance to see mfg. processes - something I would think we need but haven't seen up close until now.

What did you like least?

- doing this project at 7:30am
- having to clean up
- only one deliverable like this
- no refreshments
- the length of time it took
- leaving the shop
- the goggles
- it went so quick
- we only get one day in the shop

The comments make it apparent that the thing the students liked best was "the fact that [they] had something material to bring home and say 'I made this in class'." The two things that they liked the least were "only get[ting] one day in the shop" and "leaving the shop."

VII. Conclusions

Making the students' feel comfortable, so that they have little fear while using the machines is extremely important. In order to obtain a comfortable atmosphere, the level of instruction and assistance needs to be balanced, allowing the students to learn by operating the machines themselves. The females and minorities showed the highest level of fear while using the machines, which could be due to one of two reasons. Females in general are less familiar with large pieces of equipment, making them less comfortable around the manufacturing equipment used. Why then are the minority males more afraid then the Caucasian males. Manufacturing and machining use a whole new set of vocabulary, which may be unfamiliar to students who's native language is not English, causing occasional verbal communication difficulties. The results showed the level of instruction and assistant to be 2.8 and 3.4. Therefore, the level of instruction and assistance was almost the perfect amount. As a student put it, "you held our hands just enough."

As with any course, it is important that the students learn. The results showed that whether the student was Caucasian, Asian, male, or female, their knowledge of manufacturing increased, making them more well-rounded engineers. Determining the exact cause as to why one gender or ethnic group learns more than another is speculation. Possible vocabulary deficiencies were mentioned earlier, which could certainly cause a person to feel as though they do not understand the material as well as others. Studies have shown that given both males and females of equal education, the females often rate their abilities lower then males rate their abilities, which could certainly be a factor in self evaluation. Regardless, everyone felt their level of knowledge increased, which is the goal of the exercise.

VIII. Acknowledgements

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