LEARNING FROM THE EXPERIENCES OF WOMEN AND UNDER REPRESENTED MINORITIES IN A FIRST YEAR PROGRAMMING COURSE

Author:

Helen Burn, University of Michigan, Ann Arbor, MI, 48109, hburn@umich.edu

***Abstract* —** *This study combined quantitative and qualitative data to explore what helps and hinders students enrolled in Engineering 101: Introduction to Computers and Programming, a required course for engineering majors at the University of Michigan. The objective of the course is to introduce students to programming (C++ and Matlab) and algorithmic thinking. The study resulted from a collaborative effort between faculty in the College of Engineering and researchers in the School of Education aimed at increasing retention of women and under represented minorities. Online surveys were administered during the first and eighth week of the fall semester, 2003, to 185 students enrolled in the lead instructor's section of the course. Information captured by the surveys suggested motivational problems associated with the course and possible over reliance by students on a newly deployed "autotester" designed to provide students with instant feedback on their computer code. Concern over the survey results inspired 20 semi structured interviews with students in the course. The sample included 12 female and 8 male students. Six of the student in the sample identified themselves as African American, two as Latino, eight as Caucasian, and four as Asian/Asian Americans. Thematic coding captured categories and themes that emerged from the interviews, including motivational problems, ineffective use of group work, and possible over reliance on the autotester. Particularly alarming was the perception by the majority of the respondents that learning to program was not important to their identity as engineers, and that they did not view programming as useful to their educational or career goals. The paper presents results from both the surveys and the interviews, using a conceptual framework derived from the literature on teaching first year students, student motivation, and large class formats. Differences by race and gender are included in the analysis. The paper includes suggestions for improving student motivation and for more effectively using group work and the autotester.*

***Index Terms* —** *first year experience, programming, women, under represented minorities.*

INTRODUCTION

Engineering 101: Introduction to Computers and Programming is a required course for all engineering majors at the University of Michigan. Engineering 101 [Engin 101] is designed to develop open ended thinking skills, and to enhance problem solving skills. Having students create and write programs using C++ and Matlab develops these skills. The vast majority of the students in the course are first year students.

In the fall of 2003, the Hewlett Packard Corporation provided funding for an Engineering/Computer Science Retention Initiative. The Retention Initiative was based on evidence of differential success rates in first year courses. Specifically, in Engineering 101, there was a reported .7 gap in average course GPA between under represented minorities (African American, Hispanic/Latino, and Native American students) and majority students (white and Asian/Asian American), and a .4 gap between females and males. Further, between 1999 and 2002, "12% of students in Engin 101 received a grade of C minus or below, while 29% of minority students received a grade of C minus or below" [22]. As such, Engin 101 was believed to be discouraging, rather than inspiring, women and under represented minorities to pursue degrees in engineering.

As part of the Retention Initiative, a research team formed comprising members of the College of Engineering and the Center for the Study of Higher and Postsecondary Education at The University of Michigan. I was assigned to be a member of that team as part of my graduate research assistantship. Surveys were administered during the first and eighth week of fall semester of 2003 to all students (n=185) enrolled in the lead instructor's two sections of Engin 101. The surveys were designed to capture student background characteristics, self assessed ability levels, commitment to engineering, and to determine how helpful they found the resources for the course, such as lectures, labs, assignments, exams, and the autotester. The survey results, which are discussed in a separate section of this paper, provided helpful information but also raised some concerns and questions. Unfortunately, the small number of under represented minorities and in the class made subgroup analysis of the surveys difficult.

Further, an "autotester" was deployed during fall semester of 2003 to provide student with instant feedback on their homework assignments. Midway through the course, homework grades had increased over previous semesters, but exam scores were not rising commensurately. This led the research team to suspect that students may be over relying on the autotester and to wonder if it was hindering the achievement of course goals.

In an attempt to understand how students experience Engin 101, I did over 20 classroom observations during fall of 2003. The large lecture format and scant discussion in the lab sections made it difficult to understand how students were experiencing the course material. As a result, I proposed a qualitative study to identify factors that help or hinder the success of students in Engin 101, with particular attention paid to women and under represented minorities. The bulk of the data for the study came from twenty semi structured interviews with students in Engin 101 conducted between November of 2003 and February of 2004. The interviews explored many questions and facets of students' experiences in Engin 101. The following areas form the scope of this paper: (1) organization of the course, (2) respondents' major and commitment to engineering, (3) programming experience, (4) respondents' perception of the relevance of the course and expectations for programming in the future, (5) respondents' use of group work, and (6) exams. Differences by gender and race/ethnicity are explored.

LITERATURE REVIEW

Under representation of Minorities and Women in Engineering

Institutions of higher education in the United States continue to work to increase the number of students choosing to be engineering majors. Many efforts are aimed at getting more African American, Hispanic or Latino, and female students interested in engineering, as these groups have traditionally been under represented in engineering [4]. In the past, concern about under represented groups was inspired by a belief in equity in education. While equity continues to be a factor, the rhetoric of today centers on warnings that increasing global competition makes our nation's dependence on foreign born science and engineering talent untenable. This claim, combined with the changing demographics of the United States, makes it imperative that success rates improve among students from groups traditionally under represented in engineering [16]. An additional argument about the importance of a diverse engineering workforce is that the *quality* of engineering is affected by diversity. Specifically, finding the best engineering solution requires a diversity of perspectives and life experiences [25].

Large Class Formats

Colleges and universities are choosing to redesign their introductory engineering courses given abundant evidence that first year experiences are causing them to change their plans rather than inspiring students to continue on in engineering [19]-[23]. A major factor in their decision is the quality of teaching students experience in introductory courses, which are typically taught in a large lecture format [19]. A 1994 study conducted at the University of Maryland revealed a general dissatisfaction with large class learning experiences [3]-[5]. Students' complaints included (1) lack of interaction with faculty in and outside of class, (2) lack of structure in lectures, (3) dissatisfaction with discussion sections and teaching assistants, (4) inadequate classroom facilities and environment, and (5) lack of frequent testing or grading. This study revealed that over half (56%) disagreed or strongly disagreed with the statement "The size of the class does not affect my ability to learn." Further studies reveal that students report that large classes result in less individual accountability, a more impersonal environment, and decreased student motivation [5]-[26].

Large class formats also make it more difficult to attend to different learning styles and may encourage rote learning or memorizing at the expense of instructional goals such as retention of information, development of thinking skills, and changes in motivation or attitudes [13]. In fact, research suggests engineering faculty learning styles differ sharply from those of their students. For example, a study using the Myers Briggs Type Indicator*TM* revealed that 64% of the faculty were intuitive thinkers, whereas intuitive thinkers comprised only 30% of the students. Further, 70% of the students were extroverted compared with less than half (46%) of the faculty [10]-[15].

First Year Students

In addition to the difficulties posed by large class learning experiences, introductory engineering courses are populated by first year students who are experiencing the transition from high school to college. For these students, many of whom have chosen their majors with little knowledge of the field, it is important to engage their curiosity, stimulate their interest, engage them in intellectual experiences, and involve them in college activities [8]. Personal relationships with faculty are important for first year students, although the expectation of strong faculty student relationships may be "rooted in [students'] genuine anxiety about their ability to perform according to strict and impersonal academic standards" [8] (p. 9).

First year students typically come to college needing a new approach to learning and often have poor study habits and time management skills. These students need to be taught explicit thinking and problem solving strategies in conjunction with subject matter content [11]-[14]. Textbooks become an extremely important resource for students, particularly in large classes, where opportunities to ask questions may be limited. However, first year students may need to be taught strategies for reading a textbook effectively. In addition, these students are encountering an entirely new social circle and need help focusing on their academic life rather than the demands of their new social life. Ideally, these issues would be addressed on some level in introductory courses, although this places new requirements on faculty members, teaching assistants, or on the institution to provide support networks outside the classroom.

Grades are particularly important to first year students. For many of these students, getting good grades in their first semester is their only indicator that they fit in and are adjusting to college life. Receiving even one failing grade can indicate to a first year student that they do not belong [8]. Reference [20] showed that early academic success is particularly vital to under represented groups. Their study of minority students at predominately white campuses revealed that these students were more negatively affected by a fear of failing their families and their communities than their non minority counterparts. In addition, these students were more reluctant to seek academic support because they had never had to seek help before. This latter finding may apply to many high achieving first year students regardless of race or ethnicity.

Differential Preparation of Women and Minorities in Computer Science

The literature on gender and race differences with respect to prior programming and computer experience is germane to this study because programming and computers form the core of Engineering 101. While women surf the web at rates comparable to men, fewer women than men enroll in programming or advanced computer science classes in high school [12]. As a result, they arrive at university less prepared, less interested, and less knowledgeable about programming and computers in general.

Minority preparation in computer science is linked to socioeconomic status [SES]. Students in lower SES schools have less access to computers and to teachers adequately prepared in computer science [9]. Further, students from under represented groups may also suffer from "stereotype threat" [21]. Specifically, when students find themselves in a situation where negative stereotypes about their group apply—such as women not being good at computers—this creates a "stereotype threat," which can lead to disidentification and poor performance in the field. Students disidentify by retreating from a field and by not relating success in the field to their self identity.

There is also evidence that women have specific needs that should be considered if the goal of retaining these students in engineering is to be realized. Reference [2] suggests that women may be more empathetic in their approach to learning and more interested in making connections and collaborating. While faculty members in general support the presence of women in the classroom, they tend to interact more often with male students and respond more favorably to their comments [1]. Women may be less vocal in class, less willing to express their opinion and more likely to be silent as they listen to a discussion.

Motivation and Self Regulated Learning

Students not caring about their work, procrastinating, lacking interest, and overemphasizing their grades at the expense of learning can be partially explained by the literature on student motivation and self regulated learning [17]-[18]. Self regulated learning involves planning, goal setting, monitoring, metacognitive awareness, student efforts to control and regulate various aspects of the behavior or task, and reaction or reflection after the task is completed. Both motivation and self regulated learning need to be present for true learning and understanding to occur [18].

A well researched model of student motivation is Wigfield and Eccles' expectancy/value model [24]. "Expectancy" refers to expectancy for success or how well students believe they will do on a task. This is also referred to in the literature as *self efficacy*. Students' expectancy for success is a strong predictor of their performance. As an example, if students perceive they are unlikely to be successful on an exam, they will be less likely to study for the test [18].

The "value" component of the expectancy value model refers to task value and relates to whether a student cares about a task. High levels of task value have been shown to be positively associated with high self regulation and higher levels of achievement [18]. Value is broken down into four components: (1) attainment value or importance, (2) intrinsic value or interest, (3) utility value or usefulness of the task, and (4) cost [24].

"Attainment value" pertains to identity issues and the personal importance to the student of doing well on a task. Students view tasks as important when they view them as connected to their sense of self. For example, first year engineering students will believe a task is important if engaging in the task reflects on their identity as an engineer or as a student at the University of Michigan. Gender identity also comes into play when talking about attainment value since tasks offer opportunities to demonstrate aspects of one's self conception, such as masculinity or femininity.

"Intrinsic value" pertains to the enjoyment a student gains from doing a task. Intrinsic value relates to interest and intrinsic motivation. Interest has been shown to be course specific. In fact, Pintrich and Zusho [18] state that students generally are not interested in courses at a global level, yet an individual course or topic within a course can activate interest. Students who are self regulated learners are able to control their interest in a task by finding ways to make it more interesting and can persist in the face of an uninteresting task.

"Utility value" or "usefulness" is connected to how a task fits into students' future plans. For example, students will be more motivated to engage in an assigned task if they believe it is relevant to their future academic or career goals. Students may perceive some course assignments as more useful than others and as a result be more or less engaged in the task.

Finally, "cost" refers to the sacrifices the individual makes in completing a task. For example, is it worth it to a student to study sufficiently to receive an A on an exam? Negative aspects of doing a task, such as fear of failure or success, are considered when conceptualizing of cost. Students develop coping strategies to avoid failure, such as choosing easy tasks, over relying on groups, or procrastinating. For example, students who procrastinate in studying for an exam are able to attribute their lack of success to their procrastination rather than their aptitude. Alternatively, if they are successful on the exam, they can attribute their success to superior aptitude.

The nature of academic tasks and reward structure of a course are also shown to influence motivation and self regulation which in turn affect academic achievement. Ideally, tasks should be challenging to the students but within the range of most students' capabilities. While there is much evidence that students working cooperatively to accomplish tasks can increase their sense of self efficacy and interest, promote cognitive engagement, lower anxiety, and increase performance, cooperative work is most beneficial when students are held individually accountable for their work [18].

This study seeks to understand what helps and hinders students' learning in Engin 101 by listening to and analyzing the interviews of 20 students enrolled in Engin 101 during fall semester of 2003. As I conducted and analyzed the interviews, I hoped that themes would emerged that might suggest ways to increase exam scores and retention. Throughout this paper, I refer to the interviewees as "respondents," and unless otherwise stated, the respondents are first year students. Although the interviews explored many questions and facets of students' experiences in Engin 101, the following areas form the scope of this paper: (1) organization of the course, (2) respondents' major and commitment to engineering, (3) programming experience, (4) respondents' perception of the relevance of the course and expectations for programming in the future, (5) respondents' use of group work, and (6) exams. Differences by gender and race are explored.

METHODS

Research design

This study primarily uses qualitative methods: semi structured interviews, an analysis of assignments and exams, and classroom observations. I conceived of the study after analyzing quantitative surveys administered as part of an Engineering/Computer Science Student Retention Initiative. The results of the survey that inspired the interviews are discussed briefly in a separate section. The research team from this project agreed that student interviews would be useful in clarifying and expanding on the results of the survey. IRB approval was received for the study.

Sample Selection

Table I shows the race and gender of the respondents. All of these students, with the exception of one who dropped, completed the course during fall of 2003.

TABLE I
RESPONDENTS IN THE STUDY

	African American	Hispanic/Latino	Asian/Asian American	White	Total
Female	4	0	3	5	12
Male	2	2	1	3	8
Total	6	2	4	8	20

I was interested in interviewing as many under represented minorities (African Americans and Hispanic/Latino(a)s) as possible. I sampled from students who participated in the initial and/or follow up survey. Only 7 under represented minorities responded to both the initial and follow up surveys. To increase the number of under represented minorities, I invited via email all of the under represented minorities who participated in the initial survey to participate in interviews ($n=17$). I received 10 responses. I made the judgment that two female students from this group who identified themselves as "other" were white. I made this judgment after completing the interview, and it was based largely on appearance. I chose not to ask these students about their survey response. Thus, 8 of the respondents were under represented minorities.

For the remainder of the sample, I used a random number generator to choose from the pool of students who identified themselves as Asian/Asian American or white, and who had completed both the initial and follow up surveys. I randomly selected 8 students who identified themselves as Asian/Asian American and 8 students who identified themselves as white. The remaining 10 interviews came from among these 16 students. The College of Engineering' Minority Engineering Program Office provided a $25 incentive per student to participate in the interviews

Situating the researcher

I feel it is important to situate myself in this process. I am a mathematics faculty member at a community college in Seattle, Washington. I am on professional leave and halfway through the doctoral program at the Center for the Study of Higher and Postsecondary Education at the University of Michigan. My interest is in improving undergraduate mathematics and science teaching and learning. It is my personal belief that many more students can succeed in mathematics and science than currently do. This belief is based on my success and the success of my colleagues in helping unmotivated students learn mathematics in a community college environment. I tend not to place blame on students for their lack of success in math and science, because I feel faculty have not fully explored ways to improve instruction and student motivation. I believe the respondents sensed that I was sympathetic when they expressed difficulty with Engin 101, and this allowed them to openly share their experiences.

Second, I am new to the field of social science, and this is my first qualitative study. This, combined with my status as a white female, made me feel ill equipped to address the issues of race/ethnicity in these interviews in any significant way. Thus, readers expecting a sophisticated treatment of race/ethnicity may be disappointed by my analysis. However, differences by race/ethnicity did reveal themselves, and I do discuss them.

Data Collection

Data was collected from several sources, including a document analysis, classroom observations, quantitative surveys, and semi structured interviews.

Prior to the interviews, I reviewed the weekly assignments and exams from the past two semesters for Engin 101 so that I could understand more fully the objectives and expectations of the course. To better understand the flow of the course, expectations of the course, and to develop a deeper understanding of the skills and concepts required to complete the weekly assignments, I did 10 observations in the summer of 2003 of a summer bridge program for minority students entering the University of Michigan in fall of 2003. Beginning in fall of 2003, I did classroom observations of the lecture and lab sections of Engin 101. In addition, I met with several staff members in the college of engineering for informal interviews. Dr. Malone is the lead instructor for Engin 101, and I visited his lecture section 11 times during September and October of 2003. In addition, I twice visited a second section of Engin 101 taught by a different instructor.

Three graduate student instructors [GSIs] taught lab sections for the lead instructor. I visited the lab sections of two of the GSIs—Edward and Phillip—extensively to see what transpired in their labs, to get a sense for how the labs flowed with the lectures, and to get further insight into areas of student difficulty. I visited Edward's lab 6 times and Phillip's lab 5 times during September and October of 2003. These observations helped me understand what was required of the students to complete the weekly assignments and also to see the classroom environment. I believed these observations would enable me to make suggestions about why students—particularly women and under represented minorities—might be having difficulty with Engin 101. However, students were typically silent during lectures, and there was little student interaction during labs I visited. This fact, in addition to wanting to clarify the survey results, inspired me to propose conducting interviews.

All 185 students enrolled the lead instructor's sections of Engin101 in fall of 2003 were administered an initial survey at the end of the first week of the semester and a follow up survey during the eighth week of the semester. Both times, I attended class to invite students to participate in the survey. The response rate was 88% (162/185) for the initial survey and 69% (127/185) for the follow up survey. A total of 119 (64%) of the students participated in both the initial and follow up surveys. I designed the surveys with the help of my advisor, Dr. Eric Dey, and Dr. Malone. The survey results will be brought into my analysis as appropriate.

The majority of the data for this study come from semi structured interviews of 20 students enrolled in Engin 101 during fall semester of 2003. Five interviews were conducted during November and December of 2003, and the remaining 15 took place during winter semester and were completed by mid February, 2004.

I met with the respondents at local coffee shops on central campus at a time chosen by them. Many of them recognized me from my classroom observations. As such, students knew me as someone working on a project aimed at improving the course. During the interviews, respondents seemed appreciative of my efforts and very willing to share their stories. I believe that students were honest with me during the interviews, and I alert the reader when I feel this was not the case. Although most students did have suggestions for improving the course, several were clear in indicating that they thought the course provided them with an excellent introduction to computers and programming.

The interview protocol was informed by the document analysis, classroom observations, and surveys. The interviews began by asking students why they decided to take Engin 101, how committed they were to being an engineering major, and what type of programming or computer experience they had coming into the course. Next, I asked students what they noticed about the transition from high school to college. I also asked students what they liked and disliked, what they felt helped and hindered their learning. After several interviews, I added to the interview protocol to ask what students gained from the various components of the class (lectures, labs, textbook, weekly assignments, exams, and the autotester) based on suggestions in the literature [19]. Asking students what they gained provided deeper information than asking what they liked or disliked and what they felt helped or hindered their learning.

Coding

I analyzed the interviews by first listening to the taped interviews, reviewing my interview notes, and then doing thematic coding [6] using NVivo software. The thematic coding involved reading through each interview individually and highlighting and saving the sections of the interviews according to the topic being discussed. For example, I created a file that contained all references students made to their prior programming experience. In the end, I had over 30 categories or themes. These themes included programming experience, interest in computers, relevance of the course, and numerous other categories related to students' comments on lectures, labs, etc. I decided to create as many categories as possible so that this data can be used in future research. I next looked at each of these categories and, if necessary, refined them or created new categories. For example, in exploring the category "programming experience," I created two new categories: "help for novices" and "experienced programmers."

Analysis

My analysis began as I listened to the taped interviews and reviewed my interview notes. After completing my coding, I reviewed each category or theme. For a particular category—for example, students' commitment to engineering—I created a spreadsheet and made notes on each student's response. Simultaneously, I also picked out quotes that I thought were relevant. For some themes, I had information for each of the 20 respondents. For others, only some students volunteered information. When possible, I made counts of responses. For example, I counted the number of students who were highly committed to engineering. Although I reviewed all categories, the major categories or themes used in this paper are: instruction, major, commitment to engineering, programming and computer experience, perceived relevance and utility of Engin101, use of groups, and exams. I took the information from the spreadsheets and quotes and wrote integrative memos on each theme. These integrative memos form the basis of the findings section. I present the respondents' quotes verbatim, with only minor editing for ease of reading. I use the long dash "—" or ellipses to indicate a pause, hesitation, or false start by the student. I use the convention […] to indicate that I omitted portions of the text or my question. All names of respondents, instructors, and GSIs were changed to protect confidentiality.

Significance, Benefits, and Limitations of the Research

The goal of this research is to inform the Engineering/Computer Science Student Retention Initiative and to provide faculty and staff in the College of Engineering with possible reasons for the differential success rates of students in Engin 101. In addition, this "first swipe" at the interview data will provide me with ideas for further analysis. A limitation of this study is clearly the sample size. Admittedly, a sample of 20 students is not representative. To ameliorate this, I triangulate my findings with survey results when possible. My hope is that my methods and analysis are clear and cogent such that the reader can see that, although possibly not representative, this research has useful insights and information to share.

Finally, it was during the analysis of the interviews that I realized the relevance of the student motivation literature to this project. As I delved into that literature, I became aware that self regulated learning is intimately connected to student motivation, both of which affect persistence and achievement. While my findings include a discussion of student motivation, I do not believe the respondents provided enough information for me to comment on their self regulated learning.

FINDINGS

I begin with an explanation of how Engin 101 is organized and the respondents' perception of the organization. This section captures what respondents said about the textbook and the autotester. Next, I address how the respondents talked about their majors, their commitment to being engineering majors, and their prior programming experience. Following this, I explore how the students perceive Engin 101 as relevant, or not, to their future academic or career goals. I then analyze the different ways respondents used group work in completing the weekly assignments for the course. Finally, I present findings with respect to exams.

Organization of Engin 101

Engin 101 is designed to develop open ended thinking skills, to enhance problem solving skills, and to use those skills in creating algorithms using the programming languages C++ and Matlab. Engin 101 begins with C++ and switches to Matlab during the final month of the course. Students are offered three weekly lectures (Monday, Wednesday, and Friday) in a large lecture hall on North Campus. Dr. Malone was the lead instructor for the course and taught two sections of Engin 101 during fall semester of 2003. Each section had roughly 100 students. In addition to the lectures, students are assigned in groups of 25 to a lab section run by a graduate student instructor [GSI]. Dr. Malone's had three GSIs during fall semester of 2003: two white males and one Asian male. The course syllabus, course information, and weekly assignments are available on a course website [6] and it is expected that students access information via the website. The lectures and labs are designed to provide students with instruction sufficient to complete the weekly assignments and to prepare students for exams. There are two textbooks for the course, one for C++ and one for Matlab.

Dr. Malone is a very animated and energetic professor, and most of the respondents commented positively about this during the interviews and indicated this helped keep their attention during lecture. Several respondents indicated the large lecture format did not fit their learning style and was an unwelcome change from high school. However, these same respondents appreciated the energy and enthusiasm of Dr. Malone and the GSIs. During the lecture, Dr. Malone writes on the white board with large markers and often projects computer code for the students. This code is available to the students via the course website. During the lecture, Dr. Malone fields students' questions. Lab sections met twice weekly at various times in a computer lab in the basement of Pierpont Commons. The two GSIs I observed—Edward and Phillip—had different styles of conducting labs. In the classes I observed, Edward tended to begin with a brief clarification of the lecture and then spend the remainder of the class walking around fielding individual questions. Alternatively, Phillip began by presenting students with a formal exercise designed to help them with the weekly assignment and spent considerably more time lecturing.

Fifty percent of the student's grade is based on weekly assignments that require students to write computer algorithms to solve problems that typically come from physics or calculus. The respondents told me that these weekly assignments comprised the bulk of their work during the semester. The remaining 50% of their grade is based on six hours of in class exams. Students had access to Dr. Malone and the GSIs outside of class. Dr. Malone met with students after lecture in the atrium outside the lecture hall and during office hours. The GSIs had office hours at various times during the week. In addition, Supplemental Instruction sessions run by the Minority Engineering Program Office were offered three times per week on Central Campus. These were open to all students. Only 35% (7/20) of the respondents had heard of the Supplemental Instruction; and of these, only 3 indicated they attended any sessions. Group work is not required in the course. Finally, new this semester, students had access to an autotester to get instant feedback on the computer code they wrote for their weekly assignment. Students could use the autotester an unlimited number of times.

The vast majority of respondents spoke positively about the instruction and organization of the course. When I asked the respondents what they liked about Engin 101, the most popular response was the professor and/or the GSIs. With a few minor exceptions, all of the respondents felt the labs and lectures were well coordinated. The respondents varied with respect to whether they felt they gained more from the lecture or from the lab; but between the two formats, most of them felt they received adequate instruction. Respondents tended to state that the coordination "works pretty well" or is "all right." This echoes the survey findings, where 82% of the survey respondents agreed that the instruction they received in lecture and lab was adequate to prepare them to do the weekly assignments, and well over 90% of the survey respondents agreed that the content and grading of the exams and weekly assignments was fair.

All of the respondents indicated the autotester was helpful in completing the weekly assignments. One student called the autotester her "best friend." Most respondents indicated that they used the error information given by the autotester. However, I did not get the impression that most of the respondents could test their own code without the autotester. For example, when I asked Rachael, a white female, if she understood what the autotester did to their code, she replied, "I guess I really don't. I guess it just goes...it takes our...what we're putting in, and actually does what the assignment's asking us to do.

Just checks to make sure the numbers are right." This quote does not indicate that Rachael fully understands that the autotester is running test cases on her code. In fact, I do not feel the respondents in general could test their own code by hand in the absence of the autotester. I think more explicit instruction in this might help students be more successful on their pencil and paper exams. Catherine, a white female who volunteered that she received an A minus in the course, stated

> Like the weekly assignments, you could solve problems using the autotester. But even if you didn't have the autotester, you know what I mean, you could still run through and put a bunch of "couts" in the computer code to see what it was doing when it...when it was running through. And in the exam, you just...you just had to write down and cross your fingers. That's how I felt at least personally.

At the request of Dr. Malone in January of 2004, I began asking students how many times, on average, they used the autotester per assignment. I directly asked 13 respondents about this. Roughly 40% (5/13) said they used it less than 5 times per assignment, and a similar percentage used it between 5 and 10 times. Three of the respondents indicated they used the autotester more than 10 times.

The surveys suggested that the students did not find the C++ textbook helpful. Specifically, 77% of the survey respondents found the C++ textbook somewhat or not at all helpful. This finding also emerged in the interviews, where 75% (15/20) made negative comments about the textbook. In general, those dissatisfied with the textbook indicated they wanted a "normal textbook" with "straight forward text" that told them "here is what you type in, here is what it does." They tended to want more things bolded or broken down into boxes. About half (8/15) of the respondents indicated that they rarely or never used the book and, when they did, it was just as a quick reference.

Major and Commitment

Respondents were asked directly about their major and their commitment to engineering. A complete list of the respondents' choice of major, along with their gender and race/ethnicity, is contained in Appendix A. Of the 20 respondents, only two males—one Hispanic/Latino and one white—indicated an interest in majoring in computer science or electrical engineering. The sole Asian male respondent was undecided but was possibly interested in one of these majors. At the time of the interview, he was enrolled in EECS 280, a required course for EECS (electrical engineering/computer science) majors. None of the female respondents indicated an interest in computer science or electrical engineering. The most popular majors indicated by respondents were Industrial and Operations Engineering [IOE], mechanical, and chemical engineering. Overall, half of the respondents indicated a strong commitment to being an engineering major. Table II lists the commitment level indicated by the respondents. The categories in Table II were created by me based on responses to the question, "How committed are you to engineering?"

TABLE II
RESPONDENTS' COMMITMENT TO ENGINEERING

	URM*		Majority	
Commitment Level	Female	Males	Females	Males
Committed to being an engineering	1	4	2	3
Using engineering as a stepping stone	0	0	3	0
Unsure what else they would do	0	0	2	1
Thinking about switching	2	0	1	0
Already switched	1	0	0	0

*Under Represented Minorities

I learned from these interviews that there is a difference between being committed to engineering and being committed to being an engineering major. Three white female students were primarily interested in using engineering as a stepping stone into careers in medicine, business, or law. Two male respondents—one African American and one Hispanic/Latino—also indicated they were primarily interested in business and aimed to complete an MBA after completing the IOE program. This is a degree path offered in engineering, so I categorized these two respondents as being committed to engineering rather than using it primarily as a stepping stone.

One of these respondents was Sam, an Hispanic/Latino student majoring in industrial engineering. In response to a question about his level of commitment to engineering, Sam responded that he is extremely committed to engineering and told me directly that he is "not planning on leaving." Later, he revealed his interest in business. I present this quote from Sam because it was echoed by several students and indicates their perception that a degree in engineering provides many career options. This quote also reveals some preconceptions Sam has about the intellectual merit of engineering as opposed to other subjects. Sam said,

> Engineering is ideal for someone, I think, who has the capacity for, you know, a lot of these harder subjects but doesn't...isn't particularly sure, doesn't want to commit to anything in particular. Because, you know, there's a huge possibility to get people from engineering to law, engineering to med school, but you don't have to be in pre med, you don't have to be in pre law. Or you can just do something mechanical, something scientific. I mean, there's just a lot of options with engineering. Yet they're all...it's just most everyone there is more the intellectual types, so it's just sort of like a variety of degrees that I can go with. I didn't have to decide right away. So it's still like topnotch, you know, education, you know, as far as what I'm getting out of it.

Gender and racial differences appear in Table II. Fully 88% (7/8) of the male respondents indicated a strong commitment to engineering compared with 25% (3/12) of the female respondents. This phenomenon also appeared on the initial surveys (*n*=162) that asked students how committed they were to engineering when they entered the University of Michigan: extremely, very, somewhat, or not at all. Males were significantly more likely ($p<.05$) to be extremely committed (78% versus 61%) , and women were more likely to be somewhat or not at all (39% versus 22%)

The three respondents who thought about switching were female: two African American and one white. Rachael, a white student, indicated that she was discouraged by her performance in calculus this semester, and this was causing her to question whether she could succeed in the mathematics required for engineering. However, she also stated that, "plus, like the Engin 101 class, I don't like computers very much…so that's kind of steering me away from it." A second student who was thinking about switching is an African American female named Lisa, a 2^{nd} year engineering student majoring in aerospace. Although Lisa finds aerospace engineering interesting, she is on her second attempt at Engineering 101, has experienced difficulties learning to program, and indicated she is not very committed to engineering and thinks about switching majors.

The final respondent who was thinking about switching majors, an African American female named Hannah, has not yet switched out of engineering but is considering it. Hannah indicated her dad, two older brothers, and older sister all went into engineering, although her sister later got out of engineering. Hannah took mostly science and math based classes in high school and attended summer engineering programs in high school. She was my second interview and was very open at the outset that she did not want to be an engineer. While I do not pretend to know what percentage of students fall into this category, and I do not mean to suggest that minority or female students disproportionately do, Hannah does fit a stereotype of someone steered into engineering but not interested in engineering. Hannah said,

> Um, my whole family's engineers, so I want to get out. But I have scholarships that I need, so that's why I'm in…in engineering. […] I have applied to engineering, so I have no…I was very undecided. So my dad said, "You might as well just pick something to go into." And we like had kind of arguments. So I just went into it for now. And I applied to engineering scholarships, so I'm kind of just stuck in there right now. […] I'm on an engineering [scholarship] and I'm on a general one. So that's why I'm in engineering. I really do want to get out. […] Like, I like being outdoors, and I like the environment, so I was thinking of going to like the school of natural resources. […] So, I don't know. I like that, or I want to go into like history or something like that. That's what I'm interested in, kind of. I like to read, and I like to…I just don't…I don't like math, I don't like science at all. I don't like science. Math is okay. But it's just…It's really no point for me to be in engineering because I don't like it, so…

Finally, one student had already made the choice to switch out of engineering—an African American student named Elaine. Elaine was positive about her experience in Engineering 101, and she said she chose to switch majors because doing so provided her with a shorter path towards her goal of getting into medical school. Overall, three out of four African American females interviewed had a low commitment to engineering.

Programming Experience

The literature reveals gender difference in programming experience and interest in computers [12]. The initial survey revealed these gender differences, with males being more likely than females to agree that they were proficient in programming (p=.026). These differences also revealed themselves during the interviews when respondents were asked about their programming experience. During each interview, I noted the programming experience of the respondent. As I coded the transcribed interviews, I recorded their programming experience and checked for accuracy by comparing to my original notes. Exactly half of the respondents came to Engineering 101 with prior programming. Table III displays the programming experience of the respondents in the sample, by gender and race.

TABLE III
RESPONDENTS' PROGRAMMING EXPERIENCE

	URM*		Majority	
	Female	Males	Females	Males
Yes	3	2	2	3
No	1	2	6	1

*Under represented Minorities

The female respondents were less likely than the males to have programming experience. Specifically, 42% (5/12) of the females had programming experience compared to 62% (5/8) of the males. None of the Asian/Asian American respondents had programming experience. Most of the students with programming experience received it in high school courses. Five of the under represented minorities in the sample indicated they had programming experience (three African American females, one African American male, and one Hispanic/Latino male). Two of the African American respondents, one male and one female, received their experience in the summer programs offered in advance of fall semester. Although they indicated they benefited from the summer programs, they both said they might have been overconfident during the first month because the material was mostly review. Once they encountered new material, they course became more difficult and they had to adjust.

Two of the male respondents had considerable experience in working with computers, and both were considering majoring in CSE or EECS. Curtis, a white male, did not test out of the course yet had considerable prior experience with programming. He talks below about how he felt about the workload in Engineering 101.

> Um, the workload was really light. Probably because I'm like pretty good at programming, and I might want to go into CSE. Um, so to me it seemed pretty light. I'm also really good at math and since like the point of the course is about algorithms rather than programming necessarily, that was one of the things that like he [Dr. Malone] would point out. You know, like for me the homework load seems really light, but that's because it was like the kind of stuff that I like to do. Like figuring out how to make this into a program, and I'm like (snaps fingers) easy.

Programming experience and familiarity with computers are not sufficient conditions for finding the course easy. A second student, Michael, an Hispanic/Latino male, started a computer business while in high school. Michael told me he found the weekly assignments and exams difficult, which he took as a signal that he might need to reconsider his choice to go into EECS.

> So I mean, I've always loved computers and so I just figured EECS might be a good one to go into. EECS 280, the next class up in programming they say is just like amazingly hard, and they like say this one's like a joke compared to it. So, I mean, looking at that aspect it makes me kind of be like, you know, I'll steer clear of the EECS major, you know, and maybe go into something a little more...a little more general like mechanical or industrial.

Several of the novice programmers stated they needed more help on the basic of programming at the beginning of the semester. For example, Sam, a Hispanic/Latino student, had no prior programming experience yet was successful in the course. In fact, he said that he eventually found it to be fun and "enjoyed the whole algorithm perspective." However, Sam stated,

> Um, it was tough to start out. I could have used more base knowledge in a different way. Not necessarily more time, but more structure. Like just give me a sheet with the tools that you're expecting me to find out and understand what this thing means. You know, sort of make a checklist of things to understand the basics to write a code […] You know, there needs to be a little help for those who have no idea what they're in.

The majority of the respondents lacked experience with computers apart from word processing and web surfing. However, they were in general interested in computers and liked working with computers. Only three students, all white females, directly stated their disinterest in, but not dislike of, computers. As an example, Leslie, a white, second year student, speaks of liking computers but not being particularly interested in them and not having significant experience with computers. Leslie took Engin 101 during her second year because of a personal emergency that occurred during her first year. Leslie plans to go to medical school. I described to Leslie that several students indicated their interest in computers and that they looked forward to Engin 101 because they wanted to know more about how computers worked. Leslie said,

> Leslie: Oh, no. No, no, no, no, no, no. That is not me. No. I'm glad I can turn a computer on. […] I can basically do anything with Microsoft and I can find anything on the Web. Minesweeper, too. I love that. I do. It's not...I'm not one of the students that's particularly...it's just not one of my fields of fascination is how computers work or...I mean, we take a lot of math classes. They incorporate computers. And it's really amazing the stuff that the computers can do. It's just...a lot of the guys are into like using these computers

for like whipping up stuff. And the girls are just like sitting there. "You go ahead and type," you know, "we'll just sit here and we'll kind of add input."

Q: Are you talking about in this class or in other classes?

Leslie: In this class and others.

This quote also reveals her perception of gender differences with respect to computers. Instructors in Engin 101 should be aware of these tendencies and directly address them with students to ensure that female students are actively engaged in their learning.

Perceptions of Relevance of Engin 101 and Expectations for Programming in the Future

This was for me one of the most interesting findings from the interviews. Prior to the interviews, through speaking with staff in the College of Engineering, I became aware of the possibility that students did not perceive Engin 101 as relevant to their future academic or career goals. Because of this, both the initial and follow up surveys asked the question, "I can see/imagine how the ideas from this class will be applied in my future career." On the initial survey (n=162), 74% agreed with this statement. On the follow up survey administered during the eighth week of the semester (n=127), 50% of the students agreed with this statement. I calculated the mean differences in response to this question for the students who completed both surveys (n=119). These students as a whole showed a significant decrease (p=.00) of .50 (on a scale of 1 to 5, strongly disagree to strongly agree) in response to this question. There was no significant difference by gender. However, for under represented minorities, there was a 1.38 decrease in the mean response to this question, which was a significant difference from majority students (p=.01). This question caused concern, and I addressed it directly with students in the interviews.

During the interviews, 75% (15/20) of the respondents indicated not seeing the relevance of the course. Students expressed both their own opinions and their perceptions of how other students felt. For example, in my interview with Leslie, I reminded her of the question on the survey. Without allowing me to finish my question, she stated, "And I'm guessing a lot of people said they...they disagreed." Leslie went on to say,

> Yeah. I know at least when they came in taking the survey, they were like, "You know, I don't really understand it now, but I'm sure as this semester goes on I'll realize how this has relevance to engineering." And then it kept going on. I don't think anyone really saw...If you were going into electrical engineering or computer science, it really had a lot of relevance. But to people that were going into industrial or mechanic...well, or mechanical or biomed or chem, we're all not really sure what the relevance was to our...our field of study. I know that a lot of it had to do with...I know the main purpose of the course was not programming but learning how to...about algorithms. Even so, I...it wasn't extremely...I don't think it mattered to us, anyway, and I don't think it really was...will have any relevance in my career […] It was basically "I want to be an engineer, but I never want to...I don't even care if I ever see a computer again. And so all I need to do is rock this class. And then I can go on to do whatever I want."

Leslie told me the phrase "rock this class" means to "just like get through it." Richard, an African American male, similarly cut me off in mid sentence to tell me he believed students would say "no" to the relevance questions. I asked him why, and he replied,

> This is pretty much the reason: They don't want to be programmers. Like we sit…When we're doing our assignments, we sit and joke like we're not going to become programmers when we grow up just because of this class. Maybe it's because, you know, we're not used to it, or we haven't found...they haven't like...they're not pretty that much fond of it yet, or whatever. They haven't found it interesting enough to want to pursue it as a career. But it's just throwing this at us in our freshman year and stressing us out like that it's really making us want to first not think about becoming a programmer, and then for other people actually not want to take up engineering.

Richard's quote echoes a finding on the follow up surveys, where only 41% of the survey respondents agreed that Engin 101 was making them more committed to being an engineering major. If we apply the expectancy/value model of student motivation to these quotes, there is some cause for concern. First, learning the material in the course may not be personally important to the students if learning to program is not important to students' identity as an engineer. Also, if students perceive the course to have low utility value or usefulness, this has been shown to affect persistence and achievement (Wigfield & Eccles, 2000). Stated another way, students who find the course useful will persist and achieve at higher rates than those who do not (Pintrich & Zusho, 2002). In addition, Richard directly addresses the fact that the students do not find the course interesting, which can also lead to low motivation and low achievement.

Victor, the second African American male respondent, said,

> Well, I know Engin 101 is for…like all engineers overall have to take the class. And I know like some people I was talking to, they were like, " I'm going to take IOE, industrial. I won't have to program ever, like. I don't see why I need to learn this. And other disciplines, they don't have to do this stuff, either." […] I heard it a lot. […] And I understand, too. I could see why they want some engineers to have some kind of programming experience, but I mean the stuff they were getting into, like I said before, it's like I can see it being a 102 class, not a 101. I don't know. That stuff is pretty in depth for an intro class, I think. So I don't think it's relevant to someone whose careers aren't going to be in programming or anything that has to do with that kind of stuff.. […] I can understand that everybody needs to have some kind of programming knowledge and experience and everything. But it's like it seems too in depth to be an intro class or just to give people exposure to it. It seems like it's a lot of thinking and it took a lot time to figure that stuff out. And it was like, do I really need this for finance, or whatever? I was like, I don't know.

Victor echoes the voice of the respondents who do not perceive they will program in the future. I discuss this further later. His quote does reveal that he attaches some importance to engineers learning to program. When he states that the course "is pretty in depth for an intro class" and suggests that Engin 101 should be a "102 class, not a 101," this indicates Victor has low self efficacy with respect to being successful in the course. In addition, he expresses that the course has high cost for him with respect to time and effort.

I was overwhelmed by the opinion of the majority of the respondents that Engin 101 is not relevant to their future as engineers given the pervasiveness of computers in society and their utility in engineering. In addition, since Engin 101 is a required, first year course, I would expect that the course would strive to instill in the students a sense that programming *is* important to their careers. Unfortunately, the respondents did not express that sense. Even Arnold, a white male who came to Engin 101 with programming experience and stated that he "probably would have taken it anyway even if it was not required," was unclear how programming is related to his major of naval architecture. Arnold stated,

> And for certain majors, I still don't understand when you would ever need to program anything. […] Like I'm sure there's a lot of people who go to IOE, and I don't know when they would do programming. Or programming in C++ at all in naval architecture, I don't know. Nuclear engineering, what would you need to program? Maybe to model something? […]I mean, I...I know that we model things, like...like graphically, and the programs kind of figure out by themselves how much the ship weighs or whatever. I don't exactly see how programming would fit in to all the majors. In naval architecture it wouldn't. I'm sure the logic helps and like the approach helps, but like going through the programs are like...I don't exactly see how it helps.[…] I would want it to fit in, I think. But I don't see a connection from programming to all the different fields. I think that might be an issue for a lot of people.[…] I think they should emphasize where programming would fit in to all the fields. Then people would see, well, I'm going to have to program for this, and this is why it's going to help.

The respondents were split nearly evenly in half between those who perceived they would or would not program in the future. Several students directly stated, "I'm not going to sit down and do a program for my job," or "It's not important," or "I feel like computer programming, only computer science majors need it." This can contribute to low motivation to engage in the tasks assigned in Engin 101, as noted by Richard, an African American male, who stated,

> All I heard is after Engin 101, we don't have to worry about it no more if you're chemical engineering, because we don't do anymore programming. That's all I heard. So it's like, okay, I'm learning this just to get a good grade and then I'm done with it. That's basically what I'm doing, because I don't have any other classes where I have to program.

Interestingly, the majority of the respondents who perceived they would use their programming skills in the future indicated that they already had used these skills. For example, several of the respondents had used Matlab in a subsequent course or knew of students who had. One white female respondent had a brother who was an engineer, and she knew he used Matlab and C++. The African American female, Elaine, who switched out of engineering, was part of the Undergraduate Research Opportunities Program [UROP] and saw her advisor use programs on their project. Elaine disagreed that students won't use the concepts in Engin 101 because,

> Like from my faculty sponsor for my research, like he...we're working on artificial lungs. And initially you wouldn't...you would think, well, where does programming come in with stuff like there. But it's really useful for a lot of what we do. Like I think having the knowledge and having the background, it won't be wasted. I think it'll...just knowing how to do it is good and it's quite possible that you might need it, um, eventually, at an unforeseeable time.

This quote from Elaine suggests she has a high intrinsic motivation for learning material. Students like Elaine who are interested in learning for learning's sake are less likely to suffer from motivational problems with the course [18].

As another example, consider the statement Catherine, a white female who came to Engin 101 with no prior programming experience and volunteered that she received an A minus in the course. In response to the question, "Are you typically the kind of person who says, 'Why do we have to learn this?' or 'Am I ever going to use this?'," Catherine said,

> No. […] Like even with math problems, you know what I mean, like I like solving story problems a lot better than I like solving just general equations. But I don't want to solve story problems from the get go. And usually I can...usually I can see, you know...And like a lot of times, like even with math, like you want to…like Simpson's Law or whatever, and you don't really see the application. But for me I just have to trust that it's going to be out there somewhere, that maybe I'll use it. And if I don't, I just learned something I didn't need to know, but it's still an exercise in mental thinking and remembering and manipulation of numbers and stuff, so I don't think it's worthless. It doesn't really matter about the application. […]Other people really resent having to learn stuff that's not going to go directly to their degrees, and...I have a lot of faith in education even if...I have a lot of faith in learning and...you know...

Paradoxically, the respondents did seem interested in the ideas behind the course. Being exposed to new ideas, learning to program, and learning new modes of thought were among the top five items respondents gave when asked what they liked about Engin 101. For example, Nancy, an Asian American female volunteered that she disagreed on the surveys that she could see the relevance of the course to her future career but also indicated that she liked being exposed to programming. She stated,

> I did like being exposed to programming, because I remember I was on my computer and like, have you ever heard of Zenga? […] Zenga's like a...kind of like an online journal. But my friend has this chatterbox on the side, and she...she wanted me to like make one for her…or make one for her friend. And so she sent me the link and everything and I just kind of like cut and pasted like...almost doing like...But then like how you write it on the web, it's like a code. Like there were "if" statements and then there were like, ah, "cout" and I was just like, I understand that (laughs). Like it was cool like knowing what that meant.

Relevance or utility of the course was not a problem for 5 of the 20 students. For example, Zina is a white student who transferred to engineering this year from LS&A. She was my first interview and indicated she was successful in Engin 101. I asked her if it made sense to her that Engin 101 is a required first year course. She said,

> Oh completely. Because the whole engineering standpoint is like here's a bunch of information, you have to do something with it. And math, chemistry, all those kind of things, there's all these solidified pathways to get from point A to point B. In engineering, you have to be more open to different ideas and different ways to get places. So computer programming is a great way to do that, because there is five, six ways to do every tiny little thing. So it makes you think in more than one way, and it gets you used to figuring things out for yourself.

However, when I brought up the survey questions about relevance, she said,

> Well, indirectly, sure. Directly, really only if you're going to do programming. […] It's not directly relevant. Like the things—The syntax is not relevant. And while that's not the goal of the course…I have Malone. He doesn't…He says that's not the goal of the course. But still when you're learning and you're trying to program, that is the goal. Like that's the near goal. Like you have to figure out what you have to type into the computer to make it do it. And that's what everyone seems really focused on, but that's not what they're trying to teach you, and it's not what you come out of it learning anyway. But I think when you're in the middle of it, it's really all a lot of the people can think about is what they're going through at the moment.

Zina's quote indicates that Dr. Malone emphasized that programming is not the goal of the course. I was interested to understand whether the students viewed the course as primarily focused on algorithmic thinking or programming, and I asked them this question. The majority of the students, when asked, viewed the course both as a way to teach algorithmic thinking as well as programming.

Leonard, a white male who came to the course with programming experience stated, "It does seem like it was like about half and half, or just a little bit more C++ than like logic. But there was logic, I felt." What I believe came out in the interviews is that students who had difficulty with the syntax were less able to focus on the algorithmic thinking. Leslie stated, "I just think a lot of people were thrown off by the programming aspects. They didn't even get a chance to focus on the algorithms." When I asked Hannah, an African American female, who admitted having difficulty with the programming, about whether she thinks the course is more about programming, she stated,

> Yeah. I think...I think...yeah. I don't think of it as anything else.[…] I'm seeing it a lot more as a programming course. I think...I thought...I think it is just a programming course, isn't it?

Contrast this with Curtis, an EECS major, who states,

> Well, I mean, most of the programming stuff that like we'd learn, like one with, all of it, I'd already like knew from reading the book that I had and that kind of stuff. So I wasn't like...or like I wasn't really like learning how to program stuff. And like the degree of programming know how that was needed to accommodate the assignment, I already pretty much… pretty much had. So at that point when I thought of having to do the assignment, I thought of it more as, well, I mean, I needed to figure out a like a way I can get this to work and a way I can translate into terms that I can put it into the computer, which is what the algorithm thing is about. […] But because I was like able to do the programming pretty handily, then like, you know, the part of the course that I noticed as being like what I was doing more was the figuring the stuff out.

Group Work

Many students indicated they worked in groups to complete the weekly assignments. According to the course website (Engineering 101, 2004),

> All project assignments must be completed individually. You are encouraged to form groups and to discuss projects at the conceptual level with your fellow students. This includes discussing the structure of the algorithms and implementation at the conceptual level. Translating those ideas into code, and project write up should be done without help from fellow students. Copying code from a current or former student, a former instructor, or an instructor from another section, either manually or electronically, is an honor code violation. However, you may (and are encouraged to) copy code from your current Professor, your Lab instructor, the course website, or the course textbooks.

Table IV reveals the group work engaged in by students in completing the weekly assignments, broken down by gender and race. Respondents were deemed to work in groups if they talked about working on most assignments in groups. Several of the respondents who worked mainly alone indicated they had a friend they sometimes checked with for small things. These respondents were considered as not working in groups.

TABLE IV
RESPONDENTS' USE OF GROUP WORK

	URM			Majority		Total
	Female	Males		Females	Males	
Worked in a group on most assignments	3	2		5	1	11
Worked alone on most assignments	1	1		3	4	9

Approximately half (11/20) of the respondents reported working in groups on most assignments. Table IV reveals that women were more likely to work in groups than men. Roughly 67% (8/12) of the female respondents worked in groups compared to 38% (3/8) of the men. None of the Asian or white males worked in groups, nor did two of the three Asian female respondents. Both of the African American males and one of the Hispanic/Latino males worked in groups, as did three out of four African American females. This sole African American female who worked alone dropped the course and felt that, had she worked in a group, she would have been more successful.

Working in groups can be helpful in promoting learning and in providing motivation, although ensuring individual accountability is key to effective cooperative learning. As the interviews progressed, I noticed stark differences in the way students used group. Many of the students who worked in groups indicated they were successful in the course. For example, when I asked Leslie whether she could complete the assignments on her own, she at first stated "no" but then modified her response to, "I mean, I...I could have. It would have taken a longer time." In fact, Leslie later indicated she completed the first three assignments on her own without a group. In so doing, she likely gained facility with C++ syntax.

It was my sense that many of the respondents who worked in groups did not adhere to the standards cited in the course syllabus with respect to group work. An extreme example of an over reliance on groups is revealed in Ursula's description of a typical week. Ursula is a white female who indicated she is not committed to engineering. Ursula describes her typical week,

> Um, okay. So lecture on Monday, print it off Monday night, call my best...I have...we have a group of people that I always work with. There are four of us. So I call them and say, okay, when do you guys want to get together to work on it? […]These are the people I always work with. And then there are those people

> that I know a couple from other classes that are also in that class. Because I really didn't meet anyone just being in that class. I met them in other classes or through friends, that I had their screen name online. If I had a random question I could call like so and so, "Linda, did you do that yet? Any clues?", dah dah dah. You know what I mean? […]Because none of my friends had any programming experience, okay? We were all like depending on each other's like somehow something clicks together.
>
> So we basically read until we got as much information as we could out of them [the assignments], and also we had other friends besides our group who were like those types that, "Oh, I printed it out Sunday night, ooh, I did it by Monday night." And we'd ask them, "So you did it, how long does it take?" You know, we always get these kind of like clues about how to do it, and then we all got together. And usually we finished it Wednesday nights. But there were a couple of stressful times where it came down to Friday like three o'clock, finished it right then […] The first ones we always got done on time. Near the end, it was more...the last project was crazy. I will get to that one too. But, yeah, usually get it done. If not, one of us will go to lab the next day and try to get more hands on or talk to other, outside like how...and see what we could do to finish it up. And we'd usually have it done, latest Friday night, sometimes...not...Thursday night, latest Friday morning. We do get together occasionally Thursday if we didn't finish it. […] Whereas me, if it was me working by myself, I don't know how long it would have taken.

This quotation indicates Ursula is doing more with her group than "discussing the structure of the algorithms and implementation at the conceptual level." It is important to note that Ursula does not indicate that she *cannot* do the assignment alone but that it would take her much longer to do so. Referring again to the literature on student motivation, Ursula perceives a high *time* cost if she completes the assignment alone, yet she does not seem to perceive a cost regarding learning. This is likely because she does not attach high value—importance, interest, or usefulness—to completing the assignments.

I believe an over reliance on group work could be hindering students from learning the material to the extent necessary to succeed on their exams. Victor, an African American male, admits that studying in a group compromised his learning. This passage also reveals his perception that working in groups was not addressed in the course in any significant manner. Victor told me that his group comprised people he met through the bridge program he attended the summer prior to entering Michigan. When I asked him if he could have done the assignments by himself, he stated, "No, I don't think so. It would have taken a lot of work. Maybe if it was my only class." Victor continued on to say,

> Sometimes I need to have other people working with me as opposed to figuring everything out by myself or just one person. […] But it depends on what subject. For me, for things like math, I usually try to work alone so I can pick it up and then maybe afterwards I can explain it to somebody or work together. But when I'm learning something…I like to work alone in math. It depends on what subject it is.

This quote indicates that Victor is aware that study techniques vary by course or topic and that he views studying programming as different from studying mathematics. Again, Victor does not state that he cannot do the assignments alone. In fact, very few of the respondents did. Victor stated that students were never assigned into groups, but "they didn't discourage it. Like the topic never came up." Most students, when asked, gave a similar response. I continued to probe Victor about his group work, asking if anyone ever talked to him about working in groups and the benefits, or not, of doing so. Specifically, I asked "Did anyone ever notice that you were doing all of your assignments in a group and say something like: Hey, Victor, you might try doing one all by yourself. It might help you succeed better on your exams?" He replied, "No, they never…I don't think they….No, they never said anything like that." Later, I asked, "Do you think that would have helped on your exams if you would had done the assignments all by yourself?" he replied, "Probably. I'm sure it would have, yes."

My intention in exposing this potential over reliance on group work is not meant to discourage group work in the course. Group work, when used appropriately, can actually increase student motivation and hence increase persistence and learning. However, more explicit instruction in effective group work should be incorporated into the course. Interestingly, several of the respondents, when asked what they would have done without their group, stated they would seek out more help during office hours.

An additional benefit of group work is that first year engineering students get to meet one another. Edward, a male international student from Taiwan, indicated that "last term I just work by myself." When I asked him why, he stated, "Because my first term, I didn't have made a lot of friends over here." An Asian female student, Jamie, had a similar sentiment. When I asked Jamie if she felt connected to her peers in the program, she stated, "I didn't feel really that connected with them, because we just kind of sat in silence when we were doing...during lab and then in class." Even Ursula, who in my opinion over relied on her group, mentioned that her group comprised students she knew from high school. She stated later in her interview,

> And just meeting new people. And I was just bummed for freshman year. I'm like, oh, engineering, didn't meet anyone. There's no people. I'm going to have fun being an engineering major […] If I didn't have them [her friends from high school], I don't know what would have happened in that class. It would have been very bad. That's sad though, the fact that you have to only stick with people you already know. You can't meet new people in that class.

I conclude this section with a hunch I have about a path that some fraction of students are taking in this course, given their perception that the course is not important or useful to them. Consider this statement from Ursula, who completed the course by over relying on her group. Ursula said,

> Honestly, if I had to program to save my life, I don't think I could. I don't know how I managed to. It's because of friends. That's what it is. Because if my friends didn't help me on my projects...because I got a 100 on all the projects, and my test average was like a C…but it balanced out to a B. […] But my goal was just to get like seriously a C or D and it averages out to a B in the class. Because I knew after the first exam, it wasn't going to happen. I don't know what the average grade in that class was, but I was like, okay, B minus, whatever, I'm done. So, yeah, that's how I made it.

I do not believe most respondents were comfortable enough with me to share that they took a similar path. However, given the basis of the course grade (50% weekly assignments, 50% exams), I wonder how many students might be striking a balance between achievement on weekly assignments and achievement on exams.

Exams

The respondents had varying opinions about the exams, from statements such as "they were straightforward, covered exactly what we went over" to "the programs are so unrelated to the exams." Table V shows a breakdown by race in gender of how the respondents perceived the exams. Of the 11 students who felt the exams presented no difficulty, 8 were majority students. Several of them admitted to never studying for the exams. Six of the eight under represented minorities admitting having problems with the exams.

TABLE V
RESPONDENTS' OPINIONS OF EXAMS

	URM*			Majority		Total
	Female	Males		Females	Males	
Exams OK	2	0		5	4	11
Exams difficult	2	4		3	0	9

*Under represented minorities

Two issues were typically mentioned by students who had difficulty on the exams: (1) the exams were different from exams in high school, and (2) not having the computer on the exams made them difficult. Michael, a Hispanic/Latino male, addressed these two issues. Michael worked alone on the weekly assignments. He stated,

> Yeah. High school like...like the tests in high school…the tests in high schools, all right, they'll give you, you know, a little problem, maybe a paragraph about that thing, and they'll say, oh, write a program for it. And you got on your computer, wrote the program, got to debug it right there on the spot, blah blah blah blah blah. You know, if you had it in on time you got an A or whatever, and it worked. But here it's like...it's like the tests are...are really difficult to me. Like the programming is hard in itself, but I can, I can get over that. But the tests, it's like they just give you a blank sheet of paper, you know, and they tell, you know, either...or they'll give you a code and they'll say "Fix it," or they'll say, you know, "Write a code for this." And like without...without being able to like physically put it into the computer and like debug it and like get in there and like...and like work with it, then I have a hard time like writing something that would run right off the bat first time, you know. […] And then it's like you're looking at it and you're like, all right, I want to hit the compile button so I can see what's going on, but you can't, you know. You're just sitting there with your paper and it's kind of rough.

Students might need more practice doing pencil and paper work and learning how to check their programs by hand in the absence of the autotester. Giving explicit in class instruction on this could help students be more successful on the exams as well as the weekly assignments. Richard, an African American student, describes how one of his peers gave him some suggestions as to how to approach the exams for the course. He said,

> But I might have been better on this third exam because I was talking to like...he's a junior now, and just is like a real programming whiz right now. He just...he's a computer programmer, and he's just like very, very good at programming. And I talked to him like maybe a week before we did the exam or whatever. And he was just telling me like, "When you do programming, you just got to pick it out." He was like, "Just think about something that just makes it interesting to you." He was like, "It may not make sense at one point, but just start from English and then slowly start communicating it into code. Like instead of using the word 'and' remember that two ampersands in coding is the same thing like that, and just start piecing it together." And so when I came into the exam with that mind frame of thinking, it actually helped me, and I understand what I was doing. That was like the first exam I ever took out of those three exams, where I actually understood what they were asking me, and I thought I did good on them.

Unfortunately for Richard, he was not given these suggestions until before his third exam.

DISCUSSION

This study aimed to identify factors that help or hinder students in Engin 101, with particular attention paid to women and under represented minorities. The scope of this study included: organization of the course; students' major, commitment to engineering, and prior programming experience; students' perception of the relevance of the course and expectations for programming in the future; use of group work; experiences with exams. In this discussion section, I summarize the findings and offer suggestions.

The respondents overall were very positive about the organization of the course and the instruction. When asked directly what they liked most about the class, the most popular answer was the professor and the GSIs. All of the respondents indicated the lectures and labs were well coordinated. In addition, the respondents appreciated the multiple resources provided in the course: lectures, labs, office hours, textbook, and the autotester. All of these aspects are helpful to first year students transitioning from high school to college.

The students found the autotester helpful and, with a few exceptions, I did not sense that the students over relied on the autotester. However, I do not feel the respondents in general could test their own code by hand in the absence of the autotester. I think more explicit instruction in hand executing their code might help students be more successful on their pencil and paper exams. In addition, the College of Engineering might consider limiting the number of times students can use the autotester. Based on what the respondents told me, I suggest limiting it to ten times at the beginning of the semester and five towards the end.

The interviews addressed concerns raised in the survey about the textbook. Seventy five percent of the respondents had negative comments about the textbook. Half of them did not use the textbook or used it rarely. The comments from the other half suggest to me these students found the textbook difficult to read because it is more narrative in style and not laid out like a "normal textbook," with fewer items bolded or in boxes. These students are likely accustomed to textbooks they used in high school and are having difficulty adjusting. It is important that they do adjust, as textbooks are known to be important resources for students. Since many students in Engin 101 are unaccustomed to science textbooks that are more narrative in style and also may be unfamiliar with how to study programming effectively, I suggest these items be addressed either in the lecture or in labs. Arguably, not all students in Engin 101 need this instruction. However, as the course professes to cater to novice programmers, I think it appropriate and reasonable to cover these items directly in class or lab.

Fully 90% of the respondents were interested in majors other than computer science or electrical engineering, and over half indicated a high commitment to being an engineering major. The male respondents indicated a stronger commitment to engineering than the females (88% versus 25%). This same result appeared on the surveys. Females were more likely to be using engineering at a stepping stone into another field, were unsure what else they would do besides engineering, were thinking about switching, or already had switched. Three out of the four African American females interviewed were thinking about switching or had already switched. Only two respondents, both white males, indicated an interest in electrical engineering or computer science.

Similar to what is found in the literature, female respondents were less likely than males to have programming experience (42% versus 62%). Programming experience is not necessarily an indicator for success in Engin 101, as several of the respondents who came in with programming experience were having difficulty with the course, and several novice programmers were successful. In general, the respondents expressed interest in and liked working with computers. However, three of the twelve female respondents directly stated their disinterest in computers.

Maintaining a sense of self efficacy with respect to learning programming and algorithmic thinking helps students stay motivated. This is particularly true of novice programmers. The majority of the respondents did view the course as focusing on both programming and algorithmic thinking, although there is reason to believe some novices may have trouble focusing on the algorithmic portion of the course because they are overwhelmed by learning to program. Several of the novice programmers stated they needed more help on the basic of programming at the beginning of the semester.

I suggest the instructors in Engin 101 ensure that novice programmers are indeed receiving adequate support. To learn what types of materials might best help them, the College of Engineering might conduct focus groups with students who have completed Engin 101. Further, focus groups with women engineering students can be used to develop action steps aimed at increasing female students' connection with and interest in computers. In addition, the Supplemental Instruction sessions can provide important resources and support for students and should be promoted by Engin 101 instructors and GSIs. Only seven of the respondents indicated an awareness of these sessions, and only three indicated they attended.

A major finding from this study is that the respondents did not see the relevance of Engin 101 to their academic or career goals. A striking 75% of the respondents indicated a perception of low importance and utility for the course. Specifically, they did not seem to consider programming and algorithmic thinking to be key features of their identities as engineers (importance), and they did not understand how programming would be utilized in their chosen majors (usefulness). Roughly half of the students did not think they would program in the future. The literature suggests this can lead to low motivation and to lower persistence and achievement [24]

A rival explanation to this analysis could be that students attach low importance and utility to the course because of fear of failure. In other words, by attaching low importance and utility to the course, their self esteem and self identity are protected if they fail; and if they succeed, they can attribute their success to their superior aptitude. While this is a possibility and should be recognized by instructors as a coping strategy students sometimes employ, the fact that 75% of the respondents indicated a perception of lack of relevance, including students who were very successful in the course, suggests that this is a problem that needs to be addressed. At the very least, instructors in Engin 101 should implement measures to attempt to change the students' perception that the course lacks relevance and measure the effects of doing so.

I have faced this issue personally in teaching mathematics, where students tend to broach the relevance question. I suggest addressing relevance directly in the lectures and labs throughout the semester and incorporating examples of programs that are used in the various engineering majors. In addition, the weekly assignments, which currently focus mainly on problems from calculus and physics, can be retooled to bring in applications from the various engineering majors.

First year engineering students are being socialized into a new field and are more likely to persist and succeed in Engin 101—particularly in the absence of intrinsic motivation—if programming and algorithmic thinking become personally important to their identity as engineering majors. For students not yet committed to engineering, making some of the assignments relevant to their personal lives can enhance their identification with the subject matter. This could be particularly helpful for women [12]. Perceptions of relevance, however, are not likely to change unless students see direct applications of programming in their coursework during their tenure at Michigan or realize that the exercises they engaged in are designed primarily to teach them to think. Recall that the majority of the respondents who perceived they would use their programming skills in the future indicated they already had. The quotes I included in this paper reveal that students are getting signals from their more senior peers that concepts and ideas from Engin 101 will not be used in their future coursework. This word of mouth can be best countered by direct proof.

Although there is an explicit statement on the course website about working in groups and the importance of individual work, I sense that many students are over relying on group work and as a result are not learning the material to a level sufficient to receive high grades on exams. While roughly half (11/20) of the students reported working in groups, women and under represented minorities were more likely to work in groups. This might explain the survey results that revealed women experienced a more positive change in their connection to peers than males ($p=.00$). It is important to note that respondents did not tell me they *cannot* do the assignments alone. Rather the respondents tended to indicate that doing so would take them more time and effort—that is, it would have a higher *cost* to them. However, because the course might not be important or useful to them, the respondents did not indicate a negative cost with respect to their individual learning.

One concern I have is that, upon reading this study, the College of Engineering will elect to forbid group work in Engin 101. In the face of the relevance problem, I think this would be detrimental. Rather, I suggest taking a more developmental approach to group work. Individual accountability should be directly addressed with the students, and students should be required to do some assignments individually. Requiring this at the beginning of the semester can help students develop a sense of self efficacy toward programming and may result in more students seeking help in office hours.

CONCLUSION

The respondents found the organization, instruction, and resources in Engin 101 helpful to their learning. This was echoed in the surveys, and I think it is safe to generalize this finding. While the respondents who worked in groups felt this was helpful, I believe that for many it actually hindered their individual learning and their ability to do well on exams. However, this over reliance on group work at the expense of individual learning may actually be a symptom of low motivation for the course based on a perception that the course is not important or useful. This finding appeared in both the surveys and interviews and may be disproportionately affecting women and under represented minorities. Ideally, students would come to university with high intrinsic motivation. This analysis, however, suggests that they do not—at least not for Engin 101. If the College of Engineering truly is interested in making more students successful in Engin 101, I suggest that dealing with the relevance problem should be a top priority.

I wish to thank the twenty students who took time out of their busy schedules to talk to me about their experiences in Enginering 101. One aspect of teaching that I miss most is being able to talk with students one on one about their personal experiences. As such, conducting this study was very gratifying for me. Being able to engage with faculty, staff and students at one of the best engineering colleges in the country was a gift to me, and I thank the research team for allowing me this opportunity.

APPENDIX A: RESPONDENTS BY MAJOR, GENDER, AND RACE/ETHNICITY

Table VI shows the major, gender, and race/ethnicity of the students who participated in semi structured interviews.

TABLE VI
RESPONDENTS BY MAJOR, GENDER, AND RACE

		Engineering Major	Race
Females			
	Leslie	Chemical	White
	Hannah	Environmental	African American
	Zina	Chemical	White
	Catherine	Mechanical	White
	Jamie	Mechanical	Asian/Asian American
	Elaine	Biomedical	African American
	Isabelle	Environmental	African American
	Rachael	IOE*/business	White
	Ursula	Biomed or IOE	White
	Abby	Aerospace	African American
	Nancy	Mechanical	Asian/Asian American
	Donna	IOE/Math	Asian/Asian American
Males			
	Leonard	Mechanical	White
	Richard	Chemical	African American
	Victor	IOE/MBA	African American
	Curtis	CSE**	White
	Sam	IOE/MBA	Hispanic/Latino
	Michael	Electrical Engr. Or IOE/MBA	Hispanic/Latino
	Edward	Undecided, maybe CSE	Asian/Asian American
	Arnold	Naval Architecture	White

*Industrial Operations Engineering
**Computer Science Engineering

REFERENCES

[1] Barba, R., & Cardinale, L., "Are females invisible students?: An investigation of teacher student questioning interactions," *School Science and Mathematics,* 91, No 7, 1991, pp. 306.

[2] Belenky, M.E., Clinchy, B.M., Goldenberger, N.R., & Tarule, J.M., *Women's ways of knowing,* 1986, New York: Basic Books.

[3] Carbone, E., & Greenberg, J., "Teaching large classes: Unpacking the problem and responding creatively," *To Improve the Academy* , 17, 1998, Stillwater, OK: New Forums Press and Professional and Organizational Development Network in Higher Education.

[4] Committee on Undergraduate Science Education, Center for Science, Mathematics and Engineering Education, National Research Council, *Transforming undergraduate education in science, mathematics, engineering, and technology,* 1999, Washington, DC: National Academy Press.

[5] Cooper, J.L., & Robinson, P., "The argument for making large classes seem small," *New Directions for Teaching and Learning: Strategies for Energizing Large Classes: From Small Groups to Learning Communities,* 81, 2000, pp. *5*. San Francisco: Jossey Bass.

[6] Emerson, R.M., Fretz, R.I., & Shaw, L.L. (1995). *Writing Ethnographi c Fieldnotes.* Chicago: University of Chicago Press.
[7] Engineering 101 course website, retrieved April 18, 2004, from (https://sitka.engin.umich.edu/EngineeringEducation/Eng101/Winter2004/Info).
[8] Erickson, B.L., & Strommer, D.W., *Teaching College Freshmen,* 1991, San Francisco: Jossey Bass.
[9] Fisher, A.L., "Report of the Carnegie Mellon Symposium on Minorities in Computing," 1999, retrieved April 20, 2004, from http://www.nsf.gov/sbe/tcw/events_991114w/events_991114w.pdf.
[10] Grasha, A.F., *Teaching with style: A pr actical guide to enhancing learning by understanding teaching and learning styles,* 1996, Pittsburgh: Alliance Publishers.
[11] Kurfiss, J.G., "Critical thinking: theory, research, practice, and possibilities," *ASHE ERIC Higher Education Report No. 2.,* 1988, Washington DC: Association for the Study of Higher Education.
[12] Margolis, J. & Fisher, A. L, *Unlocking the clubhouse: Women in computing,* 2003, Cambridge: The MIT Press.
[13] McKeachie, W.J., *Teaching tips: A guide for the beginning college teacher,* 1986, Lexington, MA: Heath.
[14] McKeachie, W.J., Pintrich, P.R., Linn, Y., & Smith, D.A.F., *Teaching and learning in the college classroom: A review of research literature,* 1986, Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.
[15] Montgomery, S., & Barrett, M.C., "Undergraduate women in science and engineering: providing academics support," *CRLT Occasional Paper No. 8, 1997* , Ann Arbor, MI: University of Michigan, Center for Research on Learning and Teaching.
[16] National Science Board, *The science and engineering workforce: Realizing America's potential* (NSB 03 69), 2003, Washington, DC: National Academy Press.
[17] Pintrich, P., "The dynamic interplay of student motivation and cognition in the college classroom," *Teaching and learning in t he college classroom , ASHE Reader Series* , 1994, pp. 597.
[18] Pintrich, P. & Zusho, A., "Student motivation and self regulated learning in the college classroom," *Higher education: Handbook of theory and research,* 2002, Boston: Kluwer Academic Publishers.
[19] Seymour, E. & Hewitt, N.M., *Talking about leaving: Why undergraduates leave the sciences,* 1997,Boulder, CO: Westview Press.
[20] Skinner, E.R., & Richardson, R.C, "Making it in a majority university," *Change,* May/June, 1988. pp. 37.
[21] Steele, C. "A threat in the air: How stereotypes shape intellectual identity and performance,"*American Psychologist,* 52, No 6, 1997, pp. 613.
[22] The University of Michigan, *Engineering/computer science student retention initiative,"* February, 2003, unpublished report.
[23] Tinto, V., *Leaving co llege: Rethinking the causes and cures of student attrition,* 1993, Chicago: University of Chicago Press.
[24] Wigfield, A., & Eccles, J. S., "Expectancy/value theory of motivation," *Contemporary Educational Psychology,* 25, 2000, pp. 68.
[25] Wulf, W.M., "The importance of Diversity in Engineering," *Diversity in Engineering: Managing the Workforce of the Future,* 2002, Washington, DC: National Academy Press.
[26] Wulff, D.H., Nyquist, J.D., and Abbott, R.D., "Students' perceptions of large classes. " *New Directions for T eaching and Learning. No. 32: Teaching Large Classes Well,* 1987, San Francisco: Jossey Bass.