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A Student Assessment of the Value of a Redesigned First Year Mechanical Engineering Orientation Course

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Abstract

ME 100L (Mechanical Engineering Orientation) is a one-unit introductory lab course required by all incoming mechanical engineering students at California State Polytechnic University, Pomona, with an enrollment of approximately 400 per year. Prior to 2014, ME 100L was a general orientation course with a curriculum that did not change significantly for almost two decades. Starting in Fall 2014, a new curriculum was implemented that exposes students to the Arduino microcontroller, robot building, sensors, DC motors, C programming, CAD modeling, and 3D printing. The primary objective of the redesigned course was to excite incoming students, provide them with an engaging, hands-on experience, and help them acquire useful and transferable skills. From this perspective, the redesign has been a great success as prior surveys indicated that students enjoy the new course. A detailed analysis of the redesign and survey results were presented at the 2016 ASEE Annual Conference.

Since the redesign was implemented only two years ago, our department still contains many students who took ME 100L prior to the redesign and many students who took ME 100L after the redesign. This presented a unique opportunity to examine the long-term impact of the redesign on student performance in subsequent courses, where some of the skills they acquired in ME 100L can be utilized. Surveys were administered to students in select junior- and senior-level courses to determine whether students who took the redesigned ME 100L transferred their skills to other courses. For example, prior to the redesign students typically learned about microcontrollers for the first time in their senior year. However, there are ample opportunities for students to utilize microcontrollers in class projects in their junior-level courses as well. The authors also compare the types of student projects observed in these lower-level courses before and after the redesign. Additional questions in the survey probed students' perceived usefulness of ME 100L in their entire engineering curriculum. The survey results show that students' who took the redesigned version of ME 100L have a much higher opinion of the course compared to those who took the older version of ME 100L.

1 Background

This paper presents a retrospective assessment on a recent effort to redesign a freshman-level mechanical engineering orientation course named ME 100L (Mechanical Engineering Orientation) at California State Polytechnic University, Pomona (Cal Poly Pomona). The redesign effort completely overhauled ME 100L in Fall 2014 as described in Section 2 below and in Jawaharlal et al. (2016)[1]. This redesign was motivated by two concerns: (1) The general information discussed in the old version of ME 100L, such as career options, library resources, and teamwork, is covered in a college-level introductory engineering course and hence was redundant; (2) The course's technical content was outdated, with the old version of ME 100L culminating in a rubber band car competition.

Additional motivation to update the course came from viewing engineering education from a broader perspective. Many educators in engineering also have introduced innovative freshman engineering courses focused on engaging and motivating students at an early stage[2-9]. Freshman students currently entering universities are referred to as the Net Generation[10]; they are tech-savvy and demand to know the relevance of the material they are learning to the real world. For the above reasons, the primary goal of the course redesign effort was to incorporate an exciting, hands-on experience while teaching useful and transferable skills.

While the idea of a course renovation that evolves with changing students is not new, documenting the long-term impact of such redesign efforts is uncommon, making it unclear whether or not the skills students learned in a redesigned course propagate through the curriculum. The authors of this paper recognized the unique opportunity to probe several upper-division courses where the benefits of the redesigned ME 100L could have the greatest potential impact. In Winter 2017, the students in these key upper-division courses were split among those who have taken the redesigned ME100L and those who have taken the older version; within the next couple years, almost all of the students who took the older version will have left the program. Surveys were administered across seven courses to assess whether or not the students have retained, appreciated, and/or applied the content from the updated ME 100L.

2 Summary of course redesign

A detailed account of the redesign has been previously documented[1]. Briefly, ME 100L is an introductory freshman course that serves over 400 students per year. It is a 1-unit course consisting of a 3-hour lab held once per week. The following table summarizes the key differences between the old and redesigned versions of the ME 100L.

Table 1: Key elements of the old version and redesigned version of ME 100L

	Old version	Redesigned version
Topics covered	• Library resources • Department facilities • Discussion of career opportunities • Engineering communication • Unit systems	• 3D solid modeling, 3D printing • Basic circuits / measurements • Microcontroller programming • Gearbox analysis • Sensors: ultrasonic distance, line detection • Actuators: DC motors • Soldering
Hands-on component	Construct and race a cardboard car propelled by a rubber band.	Assemble and program an Arduino-based rover robot to perform various automated tasks such as obstacle avoidance and line detection.

The redesigned course is based around building an Arduino-based robotic rover platform called a Pi-Bot[11]. Students purchase a Pi-Bot kit for approximately $100, which includes all equipment necessary for the course. Each week focuses on a different engineering concept, with the end

goal of having each student successfully build and program a robot to automatically navigate an obstacle course that includes a maze segment and a line-following segment. One of the main redesign criteria was to create an exciting and motivating hands-on experience while incorporating several fundamental engineering concepts.

3 Assessment

The first sections of the redesigned ME 100L course were offered during the Fall 2014 term. By Winter 2017, there were many upper-division students who took the older version of ME100L as well as many students who took the redesigned version of ME 100L. This presented a unique opportunity to gain insight into how the concepts from the redesigned ME 100L course have propagated through the curriculum. Surveys were deployed to students in seven courses during Winter 2017. Five courses were identified by the authors as having the most potential for lasting impact from ME 100L because they are heavily project-based and require building and programming of a physical mechanical system.

- ME 220L – Strength of materials laboratory
- ME 325/L – Machine design laboratory
- ME 340 – Modeling and simulation of dynamic systems
- ME 435/L – Theory and design of mechanical measurements
- ME 439/L – Control of mechanical systems

Two additional courses were identified as likely containing a mixture of students who took the old version of ME 100L and the redesigned version of ME 100L.

- ME 312 – Fluid mechanics II
- ME 313L – Fluid mechanics laboratory

Among the 201 surveys that were analyzed, 125 students took the redesigned version and 76 students took the older version. The survey itself contained 12 questions (below), many of which were used to establish the background of the student. Beyond basic information about the students, questions 9, 10, and 11 are particularly useful in drawing conclusions regarding the overall long-term benefits of this redesign effort.

Survey:

1) Did you take this survey in a different class this quarter?

2) Did you take ME 100L in a prior quarter?

3) What quarter and year did you take ME 100L?

4) When you took ME 100L, were you required to build a robot that uses an Arduino microcontroller?

5) Did you enter Cal Poly Pomona as a freshman or did you transfer from another college?

6) Did you take ME 233/L in a prior quarter?

7) Have you used an Arduino microcontroller for a class project, not including ME 100L?

7a) If you answered "Yes" to question 7, were you required to Arduino or did you choose to use Arduino on your own?

8) Have you used an Arduino microcontroller for a project unrelated to schoolwork?

8a) If you answered "Yes" to question 8, briefly describe the project below.

9) How confident are you in using Arduino? (circle one)

a) very confident
b) somewhat confident
c) neither confident or unconfident
d) somewhat unconfident
e) very unconfident
f) I have never used Arduino

10) How beneficial was ME 100L for your other mechanical engineering courses? (circle one)

a) very beneficial
b) somewhat beneficial
c) just a little beneficial
d) not beneficial at all

11) When reflecting upon your experience in ME 100L, what is your overall opinion? (circle one)

a) very favorable
b) a little favorable
c) neither favorable nor unfavorable
d) a little unfavorable
e) very unfavorable

12) Feel free to write any additional thoughts about ME 100L below.

Question 9 polls students about their confidence in programming the Arduino microcontroller. Arduino is an inexpensive, open-source prototyping platform that can be used in numerous applications to read sensor data and write to outputs that physically manipulate a system[12]. Arduino is appropriate for many of the projects in the abovementioned key upper-division courses. Having confidence to use this platform *prior* to beginning a mechanical design project offers the student an advantage in terms of likelihood of completion as well as overall success of the project.

Table 2: Survey results for Question 9, "*How confident are you in using Arduino?*"

	Old version (%)	Redesigned version (%)
Very confident	0.0	8.9
Somewhat confident	15.8	44.4
Neither confident or unconfident	10.5	30.6
Somewhat unconfident	14.5	11.3
Very unconfident	9.2	4.8
I have never used Arduino	50.0	0.0

Table 2 shows students' confidence in using a prototyping platform like Arduino. Interestingly, half of the students who took the old version of ME 100L were never exposed to Arduino later in the curriculum. The other half, who learned how to use Arduino outside of ME 100L, report low levels of confidence in their ability to use the microcontroller.

As expected, all of the students who took the updated version report having experience with Arduino since it was used throughout the course. Over half of the students report feeling "somewhat confident" or "very confident" in using Arduino, with only about 16% reporting they are "somewhat unconfident" or "very unconfident." This is extremely positive because knowing how to use a microcontroller like Arduino can greatly improve the chances of success for

students as they take upper-division project-based courses. This point is validated by examining the data from question 10 below.

Table 3: Survey results for Question 10, "*How beneficial was ME 100L for your other mechanical engineering courses?*"

	Old version (%)	Redesigned version (%)
Very beneficial	1.4	28.1
Somewhat beneficial	19.4	39.5
Just a little beneficial	33.3	21.9
Not beneficial at all	45.8	10.5

The responses from question 10 are perhaps the most revealing when dealing with the impact of the redesigned course. When asked how beneficial ME 100L was for other mechanical engineering courses, the redesigned version is regarded as "somewhat beneficial" or "very beneficial" by 67.6% of students. This is in stark contrast to the 20.8% of students who feel similarly about the old version. Only 10.5% of the students who took the redesigned version of ME 100L felt it was "not beneficial at all," while a whopping 45.8% of the students who took the old version felt similarly. ME 100L has transformed from a course that most students felt was not helpful into a course that has a noticeable, positive impact on their future classes.

The impact of the redesign is now evident throughout all parts of the curriculum. For example, students must take an Introduction to Machine Design course (ME 233/L) in their second year in which they are required to work in teams to create machines that accomplish specific tasks. At the time of writing in Winter 2017, all teams in all sections (118 students total) are using Arduino to control the machines without being instructed to do so. Prior to the redesign, it was uncommon for students to use any controller in that course.

While question 10 addresses the benefits of the ME 100L on future courses, the authors were also interested in the students' overall feeling about the redesigned course, which is ultimately related to the delivery method of the course. The course content could be covered in a number of different ways with more or less emphasis placed on lecturing of fundamental engineering concepts, hands-on interaction with robotic components, theoretical basis for engineering design, programming concepts, etc. Undoubtedly, each instructor had a slightly different approach when teaching this course, however, the overall theme of a hands-on, project-based experience was at the core of each section taught. Question 11 probes whether or not this approach was well received by students.

Table 4: Survey results for Question 11, "*When reflecting upon your experience in ME 100L, what is your overall opinion?*"

	Old version (%)	Redesigned version (%)
Very favorable	2.8	36.4
A little favorable	11.1	34.5
Neither favorable nor unfavorable	38.9	18.2
A little unfavorable	30.6	6.4
Very unfavorable	16.7	4.5

Table 4 compares students' sentiment regarding the overall experience in the older and redesigned versions of ME 100L. It is clear that students favor the project-based approach of the redesigned course by a large margin – 70.9% of the students who took the redesigned version hold a "very favorable" or "a little favorable" opinion of the course, whereas only 13.8% of the students who took the old version hold a similar opinion. This data supports the idea that a well-designed, project-based learning experience is much preferred by students than a more traditional seminar environment.

4 Conclusion

One of the primary objectives of the redesign effort was to introduce microcontroller programming at an early stage in the mechanical engineering curriculum. Furthermore, the intent was not to provide an exhaustive course on Arduino programming, but rather to expose students to many basic functions and make them aware of the capabilities of the platform. The data supports the effectiveness of this strategy because upper-division students who took the redesigned ME 100L course have indicated a substantially higher level of confidence in programming an Arduino microcontroller by the time they reach upper-division courses than those who took the older version.

While course redesign efforts are nothing new, students often only assess the course at the end of the term through student evaluations; follow-up assessment of those same students 2-3 years later is rarely conducted. The type of retrospective assessment presented in this paper offers a unique perspective on the long-term effectiveness of the newly designed course.

Overall, the results of this paper have shown that the benefits of this redesign effort are threefold. First, students who are exposed to the Arduino platform early in their curriculum gain confidence in using the platform and are more likely to use it later. Second, as students begin taking upper-division project-based courses, the skills they learned in the redesigned ME 100L have proven to be very beneficial; they are comfortable applying the basic programming skills to design and build their respective projects. Finally, the students' overall opinion of a project-based environment is overwhelmingly positive when compared to a traditional seminar setting. This positive learning experience occurs in one of the first core courses they take, which can boost students' confidence and inspire them to excel in subsequent courses.

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