122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #13428

Transitioning An Experimental Fundamental Programming Course From Pilot To Regular Course: Effective Solutions To Unexpected Challenges

Dr. Todd R Hamrick, West Virginia University

Dr. Todd Hamrick, PhD is an Assistant Teaching Professor in the Freshman Engineering Program at West Virginia University's Statler College of Engineering and Mineral Resources, a position he has held since 2011. He received his PhD that same year from WVU in Mechanical Engineering, with studies in efficiency improvement in well drilling and organic solar cells. Dr. Hamrick received undergraduate degrees in Mechanical Engineering and German in 1987, and returned to academia after a 22 year engineering career in industry. During his career Dr. Hamrick served in a broad range of positions including design, product development, tool and die, manufacturing, sales, and management. His teaching style brings practical, innovative, experience based learning to the classroom, where hands on projects that reflect real world applications are valued by students. Since 1998 he has mentored and lead youth organizations including Boy Scouts, Girl Scouts, 4-H, and First Robotics, with youth ranging in ages from first grade through high school. He was named a Statler College of Engineering and Mineral Resources Outstanding Teacher for 2013-14

Transitioning An Experimental Fundamental Programming Course From Pilot To Regular Course: Effective Solutions To Unexpected Challenges

Dr. Todd Hamrick
Teaching Assistant Professor
Freshman Engineering Program
Statler College of Engineering and Mineral Resources
West Virginia University

June 2015

Abstract

West Virginia University has a common first year engineering program. Two consecutive engineering fundamentals courses are taught, the second of which is a project based fundamental MATLAB programming course. The traditional course uses projects from a wide range of engineering disciplines in order to appeal to varied interests of students. However, all are computational, which was thought to leave kinesthetic learners underserved. A pilot course was developed in the summer of 2012 that used robotic projects instead of computational projects to teach programming fundamentals. This approach was quite successful, particularly with its target consort of kinesthetic learners, so the pilot was extended. It was taught the following summer, and in small sections during the 2013-2014 semesters. Much of this work is described in previous ASEE conference proceedings.

After temporary funding expires, pilot projects too frequently fail to be continued. In this case, the success and popularity of the class made conversion to regular sessions attractive. The robotic version was started as a regular section of the course in the fall of 2014, and is to be continued into 2015. Transition from pilot to regular course is often challenging. For this course it required transferring cost responsibility from the university to students, changes made to the course offering, and technical alterations to the class. Unexpected issues arose such as lower than desired enrollment in the first semester and higher than expected student costs. The long term efficacy of the course is explored through examining how students who took the course during its pilot phase fared in later courses that build upon its learning outcomes. Additionally, transition issues from pilot to regular course and solutions to implementation difficulties are described. Future work toward continuous improvement is also considered. This work extends and expands upon previously published conference proceedings by following students after pilot courses, and by describing the process, challenges, and efficacy of solutions in transitioning from pilot to regular course.

Introduction and Background

West Virginia University (WVU) uses a common first year engineering curriculum, including two consecutive introductory courses in engineering problem solving, This has become common first year engineering curricula in many institutions.[1-4] Of interest in this work is the second course, which is taught as a project based course in using fundamental MATLAB programming as a tool in engineering problem solving. The course usually requires that students complete three projects per semester, generally requiring software input and output, but no building or construction of any kind.

Hands on learning is well documented as an effective teaching tool for kinesthetic learners.[5,6] Such students seemed to be underserved by the conventional teaching methods of the course, so efforts were undertaken to create more hands-on and real world application projects. [7]

Implementation of project based courses can be challenging, but many universities have created successful hands-on project based courses. Penn State has been using robots of its own design since the mid-1990's. They have had success with a group size of three students per group.[8] Northeastern University uses semi-custom kits to teach programming and electronics with a high level of positive student feedback.[4] Both Louisiana Tech University and Portland State University have used C programming to control Arduino controllers in projects.[2,9]

Louisiana State University uses project based freshman courses that include programmable controllers and small robots. [2] Louisiana Tech University and Portland State University implemented the use of Arduino controllers for teaching of C programming, with mixed results. Student feedback about the project based approach was positive, but due to the lack of a textbook, they found that they were frustrated in learning Arduino programming. [9] Inexpensive robot platforms have been commercially available for several years. The OWI arm kit is a 5-axis arm that retails for about $50. Researchers in Thailand programmed an inverse kinematic joint controller to interface with an OWI arm using MATLAB as the software.[10]

A pilot course was developed in the summer of 2012 under a short term grant that used robotic projects instead of computational projects to teach programming fundamentals at WVU. The approach was quite successful, particularly with its target cohort of kinesthetic learners, so the pilot was extended. It was taught the following summer, and in small sections during the 2013-2014 school year. One of the classes used the Arduino controllers from the pilot course, without the robots, as a hands-on project to create a security system. [11]

Students who took the robotic version of the course appreciated the hands on aspects, and it appeared as though those students may have learned more than they would have using a more conventional approach. Some anecdotally reported that it helped with later courses, in particular a mechatronics course that uses the same Arduino controllers. [11]

After temporary funding expires, pilot projects such as this often come to an end, but the success and popularity of this project made conversion to regular class sessions attractive, however several problems had to be overcome. These included material costs, how to fit such a class into the other course offerings, how to change projects from 6-week team based to 15 week individual ones, and how to overcome an unexpectedly low initial enrollment.

Discussion

Course materials

A major concern in transitioning from pilot to regular class was how students would obtain the necessary materials. Grant funding was used to purchase materials for student use during the pilot, some of which were re-usable, but there was a fairly high attrition rate. Cost of the materials for the regular course either had to be funded by the department or other sources, or had to be shifted to the students. Since there were no other funding sources available, it was decided that students would be required to purchase their own complete kit of materials. In the pilot one robot and control system was provided by the department from grant funding for each team of three students. This was considered as an option for the regular course, however there were several advantages in having each student purchase a complete kit, some of which are listed below.

- Students are more likely to take better care of materials that they own.
- Students in each class are always working with new products with no wear.
- The instructor can be more certain that each student is doing the required work himself or herself.
- Each student has more autonomy for open ended final project development.
- Many students expressed a desire to keep the projects after investing a great deal of time in completing them, and this satisfied that desire.
- Many of the materials can be used in other applications, and owning the materials provides students with continued learning opportunities after the class is over.

The materials required by the course include an Arduino Uno controller, an OWI Robotic Arm Edge toy robot, and various electronic components. A complete list can be obtained from the author by request. A concern with requiring that students purchase the materials was cost, so several measures were undertaken to control the cost. For example, component requirements were reduced. Instead of buying ready-built motor controllers, students purchased only the materials necessary to build one on a breadboard. Additionally, some components were eliminated after being deemed unnecessary. Another way to control cost was to negotiate an educational kit price with an on-line vendor, who created a complete kit for a small discount. A third way was to provide students with a detailed list of components including part numbers. Since some students already had access to some electronics, those students could purchase or borrow only what they need. Even with these measures, the retail cost for the complete set of the materials was around $110, in addition to a required book costing about $60 new. Creative solutions to control student costs will be an ongoing process. An example of a complete robot assembly can be seen in Figure 1.

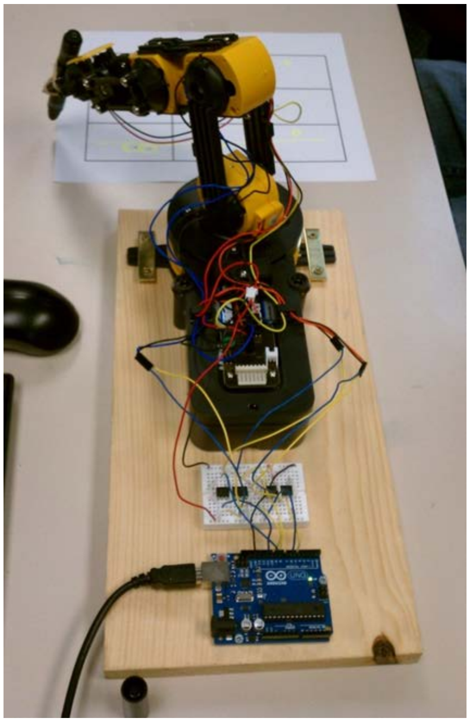

Figure 1 Example of a complete student constructed robot assembly with an Arduino Uno and motor controllers built on the breadboard.

Fitting into the curriculum

An important decision was whether this course constituted its own class, or if it should offered as a variant of the regular Engineering Problem Solving 2 course. At WVU, there are several courses approved by administration that can be substituted for Engineering Problem Solving 2, and this course could have been offered as one of those. However, the process for getting a new course approved is lengthy, requiring review and approval by several committees. A simpler alternative was to offer the course as a separate variant of the current course. This meant that the class must use the same syllabus and book as the regular course, with only the projects being different. While that has been somewhat restrictive, the compromise has been worthwhile. The class appears in the course offering along with all of the other Engineering Problem Solving 2 classes, with a note indicating that the section will use special non-optional robotic projects, and that additional materials must be purchased by students.

Curriculum changes

The course focuses on programming, so the electronic circuitry was designed for simplicity. Using supplemental instructions created by the instructor, students built the robot from a kit, and assembled the electronic components into a motor controller on the breadboard. Pre-written function files were also provided so that MATLAB could be used to control the Arduino. In this way the students wrote code in MATLAB to command the Arduino input/output pins, and the robots respond accordingly. Programming skills include pseudo code, matrix analysis, looping, conditional statements, relational and logical operators, program debugging, and much more.

Since each student owned his or her own materials, some of the projects were modified. The pilot classes were taught during 6 week summer sessions, and only two projects could be assigned due to time constraints. Since more time is available in the regular session, a project was added between the first and last one. Initial projects included simple tasks such as measurement and analysis of accuracy and precision of repetitive motions. Later projects were more open-ended, allowing students flexibility in choosing from among their own ideas. The first two projects were completed individually, with the final one requiring that they work together in teams of three to complete a more complex task. This approach allowed them to be creative, resulting in more challenging and interesting projects than could be envisioned by having the same project for everyone. Some examples of interesting robot tasks included mixing of chemicals, playing music on an i-pad keyboard, playing chess, and bar tending.

Overcoming enrollment issues

The first time that the course was offered in this variant was in the fall of 2014. While it appeared in the list of courses offered when students registered, the number who registered was lower than expected. Class size is limited to a maximum of 48, with a typical size around 42, but enrollment in the initial semester just 17. While both students and instructors like small class sizes, it is impractical to have too many classes with few students. Administration allowed the class to continue, but advised that higher enrollment would be required in order to continue the class in future semesters. Several reasons for the low numbers were considered. One possibility was that, as the second of a two semester sequence, overall enrollment in the fall is half of that in the spring when the class is traditionally taken. Another possibility was that the price tag kept students away. Feedback from students indicated that they did not know what the course entailed, and avoided committing to something they did not know about. To better inform students, an information campaign was launched during registration time in the fall of 2014 for the spring 2015 semester. It included direct emails, information provided by advisors, and fliers posted in areas where target students congregate. Enrollment in the spring semester doubled to 34, which is considered an acceptable number by administration.

Results

Student responses in surveys and end-of-semester evaluations in the pilot course were consistently excellent. Most students reported that they benefitted more from the hands-on projects than from purely computational ones, and that they appreciated the real-world applicability. Some described the projects as "fun." [11]

The student responses in the first regular semester course were similar to those in the pilot. Students enjoyed learning using hands-on projects, although they considered the class to be more challenging. Some responses included:

- "The robots were fun to work with while learning MATLAB"
- "…engaging and made the class very fun"
- "..loved the challenge…"
- "This course was certainly treated like a 200 level or above course."
- "I now have a much better understanding of how mechanical things interface with computers."

Mechatronics is a closely related course taken by students who enter Mechanical Engineering, and which has Engineering Problem Solving 2 as a pre-requisite. To evaluate overall learning, a comparison of grades of the students who took Mechatronics was made. During the period 2012-2014, a total of 263 students took Mechatronics. Thirteen took the robotic version of Engineering Problem Solving 2, and 250 took the conventional version. The GPA of Engineering Problem Solving 2 for all students was 3.30, while the GPA for the 13 robotics version students was 3.85. The GPA for all Mechatronics students during the same period was 2.13, while the students who had taken the robotic version of Engineering Problem Solving 2 scored 3.00 in Mechatronics. While the difference in the grades is noteworthy, the small number of data points made a class-by-class comparison inconclusive. This will require further study in subsequent semesters.

Conclusions

In order to better serve engineering students who respond to hands on learning, a robotic version of a MATLAB programming course was developed through a pilot program. After being taught under the pilot for two years it was integrated into the regular curriculum. It was brought into the course offering as a variant of the regular version, and so uses the same syllabus and book as the regular version. Some modifications to the course projects were made in order to allow its integration into the normal curriculum. Special materials are required for the robotic version, and students who take the course are required to purchase them themselves, at an additional cost of around $110. Efforts have been undertaken to hold this cost down where possible. The additional cost is clearly noted in the course offering each semester, but it seems not to be a major hindrance to enrollment. The initial course offering enrollment was low, but after promoting the course, the second semester enrollment was much higher. Student feedback has been positive, and self-reporting of learning has been positive, although grade comparison of subsequent courses has been inconclusive. The integration of the class into the regular course offering has been successful.

Continued Work

This course is now offered on a regular basis as a variant of the regular class, serving the segment of the population more interested in hands on learning. It will be offered in the fall of 2015. As with any course it will be subject to continuous improvement in projects, materials, and teaching methods. Further study of teaching efficacy will be carried out when more data is available. Also of interest are ways in which student costs can be contained. The course has been successfully integrated into the regular course offering, and is expected to continue into the foreseeable future.

References

[1] Dunne, B., Blauch, A., Sterian, A. (2005). The Case for Computer Programming Instruction for All Engineering Disciplines. *Proceedings of the 2005 American Society for Engineering Education Annual Conference &Exposition*

[2] Hall, D., H. Hegab, and J. Nelson. (2008) Living WITH the Lab - A Freshman Curriculum to Boost Hands-on Learning, Student Confidence and Innovation. *ASEE/IEEE Frontiers in Education Conference. Saratoga Springs, NY. October 22-25, 2008, IEEE.*

[3] McKnight, S., Tadmor, G., Ruane, M., Rodriguez-Solis, R., & Saulnier, G. (2002). Creating 'High-Tech Tools and Toys Lab' Learning Environments at Four Universities. *ASEE/IEEE 32nd Frontiers in Education Conference, 2:* S3E7-6.

[4] Jaeger, B., Freeman, S., Whalen, R., (2012) Programming is Invisible or Is It? How To Bring A First Year Programming Course To Life. *American Society of Engineering Education Annual Conference*, San Antonio, TX

[5] Felder R., Silverman, L., (1988) Learning and Teaching Styles In Engineering Education. *Engr. Education, 78(7), 674–681*

[6] Lumsdaine, L., Lumsdaine, E., (1995). Thinking Preferences of Engineering Students: Implications for Curriculum Restructuring. *American Society for Engineering Education, Journal of Engineering Education Vol 84, No. 2.*

[7] National Academy of Engineering. 2012. Infusing Real World Experiences into Engineering Education. The National Academies Press, Washington DC.

[8] Avanzato, R. (1998). Collaborative Mobile Robot Design in an Introductory programming course for Engineers. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, Seattle, WA.

[9] Recktenwald G. & Hall D. (2011). Using Arduino as a Platform for Programming, Design, and Measurement in a Freshman Engineering Course. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* Vancouver, British Columbia, Canada.

[10] Prempraneerach, P., Kulvanit, P., (2010). Implementation of Resolved Motion Rate Controller with 5-Axis Robot Manipulator Arm. *The First TSME International Conference on Mechanical Engineering 20-22 October, 2010,* Ubon Ratchathani.

[11] Hamrick, Todd R., Robin A. M. Hensel. (2013). Putting the Fun in Programming Fundamentals – Robots Make Programs Tangible. *Proceedings of the American Society of Engineering Education Annual Conference,* Atlanta, Georgia.