Holistic Mechanical Engineering Education with a Mechatronic Platform for Learning™

Vojislav Gajic[1], Donald Heer[2], Matt MacClary[3], Geoffrey Frost[4], Terri S. Fiez[5],

Abstract - **A new platform for learning has been developed for mechanical engineering programs at Oregon State University with great success. This new platform provides hands-on experience, encourages innovation, and presents the means for a more holistic education of mechanical engineering graduates. By combining experiences in electronics, programming and a heavy dose of mechanical theory and practice students can use the platform to build exciting projects and test benches.**

Index Terms – Innovation, Mechanical Engineering, Platform for Learning, Design, Mechatronic.

INTRODUCTION

In today's competitive market, there is a critical need for skilled engineering graduates. Historically, students have a good theoretical background after graduation; however, they lack practical, hands-on skills, as well as the ability to think on a system level that is critical for solving real-life engineering problems. With the introduction of the Platform for Learning™ concept three years ago, the School of Electrical Engineering and Computer Science at Oregon State University fundamentally changed the way engineering is taught. A Platform for Learning™ is a set of common, unifying objects or experiences that tie together the concepts introduced in various classes. This, in turn, fosters the much needed integration of knowledge.

The TekBots™ program at Oregon State University (OSU) has recently created a new Platform for Learning called the Mechatronic platform. This new platform combines the needs of mechanical engineering departments, with modern teaching techniques to create a unique platform.

This paper will cover the Platform for Learning concept in brief. The paper then examines the hardware and the design tradeoffs of the Mechatronic system with respect to the core learning objectives of a sample mechanical engineering program. An in-depth evaluation has been performed on the platform and its trial use in a freshman-level orientation course. These results are presented and future course integration is discussed.

PLATFORMS FOR LEARNING

The Platform for Learning concept is a teaching technique that helps students to better grasp the connections between topics in the engineering curriculum and as a result, gain a much richer understanding of a discipline as a whole.

A Platform for Learning is any object, software, or concept that is used to unify a curriculum. In an entrepreneurial program it might be a business plan; in electrical engineering, a robot; and in computer science a computer program. The key features of any of these platforms need to be: Personal Ownership, Curriculum Continuity, Context, Active Learning, and Fun. A student needs to feel ownership of the platform, and through the platform, an ownership of what they have learned. The platform should also fit with what a student is learning when they are learning it and should connect knowledge across different courses to show the 'hidden' connections between topic areas. A platform that students can interact with and that is enjoyable to interact with adds many dimensions to the platform.

A small robotic base, referred to as TekBots™, is purchased by every freshman in electrical and computer engineering at OSU, and then constructed during the freshman orientation course. Great care is taken to help students understand every aspect of the basic robot. In later courses the robot is 'upgraded' by removing systems that are no longer needed and replacing them with new systems specific to what students are learning.

In using the TekBots robotic platform, students are much more engaged in the material, are more innovative, have a much stronger sense of community, and enjoy their coursework more [1, 2, 4, 5].

THE MECHATRONIC PLATFORM

During the summer of 2003, a Mechatronic platform was developed as a tool for hands-on teaching in mechanical engineering. The long-term goal is to make the Mechatronic platform a new Platform for Learning. Therefore, the design challenge was to develop a learning tool that a completely inexperienced student could use, yet make it versatile enough that it could be used throughout the mechanical engineering curriculum and beyond. Early work with the platform has

[1] Vojislav Gajic, School of EECS, Oregon State University, gajic@engr.orst.edu
[2] Donald Heer, School of EECS, Oregon State University, heer@eecs.oregonstate.edu
[3] Matt MacClary, School of EECS, Oregon State University, macclary@engr.orst.edu
[4] Geoffrey Frost, Department of Mechanical Engineering, Oregon State University, frost@engr.orst.edu
[5] Terri S. Fiez, School of Electrical Engineering and Computer Science, Oregon State University, terri@eecs.oregonstate.edu

shown that it could be used for a great variety of projects, making the platform suitable for teaching many different mechanical engineering concepts.

The Mechatronic platform is in a form of a kit, shown in Figure 1, consisting of a printed circuit board, several motors, and other accessories. The main function of the Mechatronix kit is to provide means of control for a range of mechanical systems. The central part of the kit is the Mechatronic printed circuit board. Its main components include digital input, a programmable microcontroller, and onboard motor drivers. Using the data collected from the digital inputs, the microcontroller can control up to four small DC motors connected to the board.

FIGURE 1:
MECHATRONIC KIT

The main characteristic of the board is flexibility. Digital inputs can be received from a device as simple as an on/off switch, or as complex as an infra-red (IR) sensor or a sonar. On the other end, the microcontroller has full control of the motors, allowing changes in both direction and speed. Most importantly, the programming feature of the board makes control and design of complex systems easier. The combinations of these features provide students with a great degree of freedom for mechanical system design.

In addition to the Mechatronic board, the kit includes a complement of sensors, motors, and auxiliaries. These components provide students with basic pieces of a mechanical system that can be used in a multitude of applications. The additional parts included in the basic kit are two small DC motors, three 'leaf' switches, one 'lever' switch, six rechargeable NiCad batteries, a programming dongle, and an IR sensor.

EDUCATIONAL HARDWARE

In order to effectively teach mechanical engineering, the Mechatronic board was designed to be versatile, yet simple to use. The following illustrates this by examining the board in more detail.

The AVR microprocessor is the heart of the board. It is programmed by connecting the board to a PC using a programming dongle, and running the software that is included in the kit. The actual programming of the board is performed through a set of intuitive, pre-written C functions, allowing users with even no prior programming experience to achieve the desirable level of control. These functions are organized in a library and supported with an internet reference page that contains code function explanations, code examples, and software installation instructions. As an extended benefit of using the Mechatronix kit, some students will actually learn the basics of programming, whereas experienced users have the opportunity to obtain more complex levels of control.

The microprocessor uses Pulse Width Modulation (PWM) to control the percentage of power delivered to the motor drivers, which translates into full control of the motor speed. On the other hand, the code needed to set the speed of the motors is straightforward. For example, to set the speed and direction of a motor, a students needs to call the function 'precise'. The function takes three inputs: number of the motor (1 through 4), direction of rotation (0 or 1), and speed (on the scale from 0 to 255). For example, including 'precise (3, 0, 192)' in the code would make motor number three go in reverse direction at approximately three quarters of the maximum speed. In addition, the motors can perform electronic braking.

There are two high power and two low power motor drivers on the board, with the only difference being the maximum amount of current provided. The low power motor drivers are capable of providing 0.5A, whereas the high power drivers can source up to 1A of continuous current in either direction of the motors. If needed, the drivers will provide even more current than listed above, but only for short periods of time. The motors provided with the Mechatronix kit can run at full power with either low or high power drivers. Alternatively, students can purchase more powerful motors that could achieve full potential simply by using high power drivers.

Both the motors and switches can be easily connected and disconnected from the board using screw-type terminals and the provided screwdrivers. This removes the need for soldering wires together while making it easy to connect and disconnect peripherals an unlimited number of times.

ADDITIONAL FEATURES

It has already been mentioned that by connecting a simple on/off switch to the input ports of the board, a user can control the motors connected to the output ports. In addition, the board is equipped with Analog to Digital Converter (ADC) inputs, so that the motors can be controlled using a value on a scale of 1 to 1024, instead of only 0 and 1 values (on and off). This feature is intended for use in upper level mechanical engineering classes, although more advanced freshman and sophomore students can also find it beneficial.

In case students have a low power electrical device whose operation needs to be controlled, the Mechatronic board is equipped with two additional ports that act as digital switches.

For example, if a student wants to implement a laser pointer in his/her design without having it permanently on, a simple solution would be to use a digital switch. This way, the laser pointer can be turned on or off by programming the microcontroller.

Additionally, the Mechatronic Board is designed to have the capability of adding serial (RS-232) and infra-red (IR) communication, simply by soldering additional parts to the existing board. These features can be especially useful in upper-level mechanical engineering classes for building more complex systems where several boards need to directly communicate in real-time. A daughter board can also be mounted on each Mechatronic board, allowing another board to use the capabilities of the AVR microcontroller board.

In summary, the Mechatronic platform provides a wide array of possibilities for design of mechanical systems without sacrificing the ease of use. By using appropriate curriculum structuring, the platform can be used for teaching a variety of mechanical engineering concepts.

APPLICATION OF THE MECHATRONIC PLATFORM IN ME 101

The Mechatronic platform was first implemented in the mechanical engineering curriculum in the freshman "Orientation to Mechanical Engineering" course, ME 101. The purpose of this class was to introduce incoming students to the fundamentals of mechanical engineering. Each student was required to purchase a Mechatronix kit. The role of the Mechatronic platform was to give students a feel for what mechanical engineers do, and make the abstract concepts discussed in lecture more tangible.

Central to the course was the design competition. The students were to design, build, and implement a system that accomplished a specified task using the Mechatronic platform. This competition exemplified some of the fundamentals of mechanical engineering: working in groups, having an open-ended solution, working with real materials, troubleshooting, and communication of ideas. Most of all, students were encouraged to experiment, innovate, and have fun with their designs.

Arguably the most important benefit students got out of the design competition was hands-on experience. Instead of learning only about the theory behind building mechanical systems, they were able to design and implement one themselves and experience first-hand what mechanical engineering is like. They were exposed to the limits of physical systems and needed to modify their designs in the process to accommodate for these real-world imperfections. For example, one of the groups was trying to use an electromagnet to lift metal objects. However, once they built their design they realized that the electromagnet needed around 30A of current to operate, and that the power supply could not provide even close to that amount. Thus, a design modification followed. In the process, students developed troubleshooting skills, a very important engineering tool that is often absent from the curriculum.

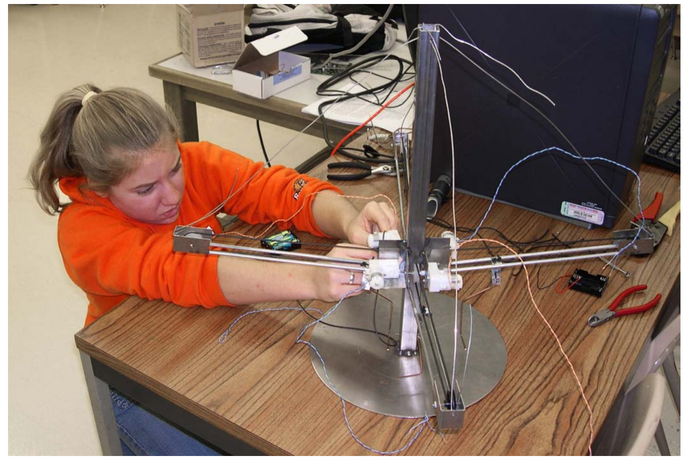

FIGURE 2:
A FRESHMAN STUDENT HARD AT WORK WITH HER MECHATRONIC PLATFORM

Throughout the design competition, students found that using the Mechatronic platform was a rewarding experience and were excited to invent and create using the knowledge they had about mechanical systems, electrical systems, and programming [3]. However, some students had no prior technical experience, and most had experience with only one of the engineering sub-areas. While working on the platform, students shared technical knowledge with their peers and learned more about the three engineering disciplines. At the same time, they were practicing technical communication.

The competition resulted in a wide variety of designs that used different engineering concepts to achieve the same goal. In contrast to solving theoretical problems, the design problems did not have just one correct answer. In order to come up with a solution, students had to be innovative and think "outside the box." Combined with hands-on experiences, this made learning engineering more fun and students became more involved with their education.

EVALUATION

Following the end of the freshman orientation course, the students were asked to participate in a class survey. The authors of the survey wanted to explore the impact the platform had on students' innovative and troubleshooting skills, teamwork, overall understanding of the lecture material, and their perception of mechanical engineering [3]. The survey included questions on demographics, previous engineering skills, and design competition experience. Of the 120 students enrolled in the class, 105 participated in the survey.

One of the most important results of the survey showed that 78% of the students thought that participating in the design competition helped them understand what mechanical engineers do in practice. In addition, 69% of the students thought that working with the platform helped them learn about programming, and 61% felt the same way about electrical engineering. In each of the three questions, less than 10% of the students thought that the experience did not improve their skills at all. After comparing the statistics with the students' prior experience levels, survey results showed that even the more proficient students found the experience worthwhile.

When asked about creativity, 92% of the students agreed that the competition and platform encouraged innovation, and 84% said they were able to think of multiple solutions for the design task. The survey also showed that students thought teamwork was important (87%) and that they were able to exchange ideas with other students (69%). In fact, the surveys showed that the Mechatronic platform succeeded in all but one goal: successfully connecting the lecture with lab material. About 30% of the students thought that lecture helped them with the design competition, and 24% thought that the competition helped them understand the lecture.

Interviews were also conducted with many students. These hour-long sessions were used to allow for a more versatile investigation where the interviewer could gather more specific data. The interviews were performed by Science and Math education students, distancing the interviewees from their professors to encourage unbiased and candid information.

The outcomes of the interviews reinforced the results of the survey and in addition, added a broader understanding of the reasons behind the survey results.

Through the interviews, a large part of the explanation of the disconnection between lecture and lab was discovered. The design competition deals with a mechanical system, whereas the system's components are discussed in lecture. For example, students thought that learning about torque in lecture and then later calculating the torque versus speed curve helped them understand the concept. However, most other concepts that were explained in lecture, even if they were used in the design competition, did not have directly-related lab exercises. In other words, students might have had hands-on experiences about some abstract concepts, but did not see a direct connection between the two. Therefore, this integration between lecture and lab was identified as the main area for improvement in the use of the Mechatronic platform in ME 101. It was encouraging to see that lab experiences did indeed follow the lecture material, and that strengthening their connection is simply a matter of time.

FUTURE COURSES

The Mechatronic platform has been presented in earlier sections showing how it was used in a single freshman-level orientation course. The platform, however, is not limited to a single course. It has the ability to be reused and to add new knowledge while maintaining a fresh understanding of previous work.

In a Mechanics of Materials course offered at OSU, students learn how materials are affected by stresses and strains to gain an understanding of how certain materials should be used. A simple stress or flex sensor can be connected to the Mechatronic platform, allowing students to perform actions based on the readings from the sensor. Students might choose to design a system that could dynamically remove stress from a piece of material under test.

In the senior-level Mechanical Vibrations course, students might use the platform to analyze the vibrations of a system in several axes using gyroscopic or acceleration sensors. Students could then build a simple system to dampen these effects. The list of possible implementations does not end here.

CONCLUSION

The creation of a Platform for Learning for mechanical engineering programs allows more students to benefit from the Platform for Learning concept. Individual courses taught by different instructors now have a natural way to connect knowledge between classes and to better mimic engineering practice.

Students are no longer allowed to simply take a class and forget it. They instead must reuse the systems and knowledge from previous courses in each class they take. This promotes a better understanding of the coursework and helps student to better internalize the information.

The Mechatronic platform has helped to enable this by having ready to use hardware and software that assist students where they have difficulties while keeping the complexity level high in areas of interest.

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