Educational Design, Evaluation, & Development of Platforms for Learning

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Abstract - **Systemic reform in undergraduate engineering education is critical to improving student ability and understanding. Electrical Engineering and Computer Science at Oregon State University has worked in collaboration with university science and math education researchers to implement large-scale curriculum reform based on a platform for learning™. To successfully approach such a large systemic problem and introduce major education reform, an approach called design research has been used. Design research involves a team of education designers that manage a series of iterative cycles of design, implementation, and evaluation. Each cycle provides the empirical evidence needed to improve instruction, and refine the education theory related to platforms for learning. The design research process has brought a much richer and expansive understanding of the platforms for learning concept and engineering education in general. In part concepts like cross-cutting competencies (which include enhancing community building, student innovation and design skills, depth, breadth and professionalism), educational hardware design, and horizontal and vertical inter-class connections have been better understood through the research. This paper summarizes the design research process as it is used at OSU to reform engineering education. Findings specific to a platform for learning and generally applicable to engineering education are discussed. Finally, implementation changes that resulted from the design research process are presented.**

Index Terms - Innovation, Design Research, Platform for Learning, Design, Evaluation.

INTRODUCTION

In the School of Electrical Engineering and Computer Science (EECS) at Oregon State University development of the Platforms for Learning™ based education is under development. This process from the beginning has been a joint effort between engineering faculty and education professionals. This collaborative effort has resulted in many new and interesting outcomes and innovations. This paper begins by describing what a Platform for Learning is. A process called Design Research is discussed in reference to the TekBots platform for learning. Some of the results of this process are then presented including the new concepts of cross-cutting competencies, educational hardware design, and horizontal and vertical inter-class connections.

PLATFORMS FOR LEARNING

The Platform for Learning concept [1], originated at Oregon State University, is a new teaching technique that helps students to better grasp the connection between concepts presented in a variety of classes and 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 are personal ownership, curriculum continuity, context, active learning, and fun. A student needs to feel ownership for 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.

The research described in this paper explores the process by which the TekBots™ robotic platform is used to enhance the educational experience of engineering students.

DESIGN RESEARCH

Efforts to reform engineering education must accommodate the complexity of the educational environment and support collaborative work with educational researchers. At the same time, engineers and educational researchers need a common language and concept of research in order to maintain something more than a fleeting interaction. Engineering may provide a model for these collaborations that is rooted in design. The complexity of educational systems in many ways resembles the complexity of engineered systems. Design methods in engineering help engineers tackle complex

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systems that involve multiple interacting factors. Engineers are driven by goals more than hypotheses and tend to look for workable solutions to specific problems rather than universal solutions.

Recent criticisms of scientific approaches to curriculum design, implementation, and evaluation have been accompanied by an alternative approach often referred to as design or development research [2]. Central to the idea of design research is that the design of the curriculum and the research on the effectiveness of the curriculum are not separated. Design and research are iterative processes that provide feedback for each other through cycles of design, implementation, and evaluation. The design is based on theories of learning while the research on the design provides clarification of the theory as it is put into practice. These clarifications then inform changes in the design. Design research accommodates the complexities associated with changes in curriculum.

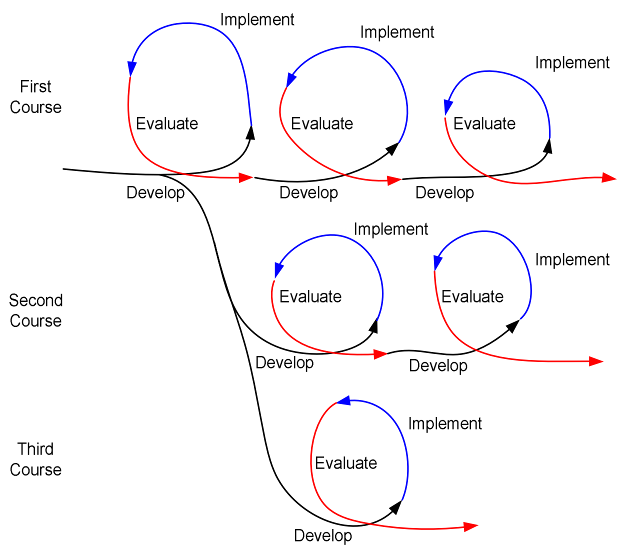

FIGURE 1
THE DESIGN RESEARCH PROCESS

Practitioners of design research use several strategies to deal with the complexities. One such strategy involves the use of a design team [3]. On the most basic level, a design team consists of a designer and a researcher who interact for an academic year. Such a small team may be sufficient for curriculum design associated with one teacher in a single classroom. Teams associated with more systemic reform over longer periods of time may need additional expertise and a much longer time commitment of its members.

In either extreme of curriculum reform, the function of the design team is similar. The team uses data gathered during implementation to refine the underlying theoretical assumptions and consequently adjust practice to accommodate those refinements. This brings up a second strategy for dealing with complexity. Formative evaluation becomes an essential tool that provides the information for design research [2]. The purpose of formative evaluation is to use empirical evidence to inform the development process [4]. Even though formative evaluation uses empirical evidence, it is not necessarily scientific. The validity of the evidence in formative evaluation relies more on triangulation of data sources than on experimental designs. Since formative evaluation is less rigid in its application than summative evaluation, it is more likely to promote more rapid applications of solutions to instructional problems.

Design Research at OSU

A complex curriculum reform within the School of Electrical Engineering and Computer Science (EECS) at Oregon State University (OSU) illustrates how a design research approach is used to manage change and promote collaboration with educational researchers. The reform is based on the use of a platform for learning that is a "unifying object or experience that weaves together the various classes in a curriculum" [3]. The specific platform is a small robot purchased by students in their first electrical engineering course and enhanced through successive courses during the undergraduate program [6, 7]. The development of the platform involves hardware design, software design, design of instructional materials, and professional development of teaching assistants.

The platform for learning evolved out of initial efforts to bring an interesting robotics application of electrical fundamentals to an introductory electrical engineering course. The commercially produced robot was replaced by a new curriculum and locally developed hardware in 2000. About that time, the primary author was asked to assist EECS with evaluation of the platform for learning. Since then, graduate students and faculty from the Department of Science and Mathematics Education (SMED) at OSU have been involved in evaluation research related to the curriculum reform [8]. A design research perspective that incorporates a design team, formative evaluation, and iterative cycles of design has been an important component of the reform process.

The design team of 10 to 12 individuals meets for one to two hours weekly all throughout the year. The team includes the EECS director, faculty, undergraduate and graduate students, representatives from SMED, and outside experts. All members of the design team are involved in projects related to the curriculum reform. These projects include educational evaluation, hardware development, and curriculum development. Team meetings tend to be informal in that there is seldom an established agenda. Each team member shares progress on individual projects or observations related to implementation of the reform. The sharing is often punctuated by impromptu discussions. The meetings are concluded after each person has been able to contribute.

There are several attributes of the team that help in the management of this complex reform process. Students comprise about 50 percent of the team. The heavy student involvement benefits the design research process through immediate feedback about the implementation of the curriculum. Some of the students are either taking courses that use the platform or are teaching assistants in those courses.

The feedback is often used to make immediate changes such as clarification of instructions or alterations of lecture content. Other times the feedback is used to revise curriculum materials for future use.

A drawback to heavy student involvement is the frequent turnover. Each year several new students may join the team while others leave. This means that each new team members has to be indoctrinated into the philosophy of platforms for learning and the dynamics of the team. This is accomplished in several ways. Team members have given presentations to community and industry groups. New team members are invited to attend these presentations and encouraged to participate. During the summer, many current and future team members are hired by EECS to develop new hardware, software, or support materials for the curriculum. During the summer, the students present their projects and defend their work in terms of the value related to platforms for learning.

Another attribute of the team that helps in management of complexity is the use of expertise outside of EECS. One regular participant in the design team is a retired engineer with expertise in wireless systems. He has provided valuable assistance in developing hardware that would incorporate radio frequency elements into the platform and insight into how these elements might enhance the educational program. Participants from SMED provide expertise in evaluation techniques and help interpret data from a cognitive perspective.

NEW CONCEPTS

Cross Cutting Competencies

One desired outcome of design research is an improved understanding of the theory that guides a curriculum change. A platform for learning is the theoretical perspective associated with the TekBots curriculum. A Platform for Learning should help students develop competencies in innovation, community, troubleshooting, design, and professionalism. The data gathered through cycles of design research indicate that these are not simple competencies developed in one course or even in one year. Instead, they cross over a number of years with increasing complexity.

Students begin troubleshooting problems in electrical circuits using simple algorithms. As they gain more experience they are able to recognize classes of problems which decreases the time needed to troubleshoot a problem. The implication of this preliminary data gathered through the design research process is that students need to have opportunities to troubleshoot circuits early in their academic program and they should be provided with explicit algorithms to help them in that process. In addition, there need to be a sufficient number of troubleshooting experiences over the span of a degree program to allow students to recognize classes of problems. This entire process has to be explicit to the student.

Educational Hardware Design

The TekBots program has a unique slant on design that does not commonly exist in other programs. With TekBots the design of the hardware given to students is not only based on good design practice, but also that the hardware will be used to teach.

With this philosophy, designs take into account that students will be trying to assemble, understand, and troubleshoot the hardware, not train, experienced technicians. This results in designs that in some cases use discrete components rather than integrated circuits, have multiple test points, and are backed with solid documentation. Some examples of this are the motor controller board used on all TekBots and the charging circuit also used on all TekBots.

The motor board contains two circuits composed into 'H-Bridge' configurations. There are single integrated circuits on the market that can perform this function, but it was decided to build it instead from individual components. This lets student use intuitive methods of troubleshooting. The charger board was designed in the same way to allow for easier understanding and testing by the student.

Horizontal and Vertical Inter-Class Relationships

Ideally the content in one class should be used in other classes taken in the same year (horizontal integration) and taken over several years (vertical integration). The assumption is that once a student has taken a class they should be able to use the information from that class. The design research process has indicated that knowledge gained in lecture is not consistently used in applications provided through TekBot labs. Surveys conducted in several classes at OSU and at another university indicate that students see very few connections between the lecture and lab experience even when both are planned to complement each other.

Observations of labs conducted as part of the design research process indicate that students use lecture material most often when it is explicitly linked to the application through common technical language or use of examples in lecture that are directly related to the robot. Since the robot is owned by the student and is used in several classes, they become very familiar with its function. Students do use concepts learned in previous labs to help them integrate new circuitry into the existing circuitry.

An early concern about the TekBot was that students would get bored with using the same robot over several years. Based on observations in lab, this does not appear to be an issue. Labs in several different classes have students building versions of a "bumper bot". Although the function of the robot does not change, the approach to the problem does change from an analog solution to a microcontroller solution. Since the students have seen how a "bumper bot" should function, they seem to be able to focus more on the solution to the problem rather than the definition of the problem.

CONCLUSIONS

The concept and process of design research has allowed experts from both engineering and SMED to communicate to better improve engineering education. This process has been used at Oregon State University for several years in conjunction with the Platforms for Learning program and TekBots.

This approach has not only succeeded in establishing TekBots as a vital new concept in engineering education, but also has revealed new and interesting areas of focus to improve engineering education. The importance of some of the concepts like educational hardware design, cross cutting competencies, and horizontal and vertical integration are proving to be very important as the TekBots program continues.

ACKNOWLEDGMENTS

The authors would like to acknowledge the individuals who have put time into the TekBots program. You are all vital to its success. This work is funded by the NSF grants numbers EEC-0230679 and EEC-0342055, and the Tektronix Corporation.

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