Course Remodeling by Integration of Project-based Education with L2L Principles for Enhanced Student Learning Experience

Parthasarathy Guturu, Murali R. Varanasi, and Oscar N. Garcia
Assistant Professor, Professor& Chair, and Dean of College of Engineering
Electrical Engineering Department, College of Engineering, University of North Texas, Denton, TX 76203
guturu, varanasi, ogarcia @unt.edu

Abstract **- We present here a general methodology for recasting traditional lecture-type courses into a new educational paradigm that assimilates project-based approach and learning to learn (L2L) principles. The six steps of this methodology are: i) Planning and reorganization of the course delivery pattern using intuitively exciting mini-projects, new or properly reworded old ones, for top-down execution, ii) Reorientation of the student mind-set to the new style of learning, iii) Motivating the students by letting them reenact the history, iv) Sustaining the motivation so generated by facilitating them to solve the problems/projects using "from-requirements-to-solution" approach, v) Evaluations that assess their learning efforts and experiences rather than their performance in time-bound examinations, and vi) Obtaining their feedback on new projects and course remodeling for toning up the course in the next offering. Feedback from the students who enrolled in the Digital Logic Design course modeled using these principles suggests the effectiveness and success potential of the proposed methodology.**

Index Terms – Project-based education, Project-orientation, Learning to Learn, L2L, Top down design, Course Remodeling.

INTRODUCTION

In a landmark paper [1], F. E. Terman, an eminent educationist from the Stanford University, stated that the history of Electrical Engineering (EE) education, since the very first appearance in the U.S. of EE curricula in early 1880's, parallels the developments in the EE industry. This statement is equally true for other engineering disciplines as well. In the early days, engineering education was mostly hands-on. But, after World War II, many educationists felt the need for inculcating in the engineering graduates the theoretical knowledge and analytical skills required for understanding complex systems. Hence, many engineering curricula were revamped by introducing mathematics and basic sciences in place of the old courses in engineering practice, such as surveying and workshop practice. Even though this model had been universally accepted, there were growing concerns about the inadequacy of this model for addressing the needs of the modern industry. Dutson *et al* echo some of these concerns in their paper [2] and report the following statement from Jerry Junkins, Chairman and CEO of Texas Instruments: "Most engineering jobs involve design and practice, not theory and research." According to the same paper, another industrial leader Robert, Stauffer stated, "The typical theoretical science and mathematics-based curricula encourage the analytical approach to problem solving, while system design, integration, and synthesis are what the industry needs." The Accreditation Board for Engineering and Technology (ABET) has also perceived a similar need for inculcating design skills in the engineering graduates and hence stipulated the students' ability to design a system, component or process as a necessary outcome of any engineering program for its accreditation (outcome 3(c) of its accreditation requirements from 3(a) through to 3(k)). Influenced by either these ABET requirements or the criticism from the industrial sector, many universities started incorporating design content in their undergraduate curricula through one or two capstone courses in the final year. Realizing the inadequacy of a couple of capstone courses for inculcation of the required design skills in the students, some universities introduced the so called cornerstone design courses in the pre-final years of their curricula. Our innovative Electrical Engineering program at the University of North Texas, which has been launched with the generous support of the National Science Foundation, goes further and takes the "Design and Project-oriented Education from Day Number 1" approach. In this model, we have project courses every semester. Our educational goal is also to foster among the students lifelong learning skills, ethical standards, and business and communication skills along with design skills. Accordingly, we have incorporated in our curriculum, courses on ethics, business management, languages, and, over and above, Learning to Learn (L2L). Further, we plan to remodel, wherever possible, our classroom lecture-type courses also with project orientation and L2L principles. Towards this end, we developed a 6-step methodology for remodeling (modeling) existing (new) courses along these lines.

In this paper, we present the aforementioned methodology. The methodology is applicable to both stand-alone courses and those supplemented with an additional laboratory or project course. It has been developed by adapting effective pedagogic principles in traditional teaching. However, unlike in the traditional approach where theory is followed by an application example, here we encouraged the students to solve the problems by adopting a "problem-requirements to problem-solution" approach used in the industrial design world. Learning of relevant theory is facilitated during the course of problem solution. Thus, in this approach, theory is a means to an end, not an end in itself.

Organization of the rest of the paper is as follows. In the following section, we present the six steps involved in the methodology and the flow diagram for execution of the methodology. The following section elaborates on the individual steps of the methodology. Experimental results are presented in a subsequent section which is followed by sections on summary and conclusion, acknowledgments, and references.

SIX STEP METHODOLOGY FOR COURSE REMODELING

Here, the word "course" is not used simply to imply either the outline of topics or detailed contents. Rather, a course, in its present embodiment, includes all the aspects related to imparting learning end-to-end. Consequently, remodeling of a course with project orientation and L2L components turns out to be a process or methodology with the following six steps: i) Course and Content Delivery Planning by preparing a list of intuitively exciting project(s) for top-down execution, ii) Reorientation of the student mind-set to the new style of learning with top-down problem solving, iii) Motivating the students by letting them reenact the history (by thought experiments when actual doing is not possible), iv) Sustaining the motivation so generated by facilitating them to solve exciting new problems or standard problems properly reworded to describe applications that pique their curiosity. Rather than following the traditional approach in which theory is followed by an application example, they should be encouraged to solve these problems by adopting a "problem-requirements to problem-solution" approach used in the industrial design world, v) Evaluations that assess their learning efforts and experiences rather than their success in memorizing a number of definitions or in obtaining correct numerical answers in time-bound examinations, and vi) Obtaining their feedback on new projects and course remodeling for toning up the course in the next offering.

Figure 1 depicts the execution flow of this six step course remodeling process. Since all courses are not amenable to project or problem orientation, an initial decision about the suitability of the course for remodeling using the present approach needs to be taken in the first step (planning) of the process. The remaining five steps then follow sequentially. The feedback collected in the final step must be analyzed thoroughly with respect to both positive and negative remarks.

Lessons learned by the teacher from the previous course delivery are always a good starting point for the next iteration. Incorporation of the suggestions from feedback could lead to anywhere from small changes in course contents, project/problem lists, and delivery modes, to total revamping.

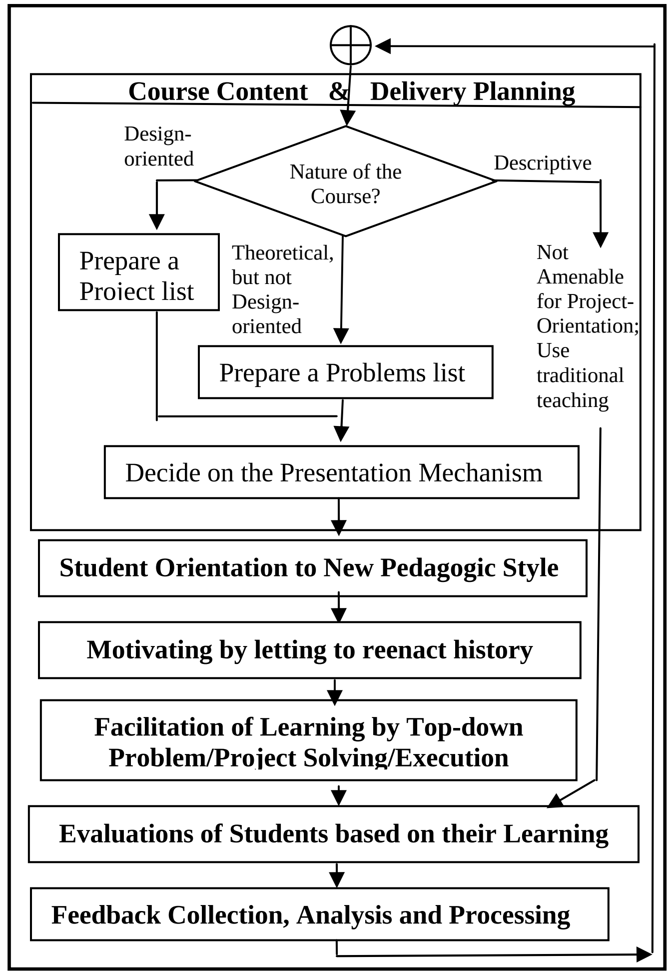

FIGURE 1
EXECUTION FLOW IN THE SIX-STEP COURSE REMODELING WITH PROJECT-ORIENTATION AND L2L COMPONENTS

INDIVIDUAL STEPS OF THE METHODOLOGY

The six steps of the course remodeling process depicted in Figure 1 are detailed hereunder.

I. Course Content and Delivery Planning

Just as the engineering projects need a lot of planning for successful execution, engineering courses, in order to be effective, must necessarily be well planned with respect to organization of the course content as well as mode of its delivery. Courses with highly descriptive contents are not suitable for project-based education and hence may be taught using traditional methods. However, many courses that are seemingly descriptive can be brought into project framework. For example, typical projects in an ethics course would be case studies which prompt the students to resolve various dilemma situations. Similarly, in a course on Government, students may be able to learn the functioning of a foreign Government using mock parliaments and other such devices. Very good management courses involve practical handling of various management scenarios or group discussions thereof.

Most core engineering subjects can easily be brought into project framework because they are either inherently design and test oriented or theoretical in nature. Even though the project-based approach is the right and natural pedagogic style for the former group of courses, traditional teaching methods are being prevalently used at many institutions. Hence, a conscientious effort must be made to revamp the course delivery pattern (with/without change in contents as necessary) to fit those courses into project-based educational framework. For the second group of (theoretical) courses, problem-oriented approach will act as a substitute for the project-based approach. In either case, students need to start with the requirements of the problem/project, and learn any required theory on their way to problem solution. Validation and testing of the projects are as important as design in the project-based approach. Analogously, procedures for cross-checking the problem solutions are very useful devices in a problem-oriented approach. They help the students to develop confidence in their learning. Hence, during the course planning stage, the teacher/facilitator needs to prepare a repository of projects/problems and validation/cross-checking procedures that help the delivery of the same course contents as a traditional course more effectively in a project/problem-based setting. It is also possible to organize the whole course as a big end-to-end project with many component mini-projects that need, for their execution, the theory/concepts from one or more of the topics in the course. Either case, it is preferable that these mini-projects/problems are small enough to be completed within 1 or 2 class hours.

It is tempting to use high-tech gadgets for course delivery. Powerpoint slides or multimedia presentations with neat diagrams, catchy animations, and bullets for crisp presentation of information are no doubt very effective. For distant education, they are the only option. The question now is whether they must necessarily be used in regular classrooms also? The right answer is that it depends on the nature of the course. For a course involving lots of complex pictures, charts, graphs and textual information *(e.g.* Computer Networks), a multimedia/powerpoint presentation is the way to go. However, for courses involving systematic design/problem-solving procedures (*e.g.* Digital Logic Design, Structural Analysis and Design), the content delivery through presentation tools will be so fast that it would be difficult for the students to grasp the systematic procedures involved in design or problem solving. Here, the right approach is "to learn by doing"- a pedagogic philosophy at the heart of project-based education. The teacher/facilitator needs to synchronize his/her pace with the students and facilitate their learning by leading them from problem/project requirements through to problem solution and validation.

II. Student Orientation to the New Pedagogic Style

Most undergraduate engineering students are quite used to the traditional class-room lecture type pedagogy (in their high schools) which, as stated in [3], is based on John Locke's philosophy that a student's mind is like a blank slate on which the teacher writes the subject matter. Hence, it is very likely that they are mentally unprepared for any shift in the paradigm. Their view that the teacher is responsible for their learning must be first corrected. It must be made clear that they are responsible for their own learning. We, here at the University of North Texas, offer a course on Learning to Learn, but it is still a good idea to remind them about L2L principles in the introductory classes of each and every course. The students must also be given a briefing on industrial project life cycle, and the effectiveness of project-based education at least with respect to development of the skills needed in their future careers. A short (1 hour) introduction to this kind of new paradigm involving project-orientation and L2L Principles will remove any misgivings regarding this approach. Consequently, they will be mentally well prepared to learn the course using the new approach.

III. Creation of Motivation

Usual approach to creation of motivation in a course with the traditional class-room lectures is to present a brief history of exciting developments in the subject area. In a project-based setting, this approach maps onto reenacting history. By this, we mean encouraging the students to reinvent historic gadgets or methods associated with the course. For example, while introducing the difference between analog and digital computation in a digital logic design course, students may be asked to write on the board the design of an analog adding machine using rulers. Hints may be given as needed to lead them to the solution. However, this may not be possible in all courses, particularly those that deal with huge systems or processes, or involve a lot of theory. Still in those cases, students may be prompted to do thought experiments. They may be given concept projects with typical questions such as, "this is the problem, outline the steps of your solution."

IV. Sustaining the Motivation

The motivation created in the students needs to be sustained throughout the length of the course. In the project based approach, this is done using the carefully chosen motivating projects for development of concepts and design thinking. This is where the effort done in the planning stage comes into fruition. Verbal description of the project/problem could be an important motivating factor. For example, a theoretical problem involving prime numbers can simply be stated as a dry mathematical relation or as a problem of cryptography used in present-day secure communications. With some imaginative thinking, the facilitator can clothe a plain looking problem with a catchy verbiage describing a contemporary problem of interest *e.g.* a bio-chemical sensor. Student learning experience can be enhanced by making them, during the course of their problem/project solution, adhere to well-established design principles (*e.g.* Divide and Conquer, Look for Patterns, Don't reinvent the Wheel, *etc.*), and a multi-stage process that parallels an industrial project cycle.

V. Student Evaluation in the New Paradigm

If our goal is to revolutionize education by a paradigm shift in pedagogy, why not extend it to evaluation of student performance in the course? In the new paradigm, learning efforts must be rewarded. We need to measure learning carefully, and students need to be graded by the amount of their learning. Concept libraries are useful tools for measuring learning of concepts. Carefully prepared concept libraries (during the planning stage) facilitate the students not only to form concepts, but also extend them. By administering the concept quizzes twice, once before the class and once after the class, and measuring the differential, the teacher /facilitator will be able to measure individual student's learning. For evaluating the student development in design/test skills and theoretical analysis, classroom interactions and mini-project submissions are useful devices. Bottom line is that we need to get away from old style time-bound examinations for evaluating students based on their memory and/or ability to make accurate computations fast enough.

VI. Feedback Collection, Analysis, and Processing

Feedback collection from the students is an important part of any good course offering. Both positive (appreciative comments) and negative (constructive criticism) feedback are useful for improvement of the course in the next offering. While the positive feedback indicates areas of strength which must be further consolidated, negative feedback gives us the directions for remodeling our mode of delivery or methods for facilitating students' learning of different topics of the course. It is also possible that they suggest novel projects to be used in the course.

EXPERIMENTAL RESULTS

We applied the proposed methodology to our sophomore course on Digital Logic Design. This course is an admixture of conceptual portions, theory, and design. We used 3 concept quizzes for testing the student learning of concepts. Quiz 1 contains 1 question on L2L philosophy, 1 on project life cycle, and 7 questions on basic ideas related to digital and analog systems. Quiz 2 contains 7 questions that help the students to extend the ideas of decimal number system to binary and other number systems. Quiz 3 contains 13 questions to facilitate students' learning of Boolean Algebraic postulates and theorems by extending their experience in common sense manipulation of logical statements in English.

Table I summarizes the results of average student's learning in the 3 concept quizzes. A negative view of the results is that the students' learning could not be much enhanced in quizzes 1 and 3 after the class session. This suggests that the concept quizzes are to be either reworded or revamped. Alternatively, we may have to give enough time to let the concepts sink in. The post-session quizzes given after a number of sessions are likely to show better learning rates.

The positive view of the concept quiz results is that the students are able to extend their prior knowledge and common sense logic. Near average performance without any help from the teacher is quite commendable. Hence, these results may be considered as a testimony to the success potential of the L2L paradigm.

TABLE I
RESULTS OF LEARNING IN CONCEPT QUIZZES OF DIGITAL LOGIC COURSE

Quiz No.	Percentage of Correct Responses in Pre-Class Administering	Percentage of Correct Responses in Post-Class Administering	Learning Percentage
1	43.75	57.98	14.23
2	44.69	84.72	40.03
3	58.46	65.38	6..92

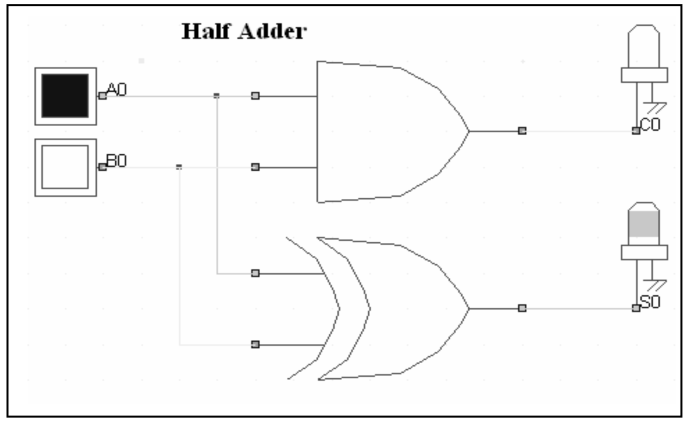

FIGURE 2 (a)
HALF ADDER DESIGN AND TESTING

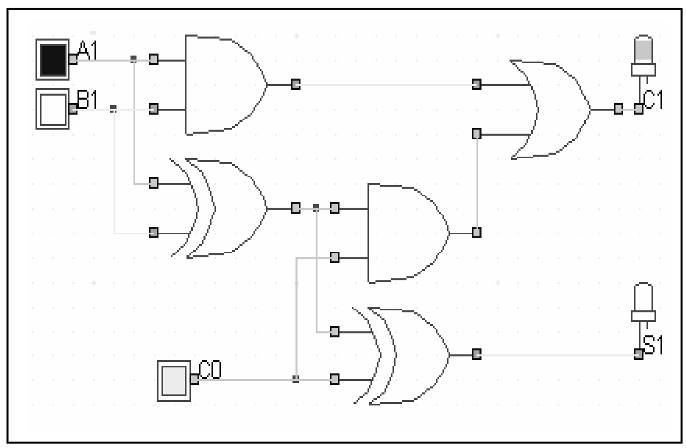

FIGURE 2 (b)
FULL ADDER DESIGN AND TESTING

For testing the student design skills and theoretical knowledge, we used classroom interactive sessions and projects of various sizes including a major project. A typical project, at the very initial stages of the digital logic design course, was on the design of a 4-bit adder with the basic understanding of logic gates, their implementation using electromagnetic switches that work on the principles of physics they learnt in school, and binary additions resembling the decimal arithmetic they know of. Figures 2(a) through to 2(c) depict the typical design diagrams developed by a student using the principle of divide and conquer. Fist, a half adder was designed just to add two bits. Then two half adders were assembled into a full adder to add two bits and a previous stage carry. Finally, a four bit adder was constructed using 3 full adders and a half adder. Eighty percent of the students have designed and developed their major project on a freeware and submitted the reports written strictly according the format used in a typical industry with separate sections for individual project phases. Hence, they obtained "A" grade. The remaining 20% of projects which did not meet the quality because of a misunderstanding about the requirements were given "C" grade.

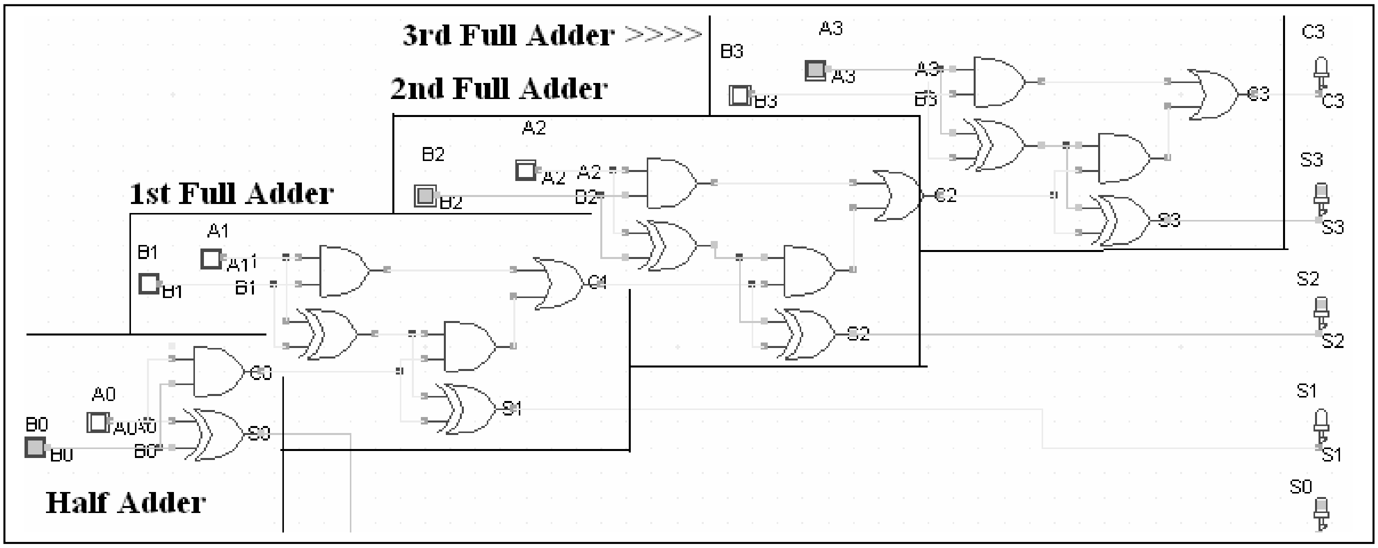

FIGURE 2 (c)
COMPLETE DESIGN OF A FOUR BIT ADDER

SUMMARY AND CONCLUSION

We present a six-step methodology for remodeling/modeling old/new courses by integrating project-orientation and L2L principles. The experimental results presented here indicate the effectiveness of the methodology and its potential for a big success. The methodology is applicable to both stand-alone courses and those supported by additional laboratory or project courses in the curriculum. In the latter case, student learning experience can be very much enhanced with the help of complex projects.

ACKNOWLEDGMENT

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