Creating an Automated Learning Management Tool in an Engineering Course Based on Interdisciplinary Metrics

Quoc-Viet Dang [1] **and Daniel D. Gajski** [1]
[1] Henry Samueli School of Engineering, University of California, Irvine, CA, United States

Abstract - *Online courses have been debated among the UC regents, numerous college administrators, faculty, and students. On one hand, online education can reduce overhead while enrolling more students. Administration wants to enroll more students while incurring minimal overhead costs. However, simply translating the classroom lectures and materials to an online environment does not necessarily produce equivalent student performance and satisfaction from the course compared to an in-class environment. Since there is no standard in online education, it has produced erratic results in terms of student performance and costs to students. A change in teaching and learning methodology by both teachers and students is required to get the most from today's technology and apply it toward improving student performance and participation. This paper presents a management tool and methodology to provide a more individualized learning experience for students in large hybrid and online courses while keeping overall costs and time commitment down as well as improve overall student performance.*

Keywords: *Computer and Web based instruction, Hybrid Methodology, Massive Online Course Management, Computing Education Research, Online Learning Efficacy*

1 Introduction

Public education is in a crisis. The University of California has increased admissions from 50, 291 in Fall 2003 to 82,850 for Fall 2013 [1] [2]. Student-faculty ratios and number of credit hours per faculty member have increased 10% in the last six years alone amidst UC budget cuts [3]. These increases present a problem for running large classes.

Online courses have been proposed and debated among the UC regents, numerous college administrators, faculty, and students. On one hand, online education can reduce overhead while enrolling more students. Administration wants to enroll more students while incurring minimal overhead costs. However, simply translating the classroom lectures and materials to an online environment does not necessarily produce equivalent student performance and satisfaction from the course compared to an in-class environment. Since there is no standard in online education, it has produced erratic results in terms of student performance and costs to students as well as administration. A change in teaching and learning methodology by both teachers and students is required to take the most advantage from today's technology and apply it toward improving student performance and participation. This paper presents a management tool and methodology to provide a more individualized learning experience for students in large hybrid and online courses while keeping overall costs and time commitment down as well as improve overall student performance.

Massive Open Online Courses (MOOCs), are still teaching in a scaled up version of the typical in-class methodology. This methodology in its present state does not work well for larger courses. Translating this method into an online environment makes the situation even worse. Although preliminary analysis [4] shows that the top 1/3 of students tends to still do well with an in-class methodology taught in an online environment, the other 2/3's of students do not perform as well when exposed to the same situation; in fact, the bottom 1/3 of students did much worse relative to the top 1/3 of students.

Different students respond to and perform differently when exposed to different teaching and learning styles [5][6]. Utilizing the results from this initial research and combining it with other research theories and methodologies, a specialized design learning tool can be developed to facilitate and automate the changes required to allow instructors to manage massive online courses significantly better than current available options.

2 Hybrid Overview

Since the hybrid methodology (Figure 1) combines ideas from both in-class and online methods, we will highlight the proposed purposes of the learning tool in this methodology; therefore, the tool and continuing research efforts will be used to address the scalability and overhead issues found in a hybrid course when trying to maintain performance and motivation with increased enrollment. These issues are also present in in-class and online environments, which allows the tool to be used across different methodologies.

One particular basis the hybrid methodology uses to help reinforce students' learning experience and keep them motivated to keep up with the course is the concept of the "Hawthorne effect," in which subjects were more productive

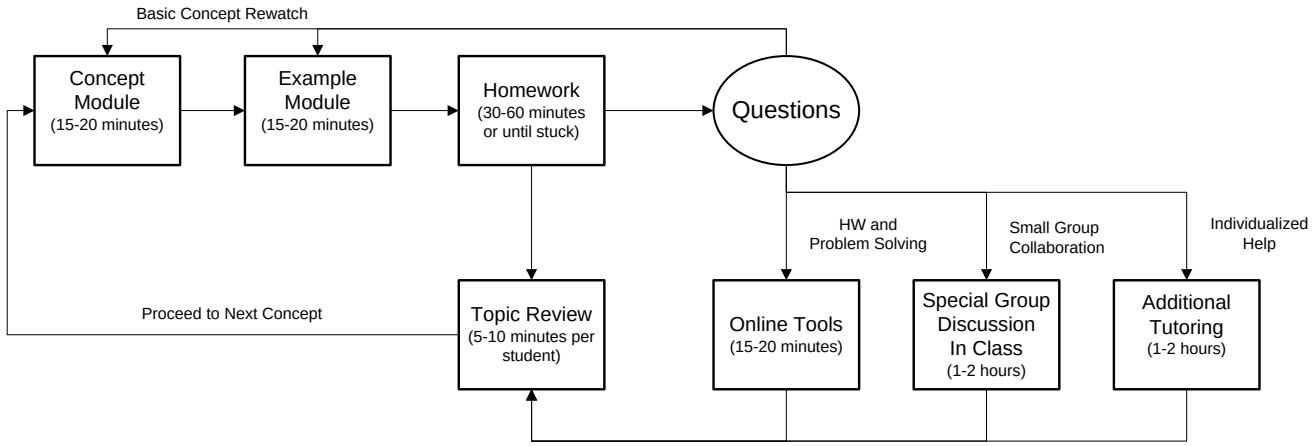

Figure 1: The Hybrid Methodology Work Flow.

when they had a manager watching them work [7]. It would not be practical to physically observe individual students did their work, like in Roethlisberger's original findings of worker management at Hawthorne Works in the 1930's [8], especially in a large distance learning course. The proposed methodology including topic review modules and feedback after each video module's questions are answered will be used to satisfy this need. This type of milestone review can guide students and provide feedback on their current weaknesses and strengths and can be automated to be done by a learning management tool.

3 Learning Tool Metrics

To address the metrics measuring student progress based on the varying skill levels of individual students, each module of the design tool will be developed toward fulfilling each of the metrics for each level of students by analyzing how each module fulfills each groups' higher and lower order needs. These needs are adapted from Maslow's Hierarchy of Needs Theory (Figure 2), which identifies a pyramid of needs [9][10][11].

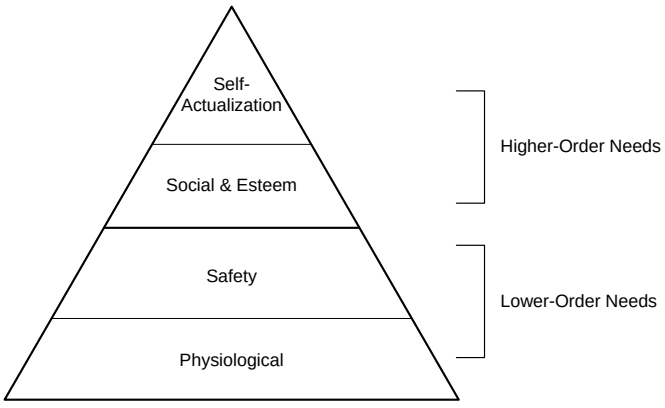

Figure 2: Maslow's Need Hierarchy Model

3.1 Lower-order Needs

Physiological and Safety Needs are lower-order basic needs. In terms of Engineering students, this includes having convenient access to course content and related resources. Furthermore, students need to be able to know their current grade standing throughout the offering of the course. Inconsistent release of material and grades affect their basic needs and limit their motivation, performance, and satisfaction with the course. An intelligent design tool can focus on these lower-order needs by providing ease of uploading and managing of course content for developers & present material to students in a timely and organized manner.

These needs are important for all levels of students, but are especially important for the beginner and intermediate students. By making sure these needs are met, student motivation and satisfaction can be maintained and even increased, allowing the rest of the design tool modules to improve student performance.

3.2 Higher-order Needs

Social and Esteem Needs are higher-order needs. Students need interaction, a feeling of inclusion, and group work. In terms of esteem, students need to build and maintain confidence and feel senses of achievement throughout the course, as well as get recognition when they perform well.

The design tool will provide an interface for developers to set goals and keep track of student achievements. The tool will also provide an area for students to interact with each other. Feedback can be given to individual students on an automated basis to minimize the amount of time developers have to invest in the tool and course to keep these needs satisfied.

The highest level of need, self-actualization, mainly affects advanced students. Students want to fully utilize their skills and abilities with challenging problems and grow as

Engineers. Optional modules and additional advanced material can be customized by developers in the design tool to facilitate this need for students who need more challenge.

4 Learning Tool Overview

The design tool will mainly focus on improving the following metrics: student performance, motivation, and course satisfaction. Students are split into several groups based on their skill and performance level. This tool has a front-end for students and a back-end for instructors and teaching assistants. This design methodology is unique to our design tool and is not currently implemented by other tools managing MOOC's.

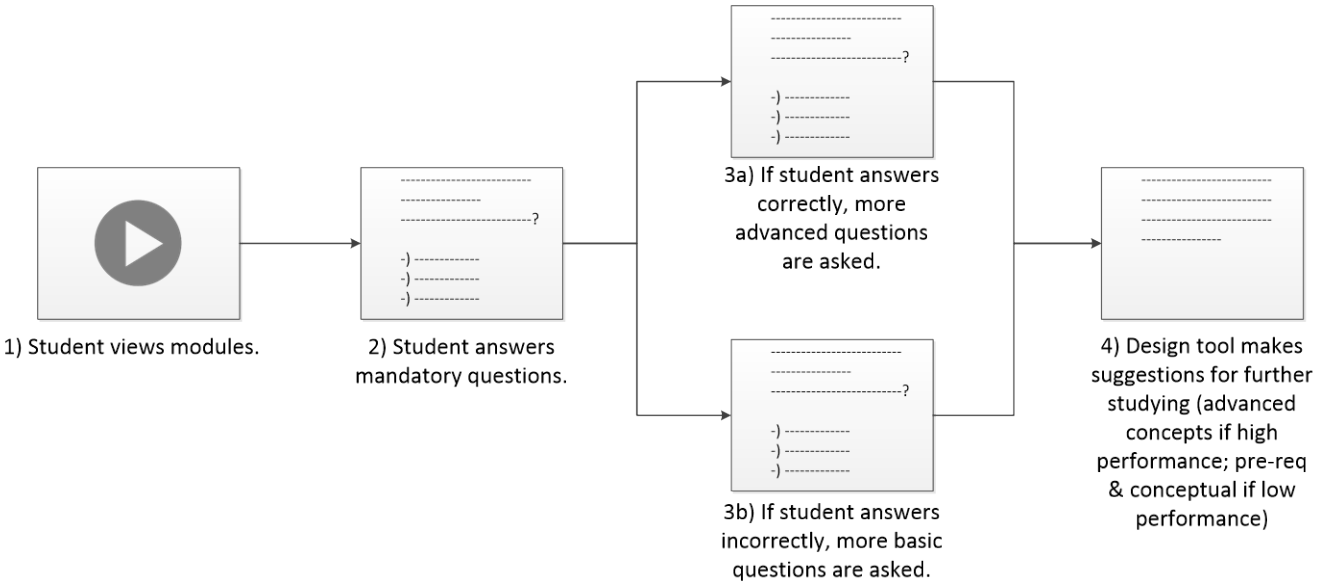

Figure 3: Concept Module Flow

4.1 Front-End Interface

The front-end interface contains modules and tools for students. Each of these modules has a corresponding interface to allow instructors to populate each module with relevant data for the design tool to generate a student profile, analyze the profile, and make suggestions to students. These modules help satisfy basic student needs of the course under Maslow's Hierarchy of Needs Theory. For each section below, the examples provided will be various student performance scenarios for a Digital Design 101 course where the student is progressing through the RTL Combinatorial Components portion of the course.

4.1.1 Concept and Example Modules

Concept and example modules replace the primary lecture and discussion sessions found in traditional classrooms. Each concept and example module is approximately 5-20 minutes in length. Students watch videos and answer questions while instructors create videos and provide questions for concept checking.

Students are presented with a list of concept and example modules. A brief quiz is provided at the end of each module. Students answer these questions and depending upon their performance, the design tool will analyze their answers and make suggestions for additional studying.

For example, a student may have just finished viewing the Arithmetic concept module (**Figure 3**). At this point, some review questions will be prompted to the student, such as:
For a 4-bit Two's Complement Adder/Subtractor, what is the result of 0010 - 1101? ____

If the student answers correctly with 0101, a more advanced question can be asked to figure out the understanding of the student. If the student answers incorrectly with a wrong answer, more basic questions can be asked to assess the student's level of understanding. The design tool will then compare the keywords associated with the questions against the concept, example, and pre-requisite modules. Based on the answers, the tool suggests further studying material. For example, if the student answered fundamental questions incorrectly, it may determine that they need to review basic binary arithmetic before coming back to two's complement numbers. If the student answered all questions correctly, it may be suggested that the student review more advanced concepts related to adders/subtractors to keep them challenged.

4.1.2 Online Tools

Online tools such as message boards provide an environment for students and instructors to interact and discuss varying concepts regarding the course but are limited

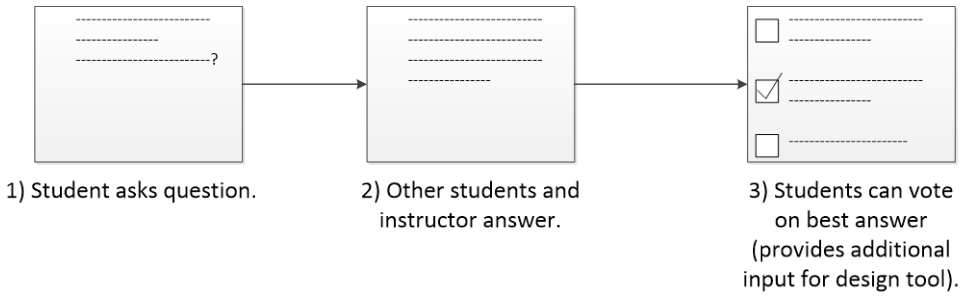

Figure 4: Online Tools Flow

in efficacy. Improving these tools by allowing for more interaction can help satisfy the social and esteem needs portion of Maslow's Hierarchy.

Threads and posts from the course message board can be added to the data set for each student profile by the design tool with help from instructors and teaching assistants (**Figure 4**). Keywords can get generated for each post by the design tool to further analyze the needs of students.

suggestions for further studying to students based on their profile and data gathered from them for each topic. This automated topic review can be sent via email automatically, minimizes the need for instructor or assistant initial intervention, and maintains the students desire for "one-on-one" interaction.

Students receive their review via email after completing the required modules and homework. Homework is downloaded,

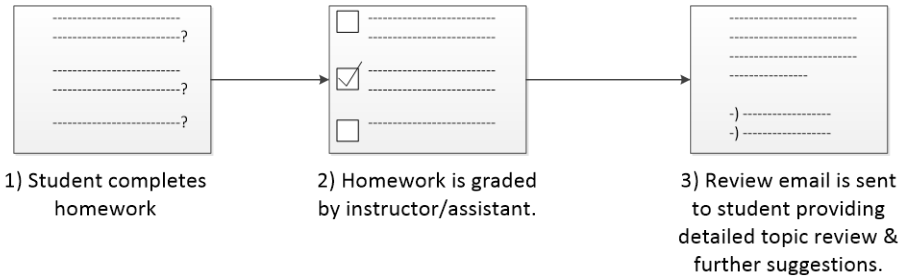

Figure 5: Topic Review Flow

The general format will ask a student to classify their own post among several different options, such as "question", "clarification requested", "typo/error found", etc. Posters can also vote for the "best solution" when a question is posed as well.

Continuing with the RTL combinatorial module example with two's complement adders, a student may post a question regarding how to handle overflow in such cases. Other students, and possibly the assistants and instructor, will answer the post. Participants vote on the best answer. The current best answer is highlighted for the topic thread and is later used by the design tool when making studying suggestions.

4.1.3 Topic Review

When homework and initial viewing of the concept and example modules are completed, the topic review can be automatically generated by the design tool, which will send completed, and submitted online through the design tool or equivalent online interface (**Figure 5**). If homework is submitted online and in the proper format, an intelligent design tool can provide all the grading and post assessment of work. The email will contain information regarding the student's current progresses, his or her strengths and weaknesses, as well as suggestions for additional review to help the student catch up if needed. For advanced students, additional challenging modules are recommended.

The homework for RTL combinatorial components contains several concept questions. Each student's homework is graded by the instructor and assistants. Optional comments may be left for the assignment. The design reviews the homework grades, matches it against previous suggestions, checks student module viewing behavior, and generates a detailed review email to be sent to each student. The review email can suggest more detailed review modules than the suggestions from the concept and example modules.

4.2 Learning Tool Back-End and Algorithms

The design tool contains two main data structures: the course data structure and student profile data structure. Together, both structures are utilized by the design tool to analyze student performance and make appropriate suggestions for students while providing a useful profile to display to the instructor for reference.

The design tool analyzes data from the design tool data structure in order to create custom reports for students and assign them additional modules for further studying when appropriate. This tool also provides a summary of each student's progress for instructors to review before meeting with students individually when needed to maximize efficiency when holding office hours.

4.2.1 Student Feedback Generation

After students each concept and example module, students answer a series of questions to check their understanding of the material. Depending on their answers, the design tool will rate the students, look through the data structure for additional modules that will help them, and provide additional feedback as appropriate.

The design tool can bases its keyword search on a Latent Semantic Analysis (LSA) algorithm or other natural language processing algorithm to find similar keywords and concepts based on the provided dataset. The design tool can index message board posts and reference the data inputted for each post by instructors and assistants, allowing for more information to be analyzed, increasing potential custom guidance for each student.

The LSA algorithm is used to find modules, posts, and questions based on the keywords of the quiz or homework questions the student misses. From there, the design tool determines which modules are most appropriate based on difficulty, closeness in relation, and previous topic review suggestion results.

4.2.2 Student Summary for Instructor Generation

Instructors will inevitably be required to meet with some students, be it in-person or online. Since the goal of the design tool is to allow for an individualized experience for students on a large scale, student summaries are generated by the design tool to help instructors quickly identify a student's weaknesses and strengths before meeting with him or her.

Similar to the Student Feedback Generation, a Latent Semantic Analysis algorithm to find matches. The LSA algorithm is used to find modules, posts, and questions based on the keywords of the quiz or homework questions the student misses and gets correctly. The design tool further analyzes how the student divides his or her time among various concepts. Suggestions are made based on student participation and focus on the modules.

5 Conclusions

This automated learning management tool can categorize and assess students by their performance levels basing its techniques from other disciplines to maximize not just performance but also motivation and self-satisfaction; existing tools for managing MOOC's follow traditional methodologies and provide the same experience for everyone, hindering motivation, self-satisfaction, and inevitably performance for many students.

Furthermore, the data structure is based on comparing student and course profiles to automate teaching and learning, which allows larger scale instruction while minimizing overhead and time commitment from both students and instructors. The structure provides a useful dataset for the design tool, which uses the data in algorithms that generate meaningful reports containing suggestions and reviews of the student's work based on each individual's progress. This automated system is integral in making a hybrid methodology for large scale courses with minimal instructor involvement possible while focusing on satisfying the metrics proposed.

Further research and data gathering for developing this automated tool is currently underway.

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