On-line Peer Review in Teaching Design-oriented Courses

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ABSTRACT

Peer review has been one of the very important design-facilitating processes practiced in education field, particularly in design-oriented courses such as MIT's 2.007 Robot Design. Typically students exchange ideas sketched on a piece of paper and critique on each other's design within a small team. We designed PREP web application backed up by a range of web services that handle the peer-review process on-line, and we argue that this is a significant step towards supporting design-oriented course on-line. We believe that the lessons learned could be applied to other interested institutes that offer design-oriented courses.

Keywords: e-learning, design-oriented, tablet pc, peer review, web services

INTRODUCTION

This paper presents an e-education platform – Peer Review Evaluation Process (PREP) system – that focuses on the peer review and evaluation process within the context of project-based design-oriented courses. We discuss the pedagogy, design philosophy, architecture and technology behind the system. PREP system has been implemented and evaluated in the International Design Contest (IDC 2002) held at Massachusetts Institute of Technology (MIT) in August 2002, and MIT's Mechanical Engineering courses 2.993 (Paths to Peace) in fall semester 2002. The system is built with the web services technology using Microsoft .NET platform. As participants of Microsoft Tablet PC Rapid Adoption Program, we were able to equip the participating students with the exciting tools of tablet PCs. They proved to be critical design resources which greatly enhanced the experience of using PREP system.

The problems

E-learning has been transforming the traditional education environment of "same time, same place, only some people" into a new instructional model that features "any time, any place and anybody". At MIT, various departments, labs and research groups have built web sites that support various aspects of the learning process. Most of these efforts focus on course content delivering. However, a significant number of courses are conducted in forms of seminar, project, design studio and etc. In these types of courses, interactions among students are equally, if not more, important as the interaction between students and instructors. Reviews and comments from learning peers are often essential to help students to develop the design concept. Few of the aforementioned e-learning environments even supports feed backs from students to instructors, let alone information flow between students.

Goals

Confronted by the above issues, we want to propose a solution that can answer these questions. The primary goal of this research is to explore new e-learning approaches for design-oriented courses. An exemplary system that handles one particular aspect of such type of courses, Peer Review Evaluation Process (PREP), is implemented and evaluated, both technologically and pedagogically. The research also investigated a new web application programming model for PREP – web services, and tested a new type of computing hardware – tablet PC.

PEER REVIEW IN DESIGN-ORIENTED LEARNING

Design-oriented learning

In courses of certain fields such as architecture studio and mechanical machine design, students engage in learning in a unique fashion. The tasks of this type of courses, such as "design a library building" or "build a robot to compete in a contest", are often loosely and broadly defined. It emphasizes the process of generating ideas based on pre-defined design parameters, encourages creative thinking to explore different strategies and concepts, relies on visual tools to communicate ideas, involves hands-on simulation or experiments, and often requires students constructing physical products (architecture drawings, building models, mechanical parts, machines, robots and etc.) using various tools.

Archer pointed out "Design is that area of human experience, skill and knowledge which is concerned with man's ability to mould his environment to suit his material and spiritual needs" [1]. Various theoretical developments in cognitively based interpretations have been given to the irregularities of designers' modes of operation [8, 9]. All of them refer to the concept of the characteristic of design, the concept that human problem-solvers are rarely in a position to identify all possible solutions to the problem at hand and therefore settle for choices that seem to satisfy the required solutions most appropriately as they see them at the time [16]. Generally, they make decisions that might or might not be the most optimal, or what Simon refers to as "satificing" [17, 18, 19]. Thus, the problem facing educators is how to rationalize the design process, or the "problem-solving process" that allow students to go through a series of steps to generate favorable but yet still unique and creative outcomes. A very successful practice from MIT robot design courses is the Deterministic Design [17] approach. Students start with building concepts, select strategies they will follow to tackle the concepts, and then build the individual modules of the project. It leaves lots of room for fee creative spirit, and lots of room for experimentation and play, yet it keeps the exploration within the boundary set by the design parameters.

Engineering design process

The task of engineering design is to apply the scientific and engineering knowledge to the solution of technical problems, and then to optimize those solutions within the requirements and constraints set by material, technological, economic, legal, environmental and human-related considerations. Because of the complex nature of modern technology, it is now rarely possible for an individual to tackle the design and develop of a product single-handed. Engineers often work in teams, which require highly efficient organization and communication. The design process has to be broken down into phases and steps so that it can be planned carefully and executed systematically. An essential part of the problem-solving method involves step-by-step analysis and synthesis. Here is a diagram of operational guideline for finding solutions for general engineering problems [14].

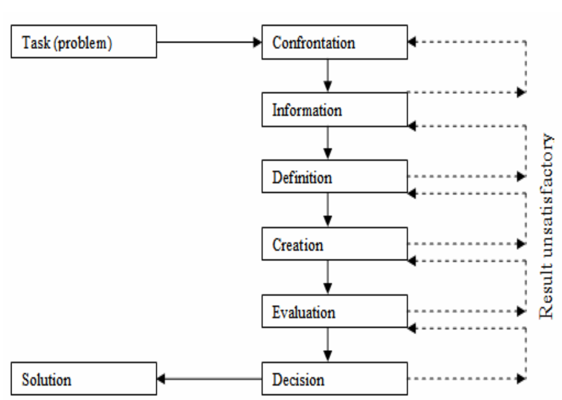


Figure 1 General Process for finding solutions

Rohrbach 635

In the above cycle of design process, to systematize the design thinking, many general methods are used. One of the widely practiced methods in the aforementioned MIT courses/events is Method 635 by Rohrbach [15]. The method is described as following:

Designs are divided into 6-person teams. After familiarizing themselves with the task and after careful analysis, each of the 6 participants is asked to write down three rough solutions in the form of keywords. After some time, the solutions are handed to the participant's neighbor who, after reading the previous suggestions, enters three further solutions or developments. This process is continued until each original set of three solutions has been completed or developed through association by the five other participants. Hence the name of the method.

Rohrbach 635 is a very effective method in that it allows creative idea to be developed more systematically. It encourages, and almost forces, team members' participation. It suppresses the dominating group member problem. It creates a democratic group atmosphere for every participant. It prevents censoring of such thoughts as might give offense to superiors or subordinates since all group members are equal. Introverted group members feel less intimidated in writing down their critics than openly discussing other people's ideas since no talking is allowed during the process. The method provides excellent documentation for itself along the way which is invaluable for the design process.

In essence, Rohrbach 635 is a peer-review evaluation brainstorming procedure. The past MIT 2.007 course adopted Rohrbach 635 effectively. Every student is required to go through a couple of iterations of this process before even starting to build the computer model. It provides a systematic means for sharing and compiling the ideas generated by all team-members, and also their opinions and comments on each other's ideas. Because of its proven effectiveness in past pedagogical practice, its importance in searching for solution for design problems which, to a lot of students, is a significant barrier of entry to design-oriented courses, and its relatively rigorous step-by-step characteristics, Rohrbach 635 peer-review process became the preferred candidate for us to model our first software module for e-education platform supporting project-based design-oriented learning.

PREP SYSTEM DESIGN

PREP web application, as the first phase of RobotWorld project, tries to implement the Rohrbach 635 method on-line using web services programming model. This section explains in detail of the design of the software itself.

Stakeholders and roles

The stakeholders in the PREP project includes a diverse group of users, each have a slightly different perspective on the development process, as well as a different role in the actual design activities.

Developers and development platform: PREP project development group consists of one professor, three graduate students and one undergraduate student, all from IESL. The development tool we used is Microsoft Visual Studio .NET.

Users and client environment: The users in the PREP application are considered to be all people who use the system via its web client interface on a daily basis. The majority of them are students who participate in the Rohrbach process. PREP system contains two levels of groups: site group and project team. The same user identity could be assigned with different roles depending on which group context he is in.

Users are expected to operate on Internet Explorer or Netscape Browser version 4 or above. There is no additional software required, and all user administrative functions have been built-in to be accessed from browser.

PREP architecture

PREP is written in C# on Microsoft ASP.NET platform and Common Language Runtime. Since it is built on the web services model, many of its web service components can be replaced with web services built with Java or other language/platform, or re-used for other web applications, as long as the standard SOAP contract is honored.

PREP is built with extensibility and flexibility in mind. The core rendering engine of PREP provides "sockets" to plug in any kind of ASP.NET user controls which in turn may be backed up by web services reside on different machines, which in turn may access database server on yet another different machine. This gives tremendous freedom for future functionalities to be easily and seamlessly integrated without affecting the existing modules.

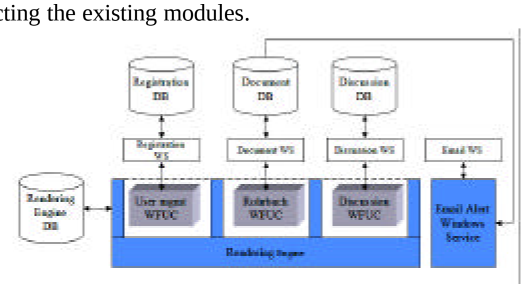


Figure 2 PREP architecture

Some notable modules from current PREP system are described below.

Rendering engine: The rendering engine is responsible for taking in user inputs, sending out requests to other service modules based on the user input, gathering all the information returned by the service modules, laying out the information on a web page generated at the run time, and delivering it back to client browser in HTML stream. It uses its own database to store page configuration information.

The rendering engine leverages the ASP.NET web form user controls (WFUC). Developer can write small "page-lets" – web form user controls. They are organized to form various virtual tabs. Depending on the tab user clicks, and his role in the current group context which determines his permissions, the controls are loaded on the fly and laid out on the current tab.

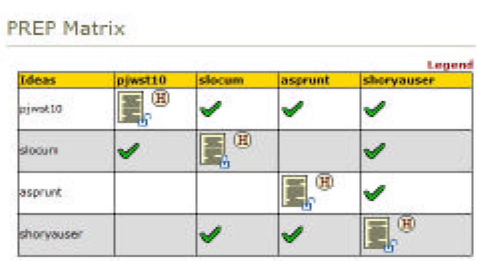


Figure 3 PREP matrix

Rohrbach process WFUC: This is a set of user controls that handles peer review process work flow. It provides web browser user interfaces to start/edit/delete a Rohrbach process, upload/download documents, lock/unlock documents and etc. It is backed up by the document web service.

A unique feature of this Rohrbach process web form user controls is the PREP matrix. This is the tool that let Rohrbach participants start their peer review process. The document icons appearing diagonally across the matrix indicate whether a particular user has uploaded his ideas for review. The green ticks indicate finished reviews. The small lock/unlock icons associated with document icons tell user if a document is checked-out for review at this moment. Just by clicking on the document icons, user can access the "downloading" function if the document is currently checked out and locked by another user, or the "check-out and review" function if the documents is unlocked and free for check-out. The supervisors and everyone in the team can get a clear, visual view of the status of current Rohrbach process.

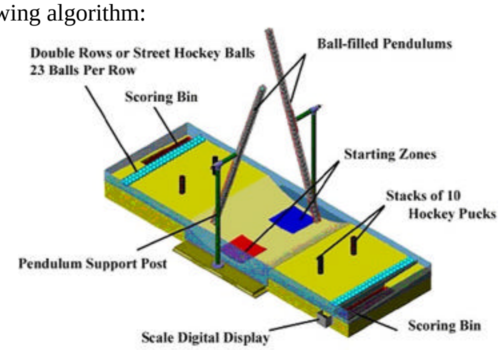
The other notable feature is the document history. In the physical Rohrbach process, it is not easy to tell which comments are made by whom unless it is carefully documented. And the documentation process does not typically happen in a brain-storming process without some form of enforcement. With virtual Rohrbach process, the document web service automatically keeps all versions of the document. By clicking on the "H" icon to the top-right hand corner of the document icon, user can get a document history that provides links to every single revision so that they can always refer back to the original document.

OBSERVATIONS AND ANALYSIS

IDC 2002

International Design Contest 2002 was held at MIT. It was a huge success, attracting 40 students from 7 leading universities of 7 different countries. They formed 8 teams, each has about 5-6 people. They overcame the language barrier, among other difficulties. And all teams successfully produced qualified robots to enter the final contest.

The objective of the competition is to build a remote-controlled shoebox-size robot that, within 45 seconds, picks up hockey pucks and street-hokey balls that are stationed on a contest table, and puts them into a bucket. At the same time, the robot is required to spin a ball-filled pendulum to get more balls onto the contest table. The mass of pucks/balls being put in the scoring bin is calculated; together with the angle in radiance the pendulum gets spun. The final score is determined by the following algorithm:



Score = (Newtons + 1) X (Radians + 1)

Figure 4 IDC contest table

Students were highly motivated by the idea of being able to design the robot using their own strategies to achieve the highest score. Project-based design-oriented learning was put in thorough test in IDC 2002. Contestants have to go through a full cycle of engineering product design in a short period of two weeks.

Tablet PC proves to be invaluable in the IDC 2002 project teams. The IDC contestants came from seven countries, speaking six different languages. Each team consisted of contestants from a mixture of countries, which means most students had to communicate in a foreign language. Although the official language is English, not every one mastered it well enough to express his or her ideas clearly. Sketching on the tablet PC becomes the natural alternative. Although they could have done it with pen and paper, with the help of MIT's wireless enabled classrooms and machine shops, the tablet PCs allowed them to share their ideas quickly without resorting to other devices such as scanners and printers.

However, the PREP software itself did not attract as much usage as we originally planned. There reason lies in a couple of facts.

First and foremost, the PREP software is designed to implement the Rohrbach process without the physical presence of team members. This would work very well with geographically dispersed teams or teams that have members operating on different time schedules. IDC, on the contrary, have all team member on-site and working together closely in a central location. It became apparent after a few days into IDC, students would rather make design sketches on tablet PCs and simply copy files through wireless network than go through the upload and download procedure using PREP software, even though PREP software provides revision history track that file system does not. The problem lies in the fact that when teams are under a tight schedule and require real-time synchronous peer-review process, direct interaction between teammates is preferred over asynchronous-oriented facilitating tools.

Further more, because of the short time-span of the project, IDC teams did not have enough time to familiarize themselves with the system. Although the software is user friendly and self-explanatory to people who have prarcied Rohrbach process, the concept of peer review is new to most of the students not from MIT. In addition to getting used to this new design thinking process, they have another million things to do in two weeks time, and learning how to use the PREP software, although simple enough, is not on their priority list.

In other words, the benefit of PREP software in this case did not justify the time spent learning and actually using the software. Interestingly enough, most students did accomplish a few rounds of Rohrbach process, with the help of tablet PCs, plain file system and the wireless network, meeting our expectation half-way in between. The PREP methodology proves again to be efficient in producing rapid design ideas in a relatively short period of time. As to the hardware – tablet PCs, students quickly adopted them as a useful design tool and made extensive use throughout the competition.

2.993 Paths to Peace

2.993 was carried out in the fall semester of 2002 following the success of IDC. It aimed at developing students' design thinking and mechanical skills through the making of an inlaid or mosaic tile that is precise and can withstand the rigors of time. A final open exhibition of the tiles made was held to MIT community and Greater-Boston public.

As a pilot course using tablet PCs as well as PREP software, 7 enrolled students were divided into 2 design teams. Unlike IDC, this was an individual project course where team collaborations were limited to commenting other member's design ideas.

After the design teams were formed, students started the Rohrbach process with the help of PREP software. Each student came up with 3 ideas for his tile design, documented them with tablet PCs and uploaded the design files into PREP system. Everyone then was responsible to comment on everyone else's ideas through the check-out, review and upload functions offered by PREP. This was the first round for design concepts. After the completion of concepts PREP, students decided on what they want to build, and then moved on to the next round of strategy PREP where they decided how to approach the design problem, how to convert the artistic theme into engineering manufacture, at the same time with risk analysis and counter measures in mind. After that students started setting up PREPs for various issues depending on their design, and they were encouraged to meet and brainstorm their ideas after finishing every round of PREP.

Students showed great interests in using the PREP software to privately comment on each other's ideas prior to the brainstorm sessions. Due to the relatively longer commitment in 2.993 (one semester) and the busy schedule each students typically had to handle, the asynchronous feature of PREP were greatly appreciated. They did not have to spend their already precious time in scheduling group meetings for Rohrbach sessions. Comments and reviews were done without the physical presence of either party. There were no "dominant" or "inert" members. Everyone's ideas were treated as equal contributions. Team moral was high and individual participation was more than active. Even the normally under-appreciated threaded-discussion board was filled with passionate posts regarding the design.

From the teaching staff point of view, the PREP software gave a very clear picture of how the Rohrbach process was carried out. They were able to find out the status of a particular round of PREP by just looking at the PREP matrix, and download a copy of any Rohrbach sheet submitted by any team member at any time. The system automatically sent out email to remind team member the approaching deadline for the current Rohrbach process he is in. The supervisors (TA or professors) also automatically received emails regarding each member's standing after one round of Rohrbach completed. The course was finished with successful results. All students accomplished their goals set by their own design strategy and concept.

CONCLUSIONS

This research has demonstrated one approach to build web system to support project-based design-oriented learning. In particular, the peer review evaluation process, or Rohrbach method, was implemented using advanced web-services model.

PREP system is built using latest web services model together with extensible ASP.NET web form user controls. Its componentized architecture simplifies development and integration of future plug-in modules on top of existing functionalities. Preliminary tests on IDC 2002 and 2.993 at MIT show the effectiveness of this targeted e-education platform and its great potential. The advantage of early adoption of tablet PCs achieves also proves that they can become critical resources for the rapid development of ideas by design teams.

FURTHER RESEARCH

PREP has lots of room for improvement. For example, although we have version-control built in for referring back to the original documents submitted by any particular user, it would be very useful to recognize the ownership of every word written, every sketch drawn right on the downloaded Rohrbach sheet without comparing to its previous version. Thus, designer can easily build a mental path of the evolution of the ideas. Currently Window Journal software does not support tracking individual strokes made by different users, but Tablet PC SDK by Microsoft would allows us to build this function on .NET platform.

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