A Framework for Design Engineering Education with Workflow-based e-Learning System

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Abstract—Education of design engineering has started to change in response to the advancement of computer technology. This paper proposes a new design engineering educational framework using an e-learning system called ShareFast, a Semantic Web-based software for document management system with workflow. The software offers a function to keep tracks of learner's behavior so that the instructor can analyze it to improve learning materials and class efficiency. It can also record learner's input and output history data for the instructor to conduct performance analysis activities. This educational framework has been used for empirical studies with university students. The results showed that the framework could help the instructor to understand the student's problems during the class, and it can shorten the students' learning duration by means of learning materials improvement.

Index Terms—e-learning, design engineering, Semantic Web, workflow, document management system

I. INTRODUCTION

Engineering design is a multi-disciplined environment, a highly integrated and integrating process [1]. It has been a human activity for many centuries. It aims to produce the documentation for manufacturing a useful product that can fulfill some of the needs of mankind [2]. Design is a central activity to all types of engineering [3]. Mechanical, civil and electrical engineers attempt to solve very different types of problems, but they all design some solution to the problem at hand. In engineering design industry, works that are related to product design and manufacturing have very high visual content [4].

Computer innovations, consequently, have been used as tools to help ease complications in design process.

Computer aided design (CAD) software, for instance, have become central to process from the earliest design phase to final production [5]. However, the engineers need not have any knowledge of the sophisticated mathematics and computer science upon which CAD systems depend. CAD enables creation and control of product information.

As a result, it is not surprising that the educational field of using computers in design engineering has responded strongly. From an early availability of one or two computer terminals for post-graduate students or research workers, it is now becoming common for educational departments to have several terminals and in some cases their own computing power.

Those in education have double motives for introducing computing into their courses. Firstly, an awareness of the need to educate students for careers in which computers will play a well-accepted part, and secondly, the attractions of using computers to assist and improve the education process itself.

One example of using computers for engineering design education is at the School of Marine Science and Technology, Newcastle University, UK. A commercial CAD software, which performs as a tool for modeling an initial ship hull form, the internal arrangement and performing naval architectural analysis upon it, has been used to support large design projects undertaken by undergraduates in the teaching of ship design as part of the Marine Design module since 1995 for the Naval Architecture degree programs. It has been used to allow students to develop a hull form, generate the arrangement and then evaluate their preliminary design. In doing so, the software allows the students to become familiar with the ship design process and the use of industry standard ship design software [6].

Not only using commercial software for teaching design that has been growing rapidly, but in-house educational design software packages developed by academic institutes has also been implemented widely. A software package, AccomDesign, has been developed by a research team as a tool for teaching functional volume design approach [7]. The primary purpose of the software

is as a training tool to acquaint students and designers with this design approach in ship design process.

However, design education using computer is not very simple. Students have to learn both design process and the use of design software, e.g. CAD software. Moreover, teachers find it difficult to manage the class that involves many information technology aspects. Wright [6] stated that one of the main problems that he encountered in teaching the CAD software was helping students to manage the files associated with the separate modules at each stage of the design process.

According to these difficulties, an e-learning based framework for design engineering education is necessarily developed to help instruct students for the overall design procedure. E-learning systems play a key role in education as an environment for improving learner autonomy, multimedia instructional content and problem-solving skills, with teachers as assisted tutors [8]. The framework should, at least, be able to simplify the design learning processes, manage learning materials, support student-teacher interaction and keep track of students during the class for class evaluation. These are the basic concepts of the e-learning system called ShareFast [9]. ShareFast is a document management system based on workflow and was developed for knowledge acquisition and representation originally for student exercises.

This paper presents a design engineering educational framework using ShareFast software, and explains the key features of the software. The first feature is to keep tracks of learner's behavior so that the instructor can analyze it to improve learning materials and class efficiency. The second feature is to record learner's input and output history data for the instructor to conduct performance analysis activities. Furthermore, the paper explains the experiments conducted on the framework to provide enhanced design assistance to aid students undertaking design coursework. The empirical evaluation of the experiments and potential improvements of the system will finally be stated.

II. THE SEMANTIC WEB-BASED SYSTEM: SHAREFAST

ShareFast, formally known as UT-ESS (University of Tokyo Educational Software for Shipbuilding), has been developed by the members of Design Engineering Laboratory, the University of Tokyo. It is an open source, client/server application for document management based on workflow using RDF metadata on Jena framework. The client program, developed using C# technology, provides a workflow editor for users to create workflows and relate any documents to each task node in the workflows. It also provides the Tree Explorer to browse the workflows hierarchically. Workflows will be stored as XML with their metadata (e.g. creator, create date etc.) in RDF format. The client program uploads them together to the server.

The server program, developed using Java Servlet technology, on the other hand, is responsible for managing documents. It keeps all workflows, workflow's hierarchy structure, metadata and documents created by the client program. It also offers a full text search engine to support document search queries from the client side. The server program, however, is encapsulated from users. Therefore, users do not need to know how it works.

Fig. 1 shows the ShareFast user interface. Users can create and edit workflow in the workflow editor panel. They can also add document files to the task node of the created workflow. After they save the workflow, a small icon with the workflow name will appear at the tree explorer, so users can browse and open the workflow again later. It is possible to create folders in the tree explorer to keep the created workflows well-organized in hierarchy format.

In order to retrieve the documents added to a task node, users can click on the task node. Then, all added document name links of that task node will be shown in the browser panel. Users can click the name link at the browser to launch the document file. Fig. 2 shows how to retrieve document from task node. Another way to retrieve documents is to use search function. Users input a text string to the search box in the toolbar, and all documents that contain the string will be listed at the browser panel.
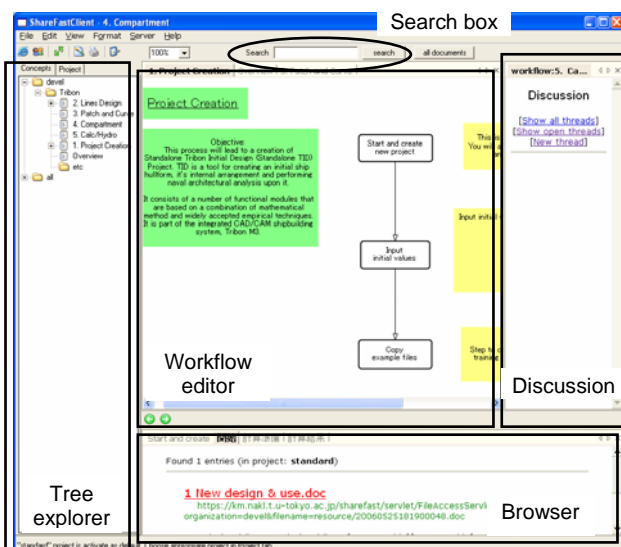

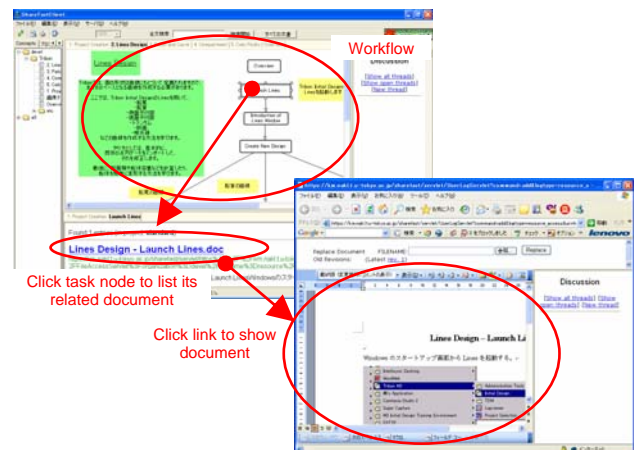Figure 1. Software user interface

Figure 2. Retrieving document from task node

Discussion thread can be added to workflow and task node, so users can communicate to each other about the matters regarding the workflow or task.

The structure of RDF used in this software is illustrated in Fig. 3. Each workflow, task and document is represented as resource. Workflow, task and document are class instances of sf:Workflow, sf:Task and sf:Document, respectively. sf:taskInWorkflow explicitly describes that a task is in a workflow, while sf:relatedTask property is defined for describing relationships between tasks and documents. Using this approach, all the workflows, tasks and documents can be identified.

III. SHAREFAST AS E-LEARNING SYSTEM IN EDUCATIONAL FRAMEWORK

Since its development, ShareFast has been applied for many aspects, such as knowledge management, information sharing environment and design support
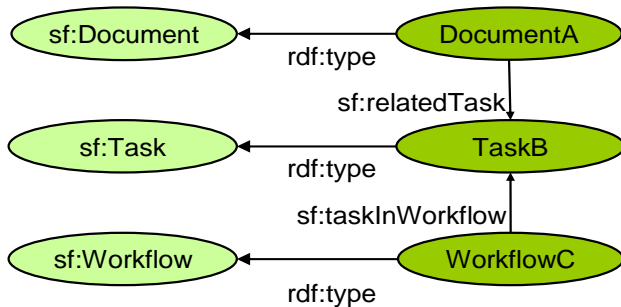
Figure 3. RDF structure used in ShareFast

system. However, one of the very first reasons to develop ShareFast is to use it as the e-learning component of a framework for supporting design education, such as CAD software learning.

The design engineering educational framework using ShareFast is illustrated in Fig. 4. The framework consists of five main components, students, teacher, ShareFast system, IT infrastructure and design software. Teacher uses ShareFast to prepare for the class. Students learn how to use design software from learning materials and facilities provided by ShareFast. IT infrastructure plays a key role in supporting both ShareFast system and design software.

ShareFast system contains many functions and activities, which can powerfully facilitate teacher and students in design learning activities. The dash lines are the activities involved with teacher, while the dot lines and the normal lines are the activities of students and ShareFast system, respectively. The star-marked boxes, i.e. Discussion thread, Log file, Class analysis, Design history recorder and analysis, are the functions that have been newly developed to support educational activities. All the functions and related activities will be explained hereafter.

A. Learning by Workflows with Releated Documents

ShareFast offers the teacher the workflow editor tool, which can be used to create workflow process, and add documents such as design manuals to the related tasks in the workflow. Students can learn design process by following each task with related documents. Workflow helps students understand the design processes more easily as it allows students to know the whole learning
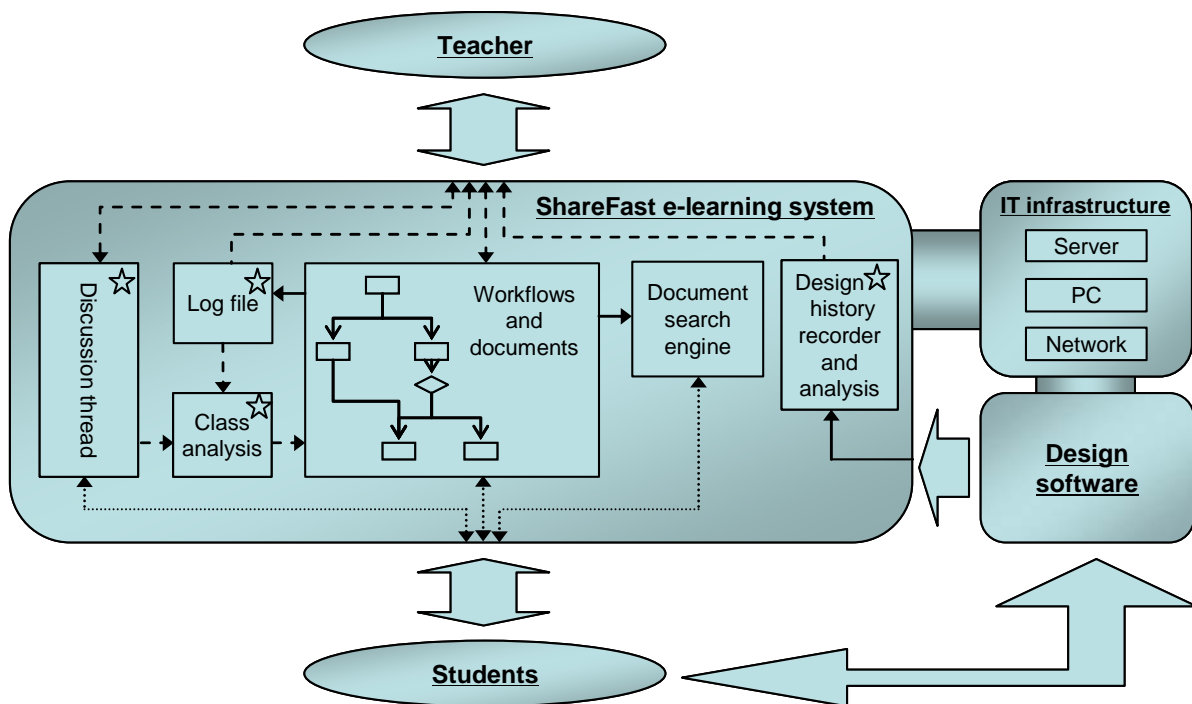
Figure 4. Design engineering educational framework using ShareFast

process before going deeper in detail of each task. This concept coincides with Bruner's theory [10] stating that clear indication of picture of whole task results in efficient education.

B. Student-teacher Communication by Discussion Threads

Student-teacher communication is important for every educational framework. ShareFast allows student and teacher to add discussion threads to any workflow or task. Discussion thread, shown by clicking the workflow or task node, is a message board for student and teacher to discuss a particular subject at process level (workflow) and task level (task node).

C. Student-based Data Management System

Students are able not only to get documents from workflow's tasks, but also to put their documents to the tasks. With this feature, together with student-based data management system, as illustrated in Fig. 5, the teacher can put standard learning document, e.g. design template file, to standard space, where every student has access. Each student works on one's own individual space. Documents added to individual space can be seen in the particular space only. This helps the teacher manage each student's learning material more efficiently.

D. Student Behavior Capture using Log Files

ShareFast keeps track of student's actions after they log in to the system by writing to log file, shown in Table I. It can tell the time that student logs in to the system, clicks and downloads learning material of each workflow and task. This is useful for the teacher to monitor student's learning activities.

E. Class Analysis and Improvement Method

From students' query messages in discussion threads and students' behavior captured by log file, the teacher can evaluate and analyze the class quality. The teacher will know the task that students spend too much time on, frequently ask questions, or the task that students have to get back to read its document many times. Teacher can consequently check the task material and improve it for the next class.
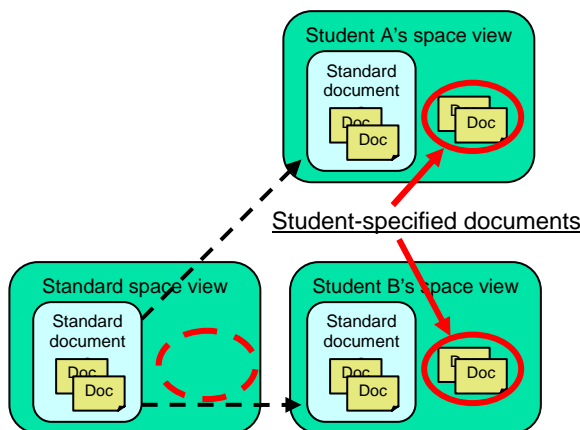

Figure 5. Student-based data management

F. Design History Record and Analysis

This function will keep all design input parameter values for some design support software entered by students during the class as well as the corresponding output parameter values. The instructor is able to extract the design parameter history recorded in the ShareFast server for analytical activities. For instance, the instructor can evaluate students' performance (input parameter values and corresponding output parameter values) in time series, not just the final input and output values. The recorded data can also be used to understand how each input parameter value affects the output parameter value. This function will play a key role in the case study two of this paper.

IV. EMPIRICAL STUDIES: SHIP DESIGN CLASSES

In order to gain experience with ShareFast and to find potential for further improvement, the authors have conducted two experimental case studies. Both cases were arranged for students in ship design classes.

A. Case Study One: Learning Ship Design with CAD Software

This case study was arranged where students used ShareFast for ship design learning with Tribon M3, a commercial CAD software package. The approach of this experiment was that six students were divided into two groups, three students each. In order to gather and analyze the class result of the first group to improve class efficiency of the second group, the class for the second group was conducted one week after the first group. The content of the classes is to teach students how to use Tribon M3 Initial Design in five modules of ship design, i.e. Project Creation, Lines Design, Patch & Curve, Compartment and Calc/Hydro (optional). After each class, students were asked to fill in a questionnaire for class evaluation.

To instruct the students, the instructor created workflows for each module, and added instruction documents and other necessary files to the related task nodes in the workflows. The students began learning from the first task of the first module, and moved to the next module after finishing the current module, while the instructor observed them in the same room. Fig. 6, for

TABLE I.
EXAMPLE OF LOG FILE CONTENT

User	Time	Session	Task
Student 1	4:55:15	login	
Student 2	4:55:43	login	
Student 3	4:56:22	login	
Student 1	5:03:16	start_task	Launch CAD
Student 2	5:03:17	start_task	Launch CAD
Student 3	5:03:17	start_task	Launch CAD
Student 1	5:03:21	start_task	Create new project
Student 1	5:03:42	start_task	Import parameter
Student 2	5:04:06	start_task	Create new project

example, shows the workflow of Patch and Curve module, which is to create a surface of a ship hull. This module consists of 6 tasks. The students started each module by clicking each task node to retrieve instruction material describing how to work with the CAD software in the module. They were also able to add discussion thread to the workflows (modules) and task nodes (tasks) that they had problems with and needed to discuss with the instructor and other students.

Fig. 7 shows how to work with ShareFast. The students, acting as knowledge recipient, learned design process through ShareFast workflows created by the instructor, and posted questions and errors messages to the instructor. The instructor, performing as knowledge distributor, analyzed those questions in order to improve the learning contents.

After the class, the instructor conducted class analysis from log file keeping tracks of student's activities. From this log, it was possible to make graphs showing the time duration that the students spent on each task and module. Fig. 8 describes the duration result of each module of this class. From the graph, it was able to know the modules that the students spent too much time on than is necessary. This log, additionally, could tell us some students' learning behaviors. For instance, the instructor found from log file, illustrated in Fig. 9, that student 3 performed the tasks "Complete the surface", "Check/adjust Isophotes" and "Release the surface" of the Patch & Curve module, and continued to the task "Surface and compartment" of the Compartment module. After that, he had to go back to perform the tasks of Patch & Curve module again. Later on, the student was asked about this and he said that it was because he could not continue the task of the Compartment module as the previous tasks of the Patch & Curve module had not been finished yet. This kind of behavior can indicate that student was unclear about the learning material, and consequently, it should be simplified.

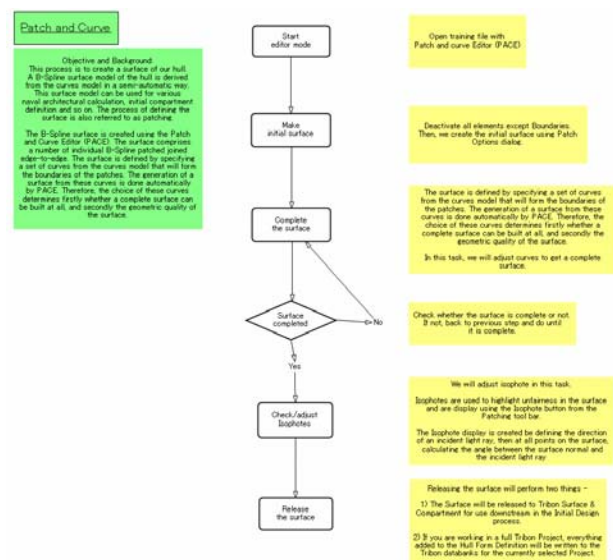Furthermore, it was ensured that discussion threads

were helpful not only to handle class communication, but also to store students' question and answer messages during the class. It was later on valuable for instructor to understand the weak points of the class, and how to solve them.

From all of the analytical techniques mentioned above, the instructor carefully refined the learning materials of trouble-causing tasks, and polished some unclear and time-consuming module workflows. For example, in Patch & Curve module, there were seven problems posted by the students to discussion threads. The instructor tried to find the causes of those problems and fix them to improve the class. Table II displays some messages in discussion threads of Patch & Curve module and their causes as well as how the problems were responded.

After that, this revised content was used to conduct the second ship design learning class in the following week, which it was also applied the same teaching approach as the previous class. The outcome revealed, as expected, that the students in the latter group posted less query messages using discussion threads than the previous group of students did. Moreover, the graph from the second class log file, illustrated in Fig. 10, indicates that the average class duration was cut from the first class by 17 minutes, partly resulting from the time duration in Patch and Curve module that was significantly reduced from 1 hour 11 minutes to 42 minutes.

All of the students were asked to fill in a questionnaire. The questionnaire consists of 4 sections. In section 1, all the six students were questioned about their knowledge of the CAD software package. It turned out that all the students had no background knowledge and experience of the CAD software at all before the classes. However, they confirmed that, after taking the class, their understanding of the software had been improved to some extent. Questions about ShareFast software were asked in section 2. The answers were satisfying as five of the students agreed that the software was easy to use and learning ship design by workflow helped them understand design process more easily. Conversely, four of the students did not think that the discussion thread function was very

Figure 6. Workflow of Patch and Curve module
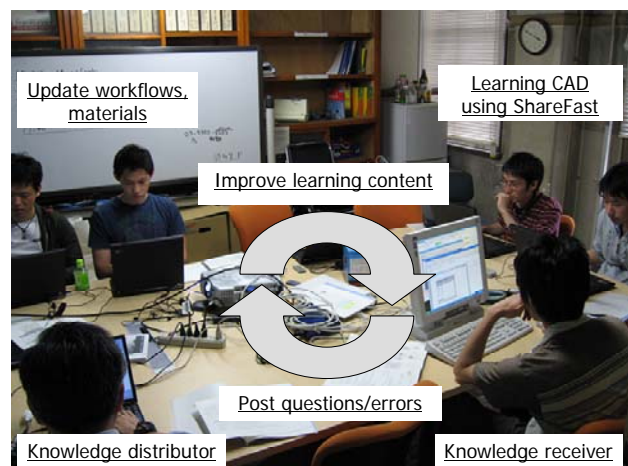

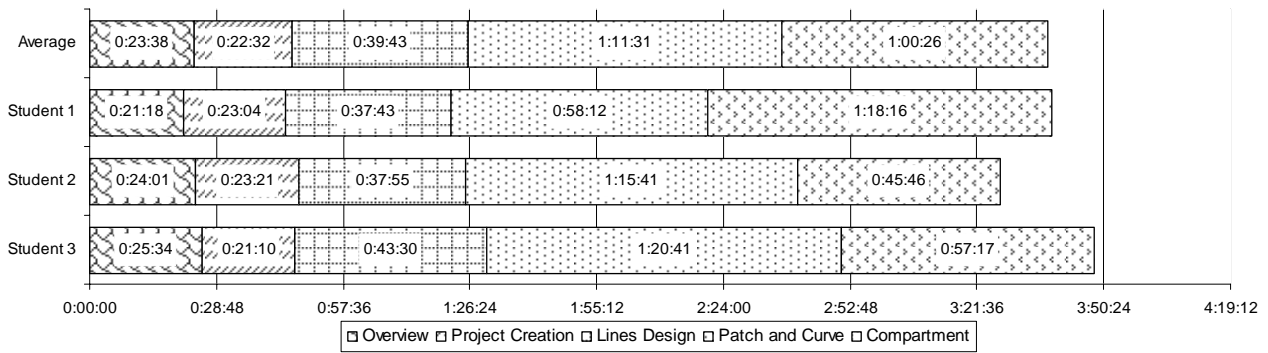Figure 7. Working with ShareFast
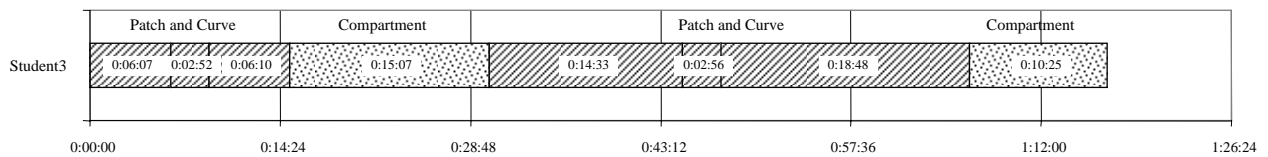
Figure 8. Class 1 duration result
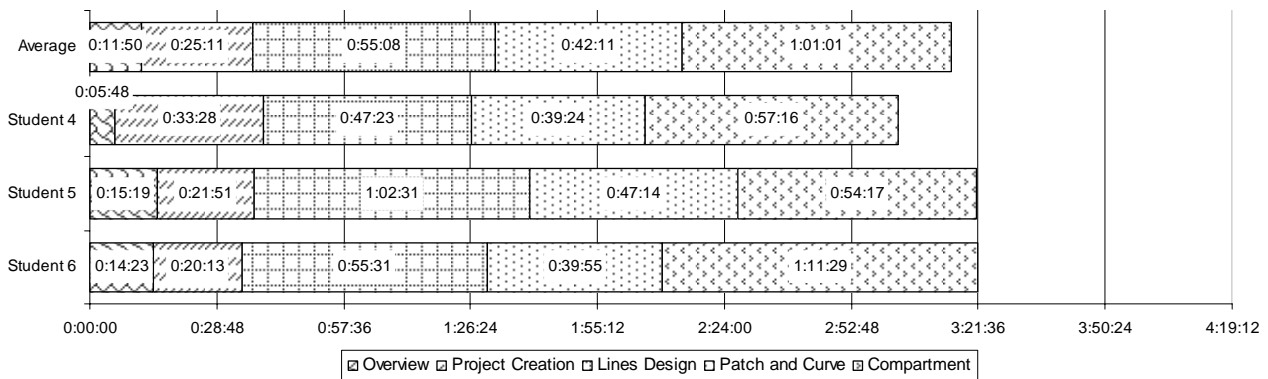

Figure 9. Analysis of student 3

Figure 10. Class 2 duration result

practical for the classes. The answers of the questions in section 3 explained to us about their feelings toward the whole class. The outcome revealed that five of the students felt that this class had an appropriate content, but time duration was not so appropriate, according to three of the students. Finally, the students wrote down comments and suggestions in section 4. Some messages from them were that it was good to have an opportunity to learn CAD from this class because it would be difficult to learn by themselves. Additionally, the learning instructions in the Compartment module were quite difficult to understand, so it would be good to simplify them and add more instructive details.

B. Case Study Two: Training of Surface Effect Ship Design

The objective of this experimental training class was to teach Surface Effect Ship (SES) design for racing ship production to four university students using ShareFast-based design educational framework. SES, shown in Fig. 11, is a class of ship that has both an air cushion and twin hulls. The SES design is a complicated task since the designer has to consider many parameter factors. However, in this training, the instructor simplified the design process to have merely three input parameters, i.e.

side hull length, cushion breadth and fan delivered power, while the other input parameters such as depth are fixed to the proper values. The design output was the ship's speed. The values of the three input parameters must be well specified in order to generate the maximum ship speed. The greater the values of the input parameters are, the better it helps life up the ship. However, it would, in return, result in increasing wetted area and friction resistance as well as reducing the power delivered to

TABLE II.
MESSAGE FROM DISCUSSION THREADS LEADING TO LEARNING MATERIAL IMPROVEMENT

Message	Cause	Response
Cannot complete the surface	Students didn't know where to add new curves	Explain more about where to add curves to complete surface in the material
Don't know the meaning of icons	No explanation in the learning material	Add description of accept, edit and profit icons to the material
Don't know how to import hull form	No explanation in the learning material	Add more information about how to do in the material
Cannot find the menu for 'Use Hull Form' command	No explanation in the learning material	Add 'File→Use→Hull Form' to the material

propeller. This simplified design process also contains several constraints of length, breadth, etc.

The teaching overview, illustrated in Fig. 12, was that the instructor created an SES design process workflow, and embedded the ship speed calculator as design application in the speed computing task. The program will receive input parameters from the students via input files. After computing, it will generate an output file containing ship speed value. Both input and output values will be uploaded and recorded to ShareFast server in RDF format. The students learned by inputting required parameters to the program until the output speed value reaches the maximum point and all output constraints are satisfied.

After the training, the instructor was able to extract the recorded input and output data from the server and made an analytical graph shown in Fig. 13. The graph displays the input and output values of a student in time series. Using this graph, the instructor can see the student's output progress in the learning interval, not just only the final output values. Moreover, the instructor can understand how the student adjusted the input parameters to reach the maximum speed. In this case, the student tried to assign and adjust the three input values during the global search period until the output value reached the maximum point. However, the student found that another output parameter did not satisfy one of the constraints, so he slightly adjusted an input value during the local search period until all parameters reached the acceptable point.

V. DISCUSSION

The results of the case study one proved that the idea of using workflow to support design learning is well received. Workflow plays a vital role in instructing learners through more well-structured design process. According to the result from the questionnaire, however, the discussion thread function performed not very well in
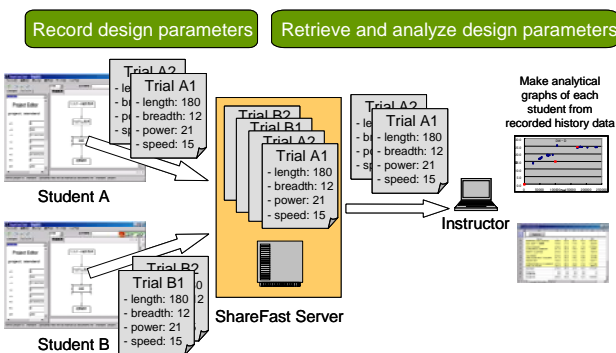

Figure 11. SES model boat

Figure 12. Overview of the design training

the experiment. From the instructor's observation during the classes, it seemed that the reason was that the experimental classes were conducted on small groups of students, where everyone, including the instructor, was in the same room. Hence, the students found it more convenient to ask questions directly to other students or the instructor. Nevertheless, it is convincing that the discussion thread function would be a significant feature when class communication can not take place on a face-to-face basis. Log file was able to help the instructor analyze class quality in many points of view. According to the experiment, log file paved the way to the class content improvement, consequently resulting in shortened class duration and trouble reduction.

The design history record and analysis function of the system was verified in the second case study. The instructor can understand how the students adjusted the input parameters to reach the design goal using the analytical graph made from the recorded data. This recorded data and its analytical information could also be used by the next design students as a reference source to understand the relation between input and output parameters.

The experimental case studies in this paper, however, were conducted with merely small groups of students. It might not be enough to prove every area of this ShareFast –based educational framework functions. Hence, the authors need to work more on further case studies of bigger number of students and more complicated study scenario.

VI. CONCLUSION

In this paper, a design engineering educational support framework using ShareFast, a client/server document management system based on workflow, was proposed and examined. The system offered several functions to assist the learner to go through the entire design learning process, and facilitate the instructor to understand the learner's behavior and problems during the class. Through the experiments, the framework was proved to be satisfying for its objectives. The students confirmed via the questionnaire that studying through the workflows of the system made learning product design with computer software more easily than ever.
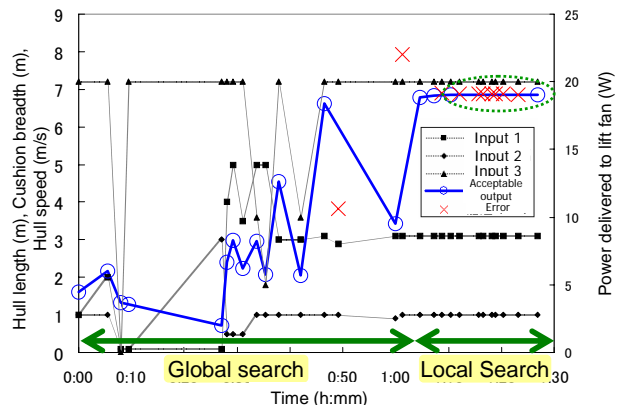

Figure 13. Analytical output graph of a student

Communication using discussion threads in the class became well-managed. Most importantly, learning materials were able to be improved from the analysis of student behavior captured from log file and data history analytical graph.

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