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Evaluation of DM-Tutor, an ITS for Training on Plantation Decision Making

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Abstract: Over the years many Intelligent Tutoring Systems (ITSs) have been used successfully as teaching and training tools with proven results through evaluation studies. Even though ITSs are effective in providing individualized tutoring to many students at the same time, very few attempts have been made to embed them with existing systems. This area of research has a lot of potential in providing life-long learning and work place training anytime and anywhere. We present the evaluation of DM-Tutor, an ITS that provides training on plantation decision making. DM-Tutor has been embedded with a Management Information System (MIS) to provide scenario-based training using real life operational data and actual plantation conditions. The pilot study conducted in February 2011 shows that DM-Tutor is an effective teaching tool; the performance of the participants on the post-test was significantly higher than their performance on the pre-test. The questionnaire responses show that the participants found the system easy to use and useful.

Keywords: Intelligent tutoring systems, embedded ITSs, management information system, scenario-based training.

Introduction

Rapid technological advances have created profound implications for all levels of education and training around the world. Intelligent Tutoring Systems (ITSs) have become an important class of educational technology that is capable of playing a crucial role helping learners of any age acquire the skills needed to succeed. ITSs have been developed and effectively used for teaching and learning for many years and have been proven in the past to be successful in providing tutoring to any number of students through highly interactive environments [8]. The ultimate goal of ITSs is to achieve the learning gain of 2 standard deviation, the same level achieved by master human tutors in one-to-one interactions with students [5]. Over the years many ITSs including LISP tutor [3], Andes [22], PUMP

Algebra Tutor [11] and others have been effectively used in many teaching and learning domains. SQL-Tutor [13], NORMIT [14], KERMIT [21], UML Tutor [4] and J-Latte [9] are among the many constraint-based tutors (CBT) [15] that have been developed and successfully implemented by the Intelligent Computer Tutoring Group.

Even though ITSs have been proven as effective teaching tools, there have been very few attempts to embed them within other systems. ETS (Embedded Training System) [6], Macsyma Advisor [10], Geometer Sketchpad Tutor [20], Excel Algebraic Tutor [12] and PAT (Personal Access Tutor) [19] are some of the attempts made to embed ITSs into existing systems. Macsyma Advisor was developed to assist users in using Macsyma, the algebraic manipulation system. Macsyma Advisor focused on assisting rather than training, which meant the user, may not have learned how to solve problems unassisted in the future. Although various parts of Macsyma Advisor were implemented, they were not combined into a full working system; and evaluation studies were not carried out to assess the effectiveness of Macsyma. Excel Tutor provided descriptive explanations and interactive guidance for students to solve excel problems and Geometer Sketchpad Tutor taught students how to sketch geometric diagrams. For Geometer Sketchpad Tutor and Excel Algebraic Tutor, users' actions were observed and monitored through the system's interface. Initial evaluations showed that Excel Tutor provided a higher learning outcome for students. However, to our knowledge no detailed empirical evaluation was done to analyze students' interactions with the system. The tutors were not assessed for their effectiveness as educational systems. ETS was developed and integrated with an existing Complex Information System for military tasks and operations. The goal of ETS was to train users on military based scenarios. ETS however was not robust enough to handle a variety of student's actions and behaviors within the system. Evaluation studies were not conducted for the system and the learning outcome was also not evaluated. PAT was added into MS Access to help students build reports and forms. Although the students seemed to like PAT, the system has not been fully evaluated.

In this paper, we present DM-Tutor (Decision-Making Tutor) [1], an ITS that provides training on plantation decision making for the palm oil domain. We aim to make several significant contributions in our research. This will be the first attempt to embed a CBT with an existing system. Secondly, we will investigate the benefits of providing on-the-job training through this integration. Thirdly, we aim to develop a framework for embedded ITSs and prove its research contribution through the development of DM-Tutor and its integration with the MIS for palm oil.

DM-Tutor has been embedded with a Management Information System (MIS) [18] that is currently being used to manage palm oil plantations in Malaysia and Indonesia. The MIS for palm oil contains operational data of yield records and plantation cultivation details. As the information contained is highly domain specific, managers who are new to the domain or to the MIS face difficulties in making accurate operational analyses and this affects the decisions they make at the palm oil plantations. As DM-Tutor is embedded within the MIS for palm oil, users will be able to practice plantation decision making using real-life operational data from the MIS. The goal of DM-Tutor is to help users apply theoretical concepts of plantation analyses into real-life plantation decision making.

This paper is organized as follows. In section 1 we describe the architecture and components of DM-Tutor. Section 2 describes the evaluation study conducted for DM-Tutor and in section 3 we present conclusions and future work.

1. DM Tutor

To the best of our knowledge, there has not been an ITS for plantation decision making, and DM-Tutor is novel in that respect. It is also the first CBT to be embedded with an existing system. DM-Tutor was developed using ASPIRE [16], an authoring system and deployment environment for constraint-based tutors. DM-Tutor is a procedural based tutor. This means that problem solving is divided into several steps and student's solution is evaluated at every step. Students will not be able to continue to the next problem solving step before submitting the correct solution for the present step. Figure 1 presents the overall architecture of DM-Tutor. DM-Tutor consists of a student model, pedagogical module, interface module, constraints that represent domain knowledge and a database of problems and solutions [2].

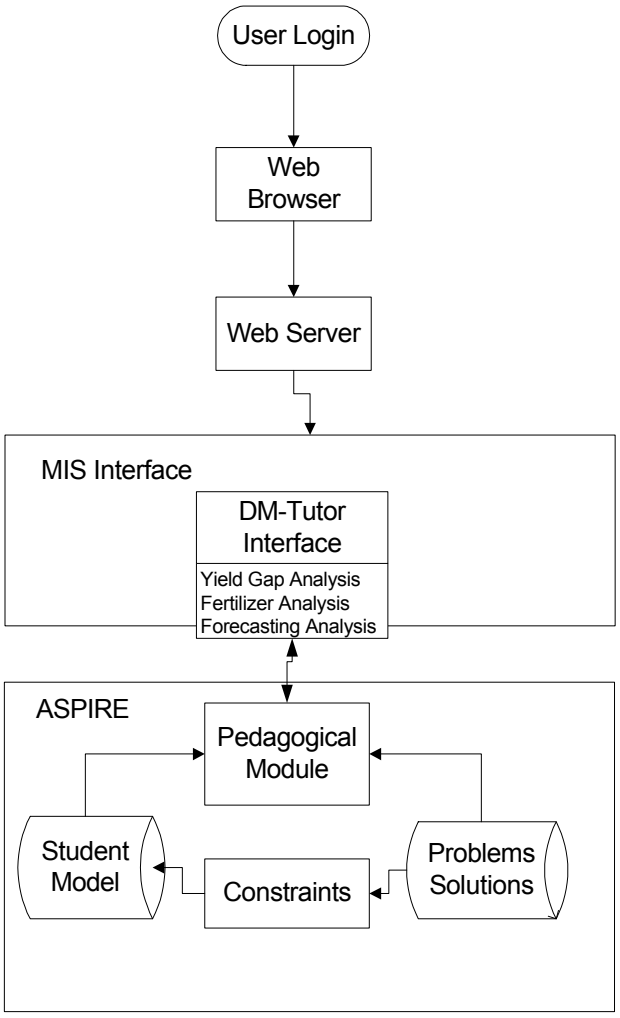

Figure 1: DM-Tutor Architecture

Student model contains information of student's knowledge and is updated every time the student uses DM-Tutor. Constraint based modeling [17] is used to model the domain and the student. The student's solution is matched to the constraints in order to identify any mistakes, and the student model is updated. The pedagogical module selects instructional actions relevant to the scenario-based problem solving strategy used. It also has the role of providing helpful feedback to users when they submit an incorrect solution.

The interface module presents the student interface of DM-Tutor. The problems and solutions component focuses on *Yield Gap Analysis*, *Fertilizer Management* and *Yield Forecasting*, three main analyses for palm oil plantation management [1]. DM-Tutor's interface is designed to reduce the cognitive load so that the student could concentrate on how to solve the problems rather than trying to understand the interface. The interface is developed using Java applets. In order to solve problems presented in DM-Tutor, users need to access relevant reports from the MIS. DM-Tutor logs information on the MIS reports that users accessed. This enables the system to provide helpful feedback about student mistakes.

The MIS is a web-based system and is accessed via a web browser. When users log into the MIS, they would see a menu on the left side of the screen. The menu consists of the various information that MIS contains. This includes maps, graphs and various reports, including yield analysis, upkeep and cultivation analysis, store analysis and vehicle management analysis. An MIS user would access the type of information she/he needs by selecting the type of analysis required, estate name, year and month to view the particular

report she/ he needs to work with. Figure 2 illustrates the MIS interface, with the menu of information on the left pane, and a sample of analysis showing *Yield Analysis* for a particular estate on the right. When user selects to view a particular report, a window opens up showing the report (center window of right pane).

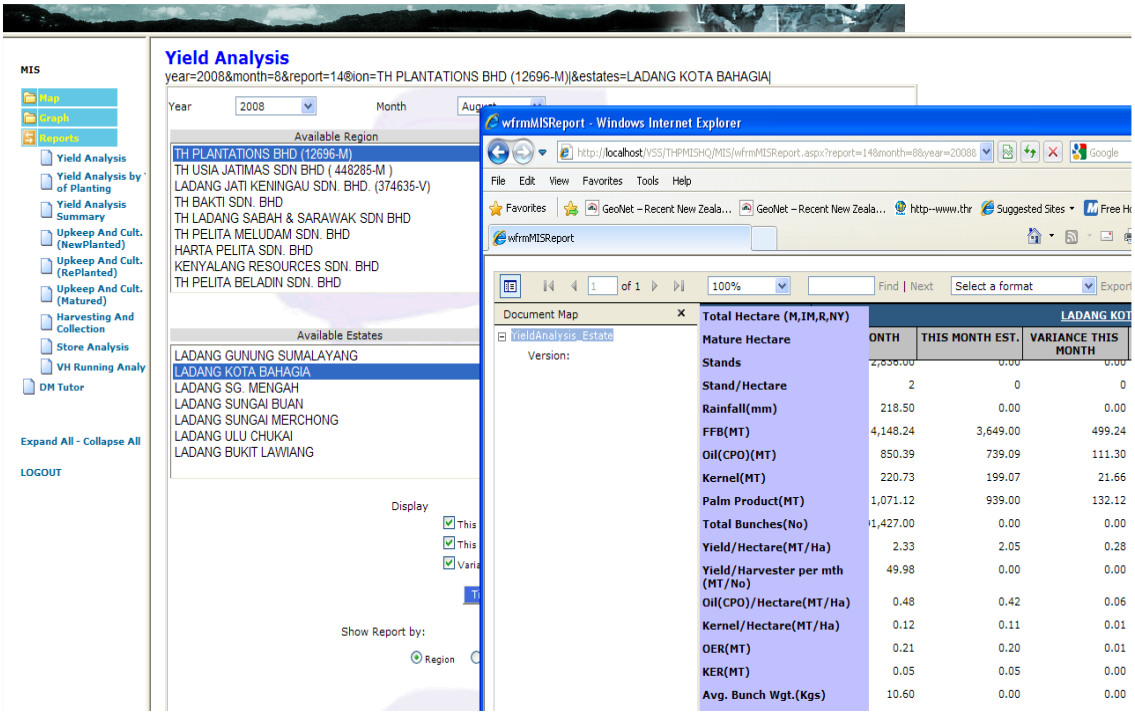

Figure 2: MIS Interface showing a yield analysis report

MIS was modified to allow the integration with DM-Tutor. The menu pane of MIS was changed by adding a selection button (visible in Figure 2) for DM-Tutor. When the student clicks on this button, he/she will be logged into DM-Tutor automatically. The tutor is served by ASPIRE, which assigns a user ID to the user. The interface of DM-Tutor is displayed in a separate window. Once logged in, DM-Tutor users are presented with the three tasks within DM-Tutor: *Yield gap analysis, Fertilizer management analysis* and *Forecasting analysis*. The tasks posed by DM-Tutor contain real life plantation situations and problems. Each task in DM Tutor focuses on one area of the plantation management's concern and requires students to access various plantation areas and specific reports from the MIS in order to answer the questions in DM Tutor. Students also need to use the correct formulas for each analysis.

For *Yield gap analysis* [23], students first have to identify relevant plantation areas and their potential yield in the MIS. Next they need to calculate yield gap between plantation areas using the correct formula. Lastly, they need to give their recommendation on how to improve yield of that particular area. The focus of this task is to train students on how to focus management's efforts on improving conditions in plantation areas that needs management attention the most.

For *Fertilizer management analysis* [7], students need to calculate the *partial factor productivity* (PFP) and *agronomic efficiency* (AE) for a given plantation area in the MIS using a formula. They need to select the accurate nutrition combination required for the palm trees based on the age of the tree (identified from the MIS). Lastly, they need to solve a fertilizer management problem to improve yield for the given plantation location. This task teaches users on how to efficiently manage plantation nutrition.

For *Forecasting analysis* [23], students are required to calculate a future yield value based on the present yield value of a given plantation area in the MIS. They will then need to provide their solution to a given plantation scenario problem where yield losses have occurred due to various plantation conditions. This task teaches students to plan the plantation area's future yield based on current yield conditions.

When students select a task, they are presented with the window that shows the problem and solution workspace. DM Tutor evaluates the student's solution step-by-step, immediately after the student submits his/her solution for the current step. If the submitted solution is incorrect, DM-Tutor provides various levels of feedback that guides the student towards the correct solution. Only when the solution is correct, the student is allowed to move to the next step of the problem. Figure 3 shows a screen shot of a problem step in the Forecasting Analysis task in DM-Tutor.

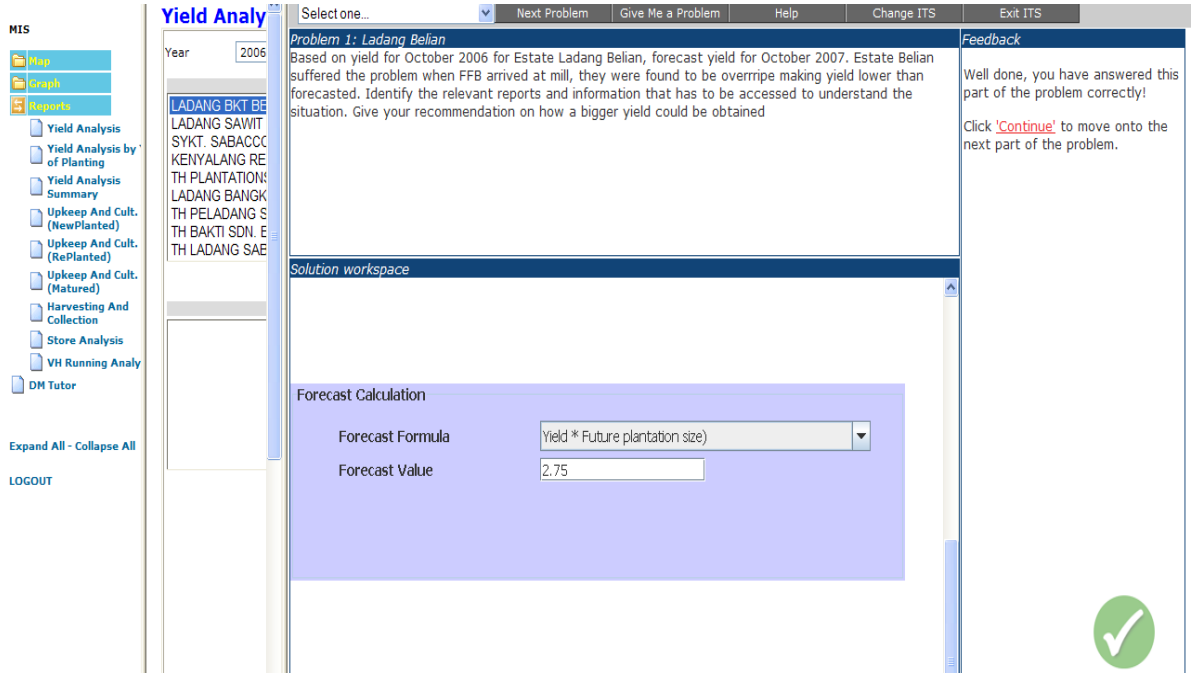

Figure 3: MIS interface with DM-Tutor's problem-solution workspace

In the example shown in Figure 3, the student has selected the correct formula to calculate yield forecast and has calculated the forecast accurately. As a response, DM-Tutor has provided a feedback message for the student to continue to the next problem step in Forecasting analysis task. The MIS and DM-Tutor frame can both be resized by the student at any time to allow more visibility for either system. All of the user's actions within DM-Tutor are recorded and used to model the student's knowledge of the domain. Once the student has completed a problem correctly she/he can choose to practice another problem or a different analysis.

2. Evaluation Study

Evaluation of ITSs should focus on the educational impact on students. We conducted a pilot study of DM-Tutor in February 2011 with the goal of evaluating its effectiveness as a teaching and training tool for the palm oil plantation decision making domains. We also wanted to identify any technical issues, interface problems and system usability concerns

that needed to be solved. The study was conducted with a group of 22 employees working for a palm oil plantation company in Kuala Lumpur, Malaysia. All the participants were already familiar with the MIS for palm oil as they use a similar version of the system for their everyday work, so their knowledge of the MIS system was not evaluated.

We provided the participants with a demonstration on DM-Tutor, describing the different tasks contained inside DM-Tutor, problem selection and the various levels of feedback messages available. They were informed during this demonstration that their participation in the study was on a voluntary basis. The participants were given a pre-test before interacting with the system. The pre-test contains three questions, one for each task of DM Tutor. Each pre-test question is a shorter and simpler version of the actual problems in DM Tutor. Participants spent 15 minutes doing the pre-test, after which they interacted with the system for one hour. Lastly, they worked on the post-test for another 15 minutes and also completed the questionnaire. The post-test also consisted of three questions, of similar complexity to those in the pre-test. Out of the 22 participants who initially volunteered, only 19 stayed through the whole study. Table 1 presents the basic statistics about the participant's interaction with DM-Tutor**.**

Table 1: DM-Tutor Interaction Results

User log data from DM-Tutor	Mean (sd)
Interaction time (min)	27.20 (24.43)
Number of problems attempted	2.85 (1.23)
Number of problems solved	2.05 (1.05)
Number of submissions made	38.05 (8.96)
Number of feedback messages seen	19.80 (8.25)
Pre-test result (%)	50 (16)
Post-test result (%)	78 (21)
Gain (%)	28 (0.15)

Only three participants interacted with DM-Tutor for one hour or more. On average, the participants interacted with the system for about 27 minutes. The possible reason for this could be that the study was held during office hours and the participants had to complete their pre-assigned daily work load as well. The number of problems attempted by participants is higher than the number of problems they managed to solve. To solve the given problems, the participants made around 38 submissions of answers to DM-Tutor (please note that a submission is a partial answer, which covers only the current step of the task). From Table 1, we can observe that the participants have utilized the feedback messages in DM-Tutor to help them to solve the given problems.

Out of the 19 participants, only 8 completed both the pre-test and post-test for this study (the others completed only one test). Therefore, we only report the pre/post test results for those 8 participants in Table 1. We found that the performance on the post-test is significantly higher than the performance on the pre-test ($t= 1.89$, $p= 0.005$, $df=7$). From the pre-test and post- test results we could observe that the participants' knowledge in palm oil plantation decision making increased after using the system; the amount of increase is strongly correlated with the time the participants spent with the system ($r=0.92$).

From the 19 questionnaire responses obtained, we found out that 74% of the participants thought that DM-Tutor was easy to use. 52% of the participants found the feedback messages in DM-Tutor to be helpful in answering the questions. When they were asked if they liked DM-Tutor's interface, 63% of the participants said that they did. One of the participants commented that he liked this new version of the MIS. When asked if DM-Tutor was able to teach them any new palm oil plantation decision making analyses, all

the participants answered 'yes'. One participant said that DM-Tutor helped to teach her how to use the information in the MIS to make better decisions. Another participant said that she knew now what yield gap analysis and fertilizer efficiency were, after using DM-Tutor. When the participants were asked if they felt that by integrating the Management Information System (MIS) with DM-Tutor they were able to learn the plantation analyses better? All of them answered 'yes'. One participant said that he liked to see the MIS and the teaching system together. Another participant stated that she liked the idea that she could stop learning and continue to work with MIS when she needed to and another participant was happy that she could choose the analyses that she needed to learn and that she could check the analysis again if she was not sure.

3. Conclusions and Future Work

ITSs have proven to be successful in many instructional domains. ITSs are better than computer-based training or multimedia-based training methods that only present information and test recall of factual information through multiple choice questions. ITSs are effective in providing individualized one-to-one teaching or learning to many people at the same time. By embedding DM-Tutor, a constraint-based tutor, into a MIS for palm oil we hoped to provide scenario-based training (SBT) on palm oil plantation decision making using real life operational data and actual plantation conditions. Our goal was to make several significant contributions through this research. DM-Tutor is the first CBT embedded within an existing live system. Through this research we aim to develop a framework for embedded ITSs. We aimed to investigate the benefits of providing training through this integration. We hoped to prove our research contribution through the development of DM-Tutor and its integration with the MIS for palm oil.

From the pilot study, we found that the users have interacted well with DM-Tutor. They have used the information from the MIS to answer the questions posed by DM-Tutor. The participants have also utilized the feedback messages in DM-Tutor to help them answer the given questions. From the pre- and post-test results it is proven that the users have improved their knowledge of palm oil plantation decision making after using DM-Tutor. It was also very encouraging to get positive comments on DM-Tutor from the participants of the study. However, our study was small in terms of the number of participants, and therefore more evaluation is needed.

Currently, we are making further enhancements to DM-Tutor. We have modified the MIS to automatically send information about which reports the user has looked at in MIS directly to DM-Tutor, thus making interaction easier for users (as they do not have to type report details). We plan to conduct a full evaluation study of DM-Tutor in 2011 with a group of students currently enrolled in the Master's in Plantation Management program at the Putra University of Malaysia. We believe that our research has many potential benefits. Apart from the research contributions discussed above, DM-Tutor also has the potential benefit of providing life-long workplace learning, anywhere and anytime.

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