e-Learning in Project Management Using Simulation Models: A Case Study Based on the Replication of an Experiment

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***Abstract*—Current e-learning systems are increasing their importance in higher education. However, the *state of the art* of e-learning applications, besides the *state of the practice*, does not achieve the level of interactivity that current learning theories advocate. In this paper, the possibility of enhancing e-learning systems to achieve deep learning has been studied by replicating an experiment in which students had to learn basic software engineering principles. One group learned these principles using a static approach, while the other group learned the same principles using a system-dynamics-based approach, which provided interactivity and feedback. The results show that, quantitatively, the latter group achieved a better understanding of the principles; furthermore, qualitatively, they enjoyed the learning experience.**

***Index Terms*—Management education, simulation software, software engineering education, student experiments, system dynamics.**

I. Introduction

E-LEARNING systems have not only become the backbone in distance education but also are also at the heart of traditional university teaching. An ad hoc survey of reputable universities' websites shows that all have online systems to support teaching activities. Initially, the Web was used as a repository to provide students with handouts, papers, etc., supporting one-way communication. Presently, e-learning systems have been extended with a series of general utilities, such as calendars, reminders, mailing lists, forums, homework drop-boxes, and even quizzes, to support continuous evaluation and facilitate asynchronous communication between students and between students and instructors. However, many current e-learning systems lack tools to provide synchronous feedback about the decisions that students take in the active process of learning, as required by modern learning theories.

This paper presents and analyzes the results of the replication of a controlled experiment involving an e-learning system that uses system-dynamics-based (SD) simulation capabilities to facilitate a dialogue between the student and the computer. Bidirectional exchange is not achieved with most current e-learning systems. In the e-learning application under study, simulation capabilities are applied to learn certain software project management techniques. Project managers make decisions in complex work contexts, where many cause–effect relationships have to be taken into account. Therefore, future project managers should be trained so that they learn to exercise sufficient control over the development process to deliver products in time, within budget, and with the required quality.

Although the potential of simulation models for the training of managers has long been recognized [1], very few experimental studies for software-project-management (PM) education have been performed. Pfahl *et al.* [2] performed a series of studies involving controlled experiments to evaluate the learning effectiveness of using a simulation model for educating computer science students in project management. The original study has been replicated at the University of Reading, Reading, U.K., as part of a software engineering course. In particular, the experiment fits as part of the Project Management section in the IEEE/ACM Computing Curriculum [3]. External replication of experiments is an important means to both verify and generalize original results. Furthermore, in this paper, the results and the design of the externally replicated experiment are discussed from the perspective of learning theory.

The organization of the paper is as follows. Section II presents related work about learning theories, and the application of SD in the context of software engineering. Section III provides a discussion of the experimental design. Section IV presents the data analysis. Section V provides a discussion on possible threats to validity. Section VI provides a discussion of the results from a learning perspective. Finally, Section VII concludes the paper and outlines future research.

II. Related Work

A. Current Learning Theories

At present, available e-learning systems lack capabilities to create a dialogue between the students and the e-learning systems, i.e., immediate feedback about the decisions that students take in the active process of learning required by modern learning theories. E-learning systems have been used primarily to provide students with handouts or submission of practical work, achieving only a one way communication. This model of education, which considers the student as a passive receptacle of teaching, has its origins in the classical Greek philosophers Plato and Aristotle. Plato's *Theory of Forms* [4] advocated that education should be reserved for the most capable. The ideal society would be divided into three classes: 1) the merchant

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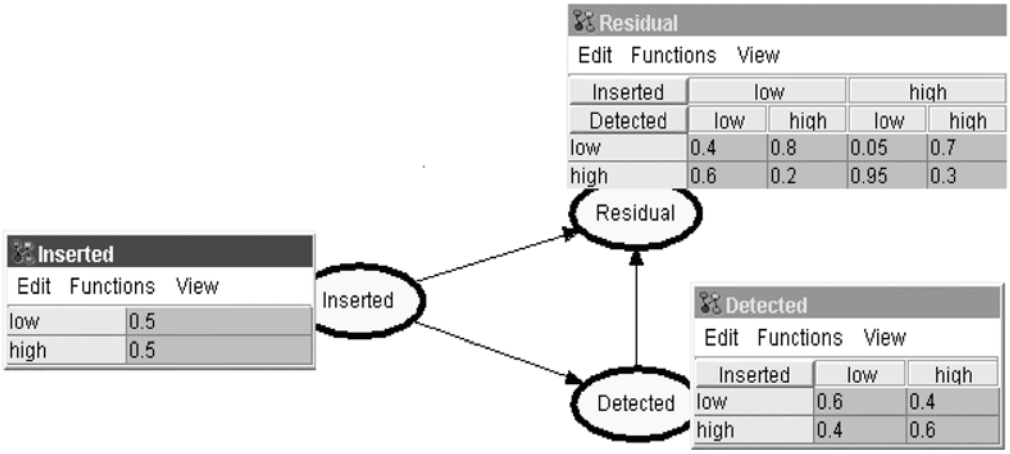

Fig. 3. Simplified BN Estimation Model.

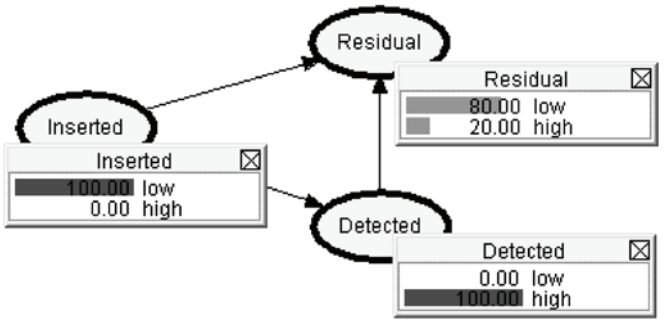

Fig. 4. Evidences and probabilities updated in the model.

3) Pragmatic quality deals with the issue of adequately presenting model and results from feasible comprehension and feasible understandability. Methods to facilitate comprehension include visualization, explanation, and filtering, which can be assessed through empirical studies. Expressive economy and structure are model properties that enable the achievement of feasible understandability.
4) Test quality results from achieving feasible test coverage.
5) Value quality results from practical utility of the models. Kitchenham *et al.* mention appropriate user manuals, training, etc., as means to achieve practical utility.

Finally, another problem relates to the ease of use of the models and tools provided to the students. Although both SD and BN tools usually provide graphical user interfaces, e-learning simulation systems may require the creation of new interfaces appropriate to the domain they are modeling to avoid steep learning curves imposed by too abstract or complex causal models.

VTT. CONCLUSTON

The empirical studies presented in this paper investigated the effect of using a Web system based on system dynamics (SD) to assist software project management education. The study was completed by replicating an experiment to gain better insight about its utility in project management in particular and in higher education in general. The treatment focused on problems of project planning and control. Tn this work, the SD models were based on a Web interactive role-play scenario against the control group without interactive role play.

The performance of the students, which was measured using a pretest and posttest, was analyzed with regard to four dimensions—interest in the topic of software project management, knowledge of typical project behavior patterns, understanding of simple project dynamics, and understanding of complex project dynamics. By studying the differences between the posttest and pretest scores of the experimental group (based on an SD model) and the control group (based on COCOMO), conclusions were drawn with respect to the effects of the different treatments.

The results indicated that students using the e-learning system with the incorporated SD simulation model gained a better understanding about typical behavior patterns of software development projects. The findings of the replicated experiment corroborates that using SD models increase the students' interest in software project management and also improve their knowledge about typical project behavior patterns. This positive result of the experiment may result from the SD simulation model being integrated into e-learning systems that achieve the level of interaction advocated by current learning theories.

Future work will be related to the creation of generic tools that facilitate easy integration of SD models into Web-based e-learning systems. Tn addition, other dynamic methods such as BN should be investigated as an alternative to SD models. An experiment that compares the effectiveness of SD and BN models in the context of software project management education is currently in the planning stage.

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