Formative Research for Enhancing Instructional and Design Methods: A Focus on Virtual Reality (VR)-Based Learning Environment

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Abstract- This paper reports the process of enhancing the instructional and design methods prescribed in an instructional design model for virtual reality (VR)-based learning environment. The study uses formative research to formatively evaluate the methods with the aim to generate hypotheses on how to improve the robustness of the model. The analysis of the data collected has revealed four principles that are hypothesized to be able to improve the model.

I. INTRODUCTION
Instructional design is a field that concerns with understanding, improving, and applying methods of instruction to bring desired changes in learner knowledge and skills [1]. The goal of instructional design is to produce a well-designed instruction that saves time and money as well as eases the learning process [2]. Indeed, the ultimate aim of any instructional design efforts is to create effective and efficient instruction.

Reference [3] proposes an instructional design model for guiding the design of non-immersive VR-based learning environments. The model prescribes instructional methods to optimize desired instructional outcomes in learning environments that are enabled by the non-immersive VR technology. Fig. 1 shows an illustration of the model that serves as a feasible and useful template to guide the design of VR-based learning environments. The macro-strategy prescribes instructional methods that concerns with the selection, sequence, and organisation of the subject-matter topics that are to be presented and the micro-strategy prescribes design methods concerns with the strategies for effective presentation of the learning contents.

II. FOCUS OF THE STUDY
This study aims to employ formative research to formatively evaluate the instructional and design methods prescribed by model in order to produce hypotheses on how to improve the model. Hence, the specific objectives of this study are to:

a. improve an instructional design model for VR-based learning environment using the formative research methodology.

b. hypothesize an improved instructional design model for VR-based learning environment based on the outcomes of the formative research.

The overall study focuses on the enhancement of both macro-strategy and micro-strategy. Nevertheless, this paper focuses only on the enhancement of the design methods prescribed by the micro-strategy.

III. METHOD
Reigeluth and Frick (1999) proposes formative research as a research methodology for developing as well as improving design theories (or models). Formative research is qualitative and iterative in nature. As pointed out by Richey and Klein (2007), the focus of formative research is to explicitly relate theory/model formation or improvement to the research process. Studies such as English and Reigeluth (1996), Kim (1994), Lee and Reigeluth (2003) have employed formative research to improve instructional theories or processes.

Fig. 1: The instructional design model (Adapted from [3])

Acknowledgement: The author acknowledges the financial support rendered by UNIMAS through Fundamental Research Grant Scheme FRGS/05(02)/616/2006(49), Ministry of Higher Education, Malaysia.
This study employs a formative research using a designed case (Reigeluth & Frick, 1999), in which the instructional design model is intentionally instantiated and then formatively evaluates the instantiation. The underlying logic of formative research is that, if an accurate application of an instructional design model is created, then any weaknesses that are found in the application may reflect weaknesses in the model, and any improvements identified for the application may reflect ways to improve the model, at least for some subset of the situations for which the model is intended (Reigeluth & Frick, 1999). This study relies mainly on qualitative data with limited use of quantitative data.

Procedure

Based on Reigeluth and Frick (1999), after selecting a design theory (or model), the formative research process continues by designing an instance of the model. A design instance refers to a specific application of the design model. In this study, the design instance was a VR-based learning environment for novice car drivers to learn about traffic rules and traffic signs. This is followed by the collection of formative data from the representative learners of the design instance via one-to-one evaluation sessions. The process then requires the collected data to be analysed. The intent is to identify and remove problems in the instance, particularly in the methods prescribed by the model as well as to confirm the appropriateness of the methods. Revisions made on the instance represent hypotheses as to ways in which the design model itself might be improved. This data collection, analysis, and revision process is repeated several cycles before tentative revisions of the model are proposed.

Formative Data Collection Techniques

The study employed one-to-one evaluation technique to collect formative data. One-to-one evaluation allows probing into the reactions and thinking of the each participant through think-aloud method. During the evaluation, the study incorporated guided interview to identify strengths and weaknesses in the design instance, explore improvements for elements in the design distance, explore consequences of removing elements from, or adding new elements to, the instance, and explore possible situationalities (ways that methods should vary for different situations).

The study also involved each participant by interviewing him or her at the end of the evaluation session. This is also known as debriefing. The collected data was highly insightful and useful or at a minimum, they provided some hypotheses worthy of testing with subsequent participants and situations.

The study also used observation to verify the presence of elements of the design model and to see surface reactions of the participants to the elements. To assist this observation process, the one-to-one evaluation sessions were audio and video recorded using the Noldus Observer system, which was a software package for collection, analysis, presentation and management of observational data.

Having observation, think aloud and guided interview during the one-to-one evaluation session as well as debriefing at the end of the one-to-one evaluation session allow multiple methods of collecting data, which is a form of triangulation. The rationale of having such triangulation is to compensate the flaw of one method with the strength of another.

Instruments

This study involved the use of two sets of instrument. The interview question set guide interactions with participant during the one-to-one evaluation sessions. Debriefing question set provides an opportunity for participants to provide their additional feedback or comments at the end of the evaluation sessions.

Elements of the Design Instance

This study identified three variables of the design instance: navigation speed, environmental richness and collision detection. These three variables were chosen as they were the common features of a three-dimensional virtual environment.

VR allows its user to perform real-time navigation through the three-dimensional virtual environment and this lead to the question on how fast the learner should be allowed to navigate or the preferred speed that will not inhibit the learning process. The study also looked into the effects of the complexity of the virtual environments as well as the system capability to detect collision in the virtual environment.

The researcher manipulated these variables to determine the settings that were perceived by the subjects as user-friendly and/or help (or at least will not interfere) their learning process. The ultimate aim of manipulating such variables is to generate hypotheses that may refine the micro-strategy of the instructional design model.

Variables

A. Navigation Speed

In this regard, the study involved the creation of three learning environments to find out whether the speed differences were noticeable and the preferred speed if they were noticeable. With all other features being similar, the navigation speed for all the five virtual road scenarios available in the learning environments was set to fast, medium and slow respectively.

B. Environmental richness

The study involved the creation of two learning environments. With other features being the same, one of the learning environments incorporated virtual objects, such as trees, buildings, bushes, lake, and etc. while another learning environment did not include all these additional virtual objects. The study is to find out whether