Formative research on the instructional design process of virtual reality based learning environments

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To date, the educational benefits offered by the virtual reality (VR) technology are generally well accepted. Indeed, many efforts are underway to explore ways, both theoretically and practically, to produce effective virtual reality learning. Chen, Toh and Wan (2004), for instance, have proposed an instructional design model that prescribes instructional methods for guiding the design of VR based learning environments. Although this model serves as a feasible and useful template to guide the design of VR based learning environments, particularly learning environments that adopt the constructivist paradigm of instruction, there are still rooms to enhance its robustness. This paper describes how formative research method can be used to improve this instructional design model. Formative research, which is qualitative in nature, is a method that has been employed to develop as well as to improve design theories (or models). The paper also reports some preliminary findings of the study.

Keywords: formative research, virtual reality, learning, instructional design model

Introduction

Instructional design is a discipline that concerned with understanding, improving, and applying methods of instruction to bring desired changes in learner knowledge and skills. It is a body of knowledge that links between cognitive theory on learning and instructional practice (Gropper, 1983). It prescribes instructional actions to optimise desired instructional outcomes. Hence, the result of instructional design as a professional activity is a 'blueprint' of what the instruction should be like. The goal of instructional design is to make learning more effective and efficient. Often, a well designed instruction saves time and money as well as eases the learning process.

An instructional design theory/model or sometimes termed as instructional theory is a theory that offers explicit guidance on how to better help human learning and development (Reigeluth, 1999). It comprises a set of practical procedures, which takes into account some principles of human learning, specifically, the conditions under which learning occurs, for the design of effective instruction (Gagne & Briggs, 1974). Unlike descriptive theories, instructional design theories are design oriented and focus on means to attain given goals for learning or development. Design theories are prescriptive in nature, in the sense that they offer guidelines as to what method(s) to use to best attain a given goal (Reigeluth, 1983;1999).

Instructional design model for VR based learning environments

Virtual reality (VR) technology offers unique capabilities that are able to provide significant and positive support for learning. Among the educational benefits offered by this technology include enabling learners to obtain three dimensional visualisation, visualise abstract concepts, articulate their understanding of phenomena, visualise the dynamic relationships between several variables in a system, obtain multiple viewpoint of a virtual environment, as well as explore and experience events that are unavailable or unfeasible due to distance, time, cost, or safety factors. Indeed, the power of VR as a tool for experiencing pre-built virtual worlds as well as for virtual world building by learners provides rich potential for the technology to be exploited and used for learning.

Today, VR systems can be implemented on affordable personal computers using conventional input devices, such as the mouse and keyboard. The availability of such relatively low cost VR system makes this technology feasible to be ubiquitously utilised. However, it is important to note that this technology is merely a tool, as is a chalkboard, television, overhead projector, or Internet. Tools by themselves do not teach. They have to be carefully and effectively implemented to assist in the learning process. As pointed

out by Reigeluth & Frick (1999), more instructional design theories (or models) are needed to provide guidance on the use of new information technology tools. Hence, the pertinent question would be on how to design the instruction to enable the effective utilisation of the VR capabilities to support the desired outcomes. What are the appropriate theories and/or models to guide the design and development of such learning environments so that the resulted learning environments are compatible with the human mind?

Chen, Toh, and Wan (2004) proposes an instructional design model for guiding the design of non-immersive VR based learning environments. Indeed, there are various types of VR systems, ranging from the expensive and high fidelity immersive systems to the more affordable but lower fidelity non-immersive systems. However, this instructional design model focuses on the non-immersive system that implements the three dimensional virtual environment through a conventional personal computer without the need of any additional peripheral. The model serves as a feasible and useful template to guide the design of VR based learning environments. As reported in Chen, Toh, and Wan (2005), Chen (2006), Chen and Wan (in press), learning environment designed based on this model is able to produce significant positive effect on cognitive gain.

Generally, the model combines the concept of integrative goals (Gagné & Merrill, 1990) with the model for designing constructivist learning environments (Jonassen, 1999). They serve as the macro strategy, which according to Reigeluth and Merrill (1978), concerns with the selection, sequence, and organisation of the subject matter topics that are to be presented. Additionally, a number of design principles, derived from the cognitive theory of multimedia learning (Mayer, 2002) as well as the research finding reported in Chen and Wan (in press), serve as the micro strategy that basically, concerns with the strategies for effective presentation of the learning contents.

This study aims to improve the model as it has yet to be developed to a state of perfection. This model functions as an initial structure that will be formatively evaluated in order to produce a more robust design model. Hence, the specific objectives of this study are to:

a. refine an instructional design model for VR based learning environment using the formative research methodology.
b. hypothesise an improved instructional design model for VR based learning environment based on the outcomes of the formative research.

Nevertheless, this paper will only report the preliminary findings obtained from the pilot study of this research project.

Method

Formative research

Reigeluth and Frick (1999) has proposed formative research as a research methodology for developing as well as improving design theories (or models). According to them, it is a kind of action research that is intended to improve design theory for designing instructional practices or processes. Formative research, which is qualitative in nature, has been used to improve existing instructional design theories and models, such as the elaboration theory (English, 1996; Kim, 1994), a theory to facilitate understanding (Roma, 1990), a theory for the design of computer based simulations (Shon, 1996), and a theory for designing instruction for teams (Armstrong, 1993).

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).

Procedure

Based on Reigeluth and Frick (1999), the process for conducting the formative research in this study is as follows.

a. Select a design theory (or model). As mentioned earlier, this study chose the instructional design model for VR based learning environment as proposed in Chen, Toh, and Wan (2004).

b. Design an instance of the model, which is a specific application of the design model. An expert in the model will be involved to ensure this design instance is to be as pure an instance of the design model as possible to avoid two types of weaknesses; omission and commission). In this study, the design instance is a VR based learning environment for novice car drivers to learn about traffic rules and traffic signs.
c. Collect and analyse formative data on the instance. The intent is to identify and remove problems in the instance, particularly in the methods prescribed by the model. In this study, design and development of the instance will be completed before implementation begins. Thus, data collection comes as a separate phase of activity.
d. Revise the instance. This revision will be based on the collected data. The nature of the revisions will be taken note as they represent hypotheses as to ways in which the design model itself might be improved.
e. Repeat the data collection and revision cycle. Several additional rounds of data collection, analysis, and revision are recommended. This is a way of confirming the earlier findings.
f. Offer tentative revisions for the model.

Data collection techniques

a. Observations
   Observations will be performed to verify the presence of elements of the design model and to see surface reactions of the participants to the elements.
b. One to one evaluations
   One to one evaluations, which include interviewing the participants will be performed to probe the reactions and thinking of the participants, to identify strengths and weaknesses in the design instance, to explore improvements for elements in the design distance, to explore consequences of removing elements from, or adding new elements to, the instance, and to explore possible situationalities (ways that methods should vary for different situations). The collected data can be highly insightful and useful or at a minimum, they will likely provide some hypotheses worthy of testing with subsequent participants and situations. Interviews are performed during as well as after the implementation of the design instance.
c. Audio and video recording
   Audio and video recording of the one to one evaluation sessions using the Noldus Observer system, which is software package for collection, analysis, presentation and management of observational data
   ** Transcripts will be produced from (a), (b), and (c).
d. Small group evaluation
   A small group evaluation, which is non-interactive will be conducted to confirm the findings of the one to one evaluations or to enhance the external validity of the study.

Having one to one evaluation and small group evaluation 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

a. Interview question set
   A set of interview questions to guide interactions with the participants during the one to one evaluations. This set of questions progress from very open ended ones to very targeted ones and strive to collect data about how to improve the specific guidelines in the theory, including adding new guidelines. These questions focus on identifying particular aspects of the implementation of the design instance that helped or hindered learning and finding ways to improve weak elements.
b. Debriefing question set
   A set of open ended debriefing questions to be administered after the implementation of the design instance. The purpose of these questions is to give the participants an opportunity to reflect on and evaluate the implementation of design instance as a whole, to point out any strengths and weaknesses not mentioned before, and to make any additional comments. Reliability or consistency across participants will be assessed so that the point of saturation can be determined.
c. Closed and open ended question set
   A set of closed and open ended questions to confirm the findings of the one to one evaluations.

Sampling

Subjects will be chosen from the population of the target learners of the design instance based on purposive sampling strategy. Learners include anyone who is eligible to attend the Road Transport

Department novice car driver instruction programme but yet to undertake it. According to Tessmer (1993), often, a series of two to four one to one evaluations will be conducted, which also means that this type of evaluation is often performed iteratively. The evaluation cycle continues until the materials receive little revision suggestions from one to one subjects. Ten subjects will be chosen for the one to one evaluations (will add more subjects if necessary) and thirty subjects will also be chosen for the small group evaluation.

Pilot study

A pilot study of the one to one evaluation was conducted to identify potential problems of the design instance, ensure the interaction guide for the person who interact with the subject during evaluation is appropriate and adequate, ensure the Noldus Observer system is functioning well, ensure the procedure for the evaluation is appropriate, ensure the clarity of the debriefing questions as well as provide a practice session for the experimenters.

A number of representative subjects were involved in this initial study and these subjects will not be involved in the real evaluation study. A number of variables that were related to the features of virtual environment were also identified for evaluation. These variables include coaching feedback, navigation speed, environmental richness, collision detection, feedback types, and input device. These variables were manipulated 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 refine the macro as well as the micro strategy of the instructional design model.

Coaching feedback
The model assumes that learning performances are likely to improve with coaching. In this pilot study, two learning environments were created. With other features being the same, one of the learning environments incorporated coaching through feedback messages (both verbal and text) while another learning environment did not incorporate such feedback. The first subject was requested to explore the environment with coaching and then repeat with the environment without coaching.

Navigation speed
The ability to navigate through the three dimensional virtual environment in real time is a distinct feature of VR. This subsequently may 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. In this regard, three learning environments were created. With all other features being similar, the navigation speed for the learning environments was set to fast, medium and slow respectively. The second subject was requested to explore the environment with fast speed, followed by medium and slow speed.

Environmental richness
This variable refers to the various virtual objects that are not mandatory in the learning process but were assembled into the virtual environment to enhance its attractiveness as well as its realism. Two learning environments were created. With other features being the same, virtual objects, such as trees, buildings, bushes, lake, and etc. were assembled into one of the learning environments while in another learning environment all these additional virtual objects were not assembled. The third subject was requested to explore the environment with additional virtual objects, followed by one without them.

Collision detection
In this study, collision detection refers to the ability of the system to determine the proximity of the learner's viewpoint with a virtual object and will stop the learner's movement through the virtual environment when his/her viewpoint is too close to the virtual object to avoid colliding and moving through it. Two learning environments were created. With other features being the same, collision detection feature is made available in one of them while in another learning environment, the learner is allowed to move through any virtual objects. The third subject was requested to explore the environment with collision detection, followed by the one without collision detection.

Feedback type
In this study, feedback refers to the message given to the learner, particularly to coach the learning process. Three learning environments were created: a learning environment with text message, a learning environment with narrated message, and a learning environment with combined text and narrated message. The fourth subject was requested to explore all these learning environments.

Preliminary findings and implications

First subject: Coaching feedback

Figure 1 shows a screenshot of the learning environment that was used as the design instance. The pop up coaching feedback required the learner to refer to the hyperlinks on the web page to obtain additional information that may assist him/her to solve the problem posed.

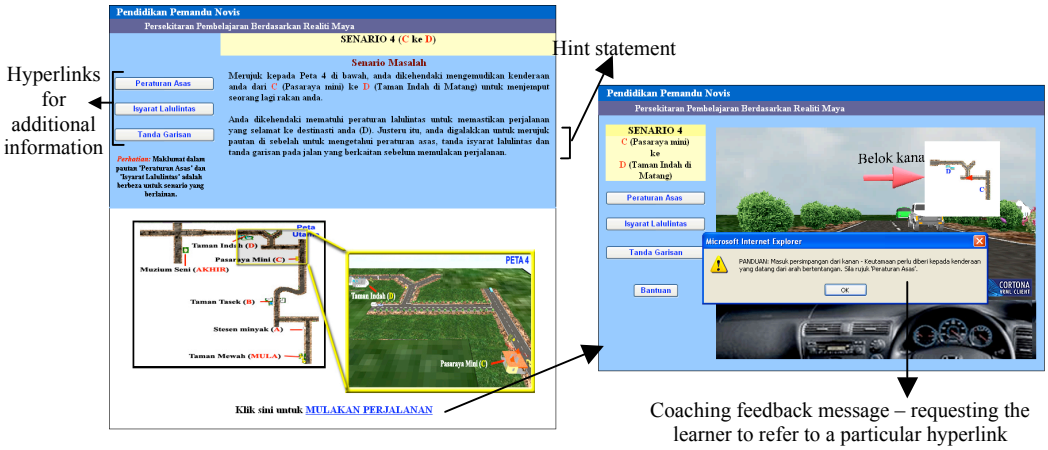

Figure 1: Screenshots of the design instance

Finding 1
The pilot had revealed that when the first subject first used the learning environment, both coaching and non-coaching, the subject had already browsed through all the information available via the hyperlinks. This was primarily due to the existence of a statement on the problem description section that encouraged the learner to refer to these hyperlinks before starting the exploration of the virtual environment. This statement was intended to serve as a cognitive tool that provided hints on how to solve the problem posed. Consequently, the subject, when exploring the coaching learning environment, did not bother to refer to that information even when she read coaching feedback message that requested her to refer to a particular hyperlink except in one incident where the subject referred to a hyperlink. The subject when exploring the non-coaching learning environment was observed as never referred to any of the hyperlinks.

Implications
This finding points to the necessity to remove the hint statement on problem description section. Such hint statement may hinder the effectiveness of the coaching feedback messages. Comparing the hint statement with the coaching feedback, coaching feedback offers a better scaffolding as it provides in time as well as contextualised assistance to the learner. As pointed out by Alessi and Trollip (2001), such assistance is better as it provides directions and aid when they are relevant.

This finding also points to the necessity to adjust the evaluation procedure. The subject should be requested to explore the non-coaching learning environment and then the coaching learning environment. Exploring the coaching learning environment first may direct the subject to refer to the information on the hyperlinks and similar to the effect of the earlier hint statement, the subject may not want to refer to the hyperlinks anymore even when he/she reads coaching feedback message that requested him/her to do so.

Finding 2
The subject was observed to spend much time trying to answer the reflection questions and had to do it twice as the reflection questions were available for both coaching and non-coaching learning environments. This may caused boredom and unnecessary fatigue.

Implications
The learning environment consists of five different virtual environments or road scenarios. The finding once again points to the need to rearrange the evaluation procedure. Instead of having the subject to work through all the five scenarios in one learning environment and answer all the reflection questions, and then repeat these five scenarios in another learning environment as well as all the reflection questions, it will be less exhaustive if the subject is just required to explore each scenario alternatively, e.g. first scenario of the non-coaching learning environment and then first scenario of the coaching environment, and only then will answer the reflection questions for that particular scenario.

Finding 3
This subject did not face any difficulty to understand the debriefing questions. Nevertheless, the subject requested for clarification on a few of the questions posed in the closed and open ended question set.

Implications
The subject's feedback helps to guide amendments on some parts of the closed and openended question set to improve its clarity.

Second subject: Navigation speed

Finding 1
This subject started with the fast navigation through the first scenario of the learning environment. Then, he repeated this scenario using medium navigation speed followed by another repetition using slow navigation. The subject could easily notice the speed difference. He commented the fast navigation was a bit uncontrollable while the slow navigation was frustrating. He preferred the medium navigation speed and perceived it as able to help him to learn better.

Implications
This initial finding shows that the differences between navigation speeds are obvious. The subject may be able to inform their preferred speed without having to work through all the five scenarios with three different navigation speeds, which is a total of 15 repetitions. Based on the finding, the evaluation procedure should once again be adjusted in a way that experimenter may terminate the use of the learning environments and proceed with the debriefing session when the subject is able to notice the differences and commented on the preferred speed.

Finding 2
As the experimenter was required to switch to different programme for each repetition with different navigation speed, the subject was observed to closely follow the experimenter's mouse action on the computer screen. The folder naming convention of the different programmes, e.g. speed_fast, speed_medium, speed_slow) was made too explicit and might hint the subject of this speed difference.

Implications
This finding points to the need to change the folder naming convention so that it will not provide any clue to the subject.

Third subject: Environmental richness and collision detection

Finding 1
This subject started by exploring the first scenario of the environment with additional virtual objects, also referred to as the rich environment, and followed by the first scenario of the environment without the additional objects. Similar procedure was repeated for the second until the fifth scenario. The subject was not able to detect the differences.

Finding 2
The subject then explored the first scenario of the virtual environment with collision detection and followed by the first scenario of the virtual environment without collision detection. This was repeated for the second until the fifth scenario. Once again, the subject was not able to detect the differences.

Implications
The findings do not indicate the necessity to amend the evaluation procedure.

Fourth subject: Feedback type

Finding
The subject explored the first scenario of the leaning environment with text message, then repeated with the learning environment with narrated message, and followed by the learning environment with combined text and narrated message. After exploring the second scenario, the subject was able to notice the differences and expressed his preference towards the text feedback message. Further investigation during the debriefing session, revealed that the subject had always preferred text rather than auditory input for his learning process.

Implications
The experimenter may terminate the use of the learning environments and proceed with the debriefing session when the subject is able to notice the differences and comments on the preferred type of feedback. The finding also clues to a possible situationality (ways that methods should vary for different situations) as there is a possible relationship between different learning styles and the preferred feedback type. Proper research method will be devised to further investigate this issue.

Conclusion

This paper has provided an elaboration of the formative research process that will be carried out to improve an instructional design model for VRbased learning environment. The findings reported in this paper, which were obtained from the pilot study, provide evidence on the importance of performing pilot study even for research that is qualitative in nature. The pilot study has revealed many necessary adjustments on the evaluation procedure to enhance its internal validity as well as amendments on the questionnaire to improve its comprehensibility. The clues to possible situationalities, for instance, also help to expand the focus of the study.

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References

Armstrong, R.B. (1993). The team instructional prescriptions (TIP) theory: A set of integrated models for prescribing instructional strategies for teams. Unpublished dissertation, Indiana University Graduate School, Bloomington, IN.

Chen, C.J., Toh, S.C., & Wan, M.F. (2004). The theoretical framework for designing desktop virtual realitybased learning environments. *Journal of Interactive Learning Research*., *15*(2), 147-167.

Chen, C. J., Toh, S. C., & Wan, M. F. (2005). Are learning styles relevant to virtual reality?. *Journal of Research on Technology in Education*, *38*(2), 123-141.

Chen, C. J. (2006). The design, development and evaluation of a virtual reality based learning environment. *Australasian Journal of Educational Technology*, *22*(1), 39-63. http://www.ascilite.org.au/ajet/ ajet22/chen.html.

Chen, C.J. & Wan, M.F. (in press). Guiding exploration through three-dimensional virtual environments: A cognitive load reduction approach. *Journal of Interactive Learning Research, 19*(4).

English, R.E. & Reigeluth, C.M. (1996). Formative research on sequencing instruction with the elaboration theory. Educational Technology Research & Development, *44*(1), 23-42.

Gagné, R.M. & Briggs, L.J. (1974). Principles of instructional design. New York: Holt, Rinehart & Winston.

Gagné, R.M. & Merrill, M.D. (1990). Integrative goals for instructional design. *Educational Technology Research and Development*, *38*(1), 23-30.

Gropper, G.L. (1983). A metatheory of instruction: A framework for analyzing and evaluating instructional theories and models. In C.M. Reigeluth (Ed.), Instructional-Design Theories and Models: An Overview of their Current Status (pp.37-53). New Jersey: Lawrence Erlbaum.

Jonassen, D.H. (1999). Designing constructivist learning environments. In C.M. Reigeluth (Ed.), *Instructional-design Theories and Models: A New Paradigm of Instructional Theory* (Vol. 2, pp. 215-239). New Jersey: Lawrence Erlbaum Associates.

Kim, Y. (1994). Formative research on the simplifying conditions method for task analysis and sequencing of instructional content. Unpublished dissertation, Indiana University Graduate School, Bloomington, IN.

Mayer, R.E. (2002). *Multimedia Learning*. Cambridge: Cambridge University Press.

Reigeluth, C.M. (1983). Instructional design: What is it and why is it?. In C.M. Reigeluth (Ed.), Instructional-Design Theories and Models: An Overview of their Current Status (pp.3-36). New Jersey: Lawrence Erlbaum.

Reigeluth, C.M. (1999). What is instructional-design theory and how is it changing?. In C.M. Reigeluth (Ed.), *Instructional-Design Theories and Models – A New Paradigm of Instructional Theory* (pp. 5-29). New Jersey: Lawrence Erlbaum.

Reigeluth, C.M. & Frick, T.W. (1999). Formative research: A methodology for creating and improving design theories. In C.M. Reigeluth (Ed.), *Instructional-Design Theories and Models – A New Paradigm of Instructional Theory* (pp. 633-652). New Jersey: Lawrence Erlbaum.

Reigeluth, C.M. & Merrill, M.D. (1978). A knowledge base for improving our methods of instruction. *Educational Psychologist*, *13*, 54-70.
Roma, C. (1990). *Formative evaluation research on an instructional theory for understanding*. Unpublished dissertation, Indiana University Graduate School, Bloomington, IN.
Shon, M. (1996). *Formative research on an instructional theory for the design of computer-based simulations for teaching causal principles.* Unpublished dissertation, Indiana University Graduate School, Bloomington, IN.
Tessmer, M. (1993). *Planning and conducting formative evaluations*. London: Kogan Page.

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