THE INSTRUCTIONAL DESIGN OF A VIRTUAL REALITY (VR)-BASED CAR MAINTENANCE LEARNING SYSTEM

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ABSTRACT
This paper reports the instructional design of a virtual reality (VR)-based learning system, which is meant for car drivers to learn about basic car maintenance procedures. The instructional design model proposed by Chen, Toh and Fauzy (2004) was chosen to guide the design of this learning system as this model is derived specifically to guide the design of VR-based learning environments. In brief, the model comprises two main strategies, the macro-strategy that concerns with the selection, sequence, and organisation of the subject matter topics that are to be presented, and the micro-strategy that proposes a number of design principles for effective presentation of learning materials. This paper provides a detail description of how the VR-based car maintenance learning system was designed in line with these strategies.

INTRODUCTION
The use of virtual reality to enhance learning has gained recognition in areas such as aircraft pilot training, building construction and design, military, and medicine. Although virtual reality technology can be used to create impressive learning tools that offer highly realistic simulations, the need for expensive high-speed graphics supercomputers, head-mounted display devices, three-dimensional graphics accelerators, wired gloves, spatial audio processing, psychological and cognitive skills and numerous other technologies and techniques (Pimentel and Teixeira, 1994) has somehow restricted its uses. Nevertheless, the availability of non-immersive virtual reality systems that can be implemented by affordable personal computers make possible the ubiquitous use of virtual reality system for education and training purposes.

This paper focuses on the non-immersive virtual reality system that uses conventional input devices, such as a keyboard and mouse to navigate through a three-dimensional environment that is displayed on a computer monitor. Learners can also use stereo glasses or other stereo projection system to obtain a stereoscopic view of the generated three-dimensional virtual environment. Non-immersive virtual reality system has increasingly been applied in many different educational applications because it is more mature and ubiquitously than the unaffordable immersive technology (Youngblut, 1998). The rapid increase of speed and capabilities of personal computers have also made possible the production of high performance virtual reality systems.

PROBLEMS
The knowledge and skills for car maintenance are currently taught by the Driving Institute or Driving School of Malaysia to the novice car drivers during practical maintenance course. This course that takes a total of three hours covers skills such as: checking the air pressure of tyre, leakage of engine oil, adequacy of engine oil, brake, door, electric system, steering, signal light, mirror, and hand brake.
A number of limitations are observed in the course. The knowledge and skills imparted are rather limited as the amount of time allocated is very limited. The course is instructor-centred in the sense that he or she demonstrates the various maintenance procedures while participants only passively observe them. The instructional decisions thus lie mainly in the hands of the instructors, which may vary greatly among them. Consequently, standardised instruction to ensure every participant receives similar instruction is impossible. Some instructors may also encourage the participants to practise the taught procedures using the participants’ personal cars without the instructors’ monitoring. This imposes risks as inadequate proficiency and lack of monitoring may cause improper fixing of the car parts, which eventually may pose risks when using the car.

An alternative for car drivers to obtain more knowledge and skills about car maintenance is through resources such as printed books or the WWW about car maintenance. However, the extensive use of text and two-dimensional static images in such resources requires the learners to have adequate language proficiency in order to understand the text as well as to mentally visualise the various parts of the car in three-dimension from the two-dimensional static images. These resources also impose a few abstraction levels that entail linguistics and spatial intelligence that differ among individuals. Due to individual differences, no doubt the sole reliance on books for imparting such knowledge and skills may cause learning difficulties for some individuals.

POTENTIAL OF VIRTUAL REALITY TO OVERCOME THE OBSERVED PROBLEMS
Unlike the instructor-directed approach, the VR-based learning environment allows the learners to individualise their learning as well as providing concrete and active experimentation of the maintenance tasks on authentic three-dimensional representations of the various parts of a car. Indeed, learners will be able to interact with the virtual environment by moving the input device (either mouse or keyboard) in order to view the objects from different perspectives, zooming in for detail and veering in any direction, instead of just seeing a static picture. Thus, as opposed to the instructor-directed approach, VR helps to create a learner-centred learning environment.

The development of the VR-based learning environment also makes new learning opportunities available to learners through the unique affordances of the technological solution. Learners will be able to carry out the tasks in simulated environment prior to manipulating real equipment, which can reduce the risk of equipment damage through incorrect actions. Learning of these tasks using the VR-based learning is also much less costly when compared with the use of real physical mock-ups. This project thus focuses on the design and development of a VR learning system for learners to learn about various basic car maintenance procedures. This paper provides a detail description on the instructional design of the system.

THE DESIGN OF THE LEARNING ENVIRONMENT
The instructional design model proposed by Chen, Toh and Wan (2004) was chosen to guide the design of this learning system as this model is derived specifically to guide the design of VR-based learning environments. As shown in Figure 1, the model comprises two main strategies, the macro-strategy that concerns with the selection, sequence, and organisation of the subject matter topics that are to be presented, and the micro-strategy that proposes a number of design principles for effective presentation of learning materials.
Figure 1: The employed instructional design model (Chen, Toh, & Wan, 2004)

Macro-Strategy
Objectives. In order to design a learning system that enables learners to master the skills effectively, it is very important to have clear objectives of the contexts to be delivered. By applying the integrative goals, the learning objectives and learning objective are specifically outlined in Table 1.

Table 1: Types of Learning with the Corresponding Learning Objectives

<table>
<thead>
<tr>
<th>Types of learning</th>
<th>Learning Objectives</th>
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<tbody>
<tr>
<td>Labels</td>
<td>Name the common car problems (overheating, balancing, engine oil and skidding.)</td>
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<tr>
<td></td>
<td>Name the tool to resolve problems</td>
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<tr>
<td>Verbal information</td>
<td>Describe the major symptoms related to each problem</td>
</tr>
<tr>
<td></td>
<td>Describe ways to prevent (overheating, balancing, engine oil and skidding.)</td>
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<tr>
<td></td>
<td>Explain the maintenance procedures to add coolant, add engine oil, pump tyre, change tyre, change engine oil and change oil filter.</td>
</tr>
<tr>
<td>Intellectual skills</td>
<td>Identify the common car problems (overheating, balancing, engine oil and skidding.)</td>
</tr>
<tr>
<td></td>
<td>Identify the correct tool to resolve each problem</td>
</tr>
<tr>
<td>Cognitive strategies</td>
<td>Reflect on the actions taken when navigating through the virtual scenario</td>
</tr>
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</table>

Integrative Goal. In design phase, an instructional designer needs to identify the component skills and knowledge that relate to the goal and design the scenario which relates each piece of knowledge or skill to the goal (Gagne and Merrill, 1990). An instructional goal must be a combination of several different objectives that are to be integrated into a comprehensive purposeful activity. The integrative goal is incorporated within the enterprise schema as verbal knowledge that relate to the goal and design the scenario which relates each piece of knowledge or skill to the goal. In this learning environment, we identify the integrative goal as...
the learners’ abilities to identify the symptoms of various basic car problems and procedures to maintain them.

**Enterprise Scenario or Problem.** The enterprise schema is expected to contain a number of knowledge and skill constituents that become associated in the service of the integrated goal. Enterprise scenario is somehow similar to the problem posed in a constructivist learning environment, in which according to Jonassen (1999), a problem consists of three integrated components: the problem context, the problem representation, and the problem manipulation space. The designer needs to identify the enterprise scenario that must be played out in conducting the enterprise.

Problem context. Problem statement of the contextual factors that surround a problem was described to enable the learners to understand the problem. The learning goal of this learning system is acknowledged once the learners launch the learning system. By revealing the value and focus of the learning environment, it assists the learners to engage with the learning activities.

Problem representation. An important function of designing for problem solving is deciding how to represent the problem to learners. In this learning environment, the virtual environments and narrative that which is presented in text, is used to assist the learner in building mental representation of the problem. In order to provide an interesting, appealing, and engaging problem representation to perturb the learner, the narrative is presented in form of stories and the virtual environments are employed to present scenarios of various car problems.

Problem manipulation space. In order for learners to engage in meaningful learning, they must manipulate something and obtain the feedback as how their manipulations affect the environment. In this learning environment, the scenarios of virtual car problem serve as the problem manipulation space that allow the learner to navigate through the virtual car parts using input devices such as mouse or keyboard. The learner can also easily reach and view the car parts in a distance that is sometimes unreachable in the real world.

**Related Cases.** By presenting related cases in learning environments, learners are provided with access to a set of related experiences or knowledge that allows them to make comparison with the problem posed. According to Alessi and Trollip (2001), knowledge and skills learned in a particular context are easily repeated by learners provided they are in a similar context. The lessons that we understand the best are those in which we have been most involved and invested the greatest amount of effort (Jonassen, 1999).

When humans first encounter a situation or problem, they naturally first check their memory for similar cases that they may have solved previously (Polya, 1957). If they can recall a similar case, they try to map the previous experiences and its lessons onto the current problem. If the goals or conditions match, they apply their previous lesson. Learners retrieve from related cases the advice on how to succeed, pitfalls that may cause failure, what worked or didn’t work, and why it didn’t (Kolodner, 1993). They then adapt the explanation to fit their current problem. In this learning environment, related cases of similar car problem caused by other symptoms are embedded in the learning environment to enhance the transfer of learning to the real setting.

**Information Resources.** It is important to determine what kinds of information needed by the learners in order to understand the problem, then, include those rich sources into the learning environment. The needed information enables learners to construct their mental models and formulate hypotheses that drive the manipulation of the problem space. In this learning environment, hyperlinks are provided to access various resources, which include the pictures and description of the needed tool to maintain a car, glossary that is related to car maintenance, related car tips, symptoms of a car problem, and the pictures of real world car parts and other related objects. The learner is free to access these resources while trying to solve the problem.
Cognitive Tools. Cognitive tools are generalisable computer tools that are intended to engage and facilitate cognitive processing (Kommers, Jonassen, & Mayes, 1992). They are intellectual devices that are used to visualize (represent), organize, automate or supplant information processing. Some cognitive tools replace thinking while others engage learners in generative processing of information that would not occur without the tool. This learning environment incorporates a few cognitive tools. The scenarios of the car problem act as a visualisation tool where learners can visualise a dynamic three-dimensional representation of the problem. Indeed, the three-dimensional representation is a lot more authentic when compared to static two-dimensional representations in a picture form. This representation helps learners in reducing the cognitive load in constructing mental images and performing visualising activities.

The virtual environment can be designed to make the abstract more concrete and visible by providing symbols that is not available in the real world. For instance, this learning environment provides blinking highlights at appropriate location of the virtual car to guide the learner in his or her learning process. Besides, narration and pop-up message is designed in this learning environment to acknowledge learners before or after an action is done. According to Alessi and Trollip (2001), reduced fidelity is known to benefit learning for a novice learner. Thus, the virtual car parts are purposely designed to be less complex in this learning environment than those in real world so that learner can concentrate on the significant aspects of the representation.

Besides, virtual environments have enabled learners to visualise and identify the complex structures that would otherwise remain hidden. According to Winn (1993), the learner's viewpoint maybe manipulated through which arbitrary levels of scale can be applied to facilitate observations. In this learning environment, the learner is able to view the car parts without sliding or crawling underneath the car or place the head under the car hood to do the maintenance task. All these components act as cognitive tools in reinforcing the learner's mental representation of the problem and assisting him or her in performing the learning activities in the learning environment.

INSTRUCTIONAL ACTIVITIES

Modelling. There are two types of modeling used in this learning environment: behavioural modelling and cognitive modelling. Behavioural modelling in the learning environment demonstrates how the virtual car is maintained with the appropriate procedures in the virtual environment and the subsequent cognitive modelling articulates the reasoning for such behaviour in a narrative (text and audio).

Coaching. A good coach relates the importance of the learning task to the learner. In this learning environment, the coaching is provided to learners through pop up feedback messages (both verbal and text) when car maintenance task is in progress. Table 2 shows the four types of coaching suggested by Jonassen (1999) and the examples of feedback messages that support each of type of coaching.

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<thead>
<tr>
<th>Types of coaching</th>
<th>Examples of Feedback Messages</th>
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<tbody>
<tr>
<td>Provide motivational prompts</td>
<td>Well Done! You have completed the task!</td>
</tr>
<tr>
<td></td>
<td>You're correct! Please proceed to solve the problem.</td>
</tr>
<tr>
<td>Monitor and regulate the learner's performance</td>
<td>Sorry, it’s incorrect. Please try again.</td>
</tr>
<tr>
<td></td>
<td>You’ve picked the incorrect tool.</td>
</tr>
<tr>
<td>Provoke reflection</td>
<td>When the bell stops ringing, it indicates sufficient air pressure in the tyre.</td>
</tr>
<tr>
<td>Perturb learners’ models</td>
<td>After loosen the valve cap, should you remove the valve cap from the valve?</td>
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</table>
Scaffolding. In this learning environment, the learning problem is divided into five problems to provide scaffold for a learner's performance by presenting the easiest maintenance procedure and gradually proceed to more difficult and complex procedure.

Micro-Strategy. In this learning environment, appropriate words or labels are used in the five learning problems. According to Mayer (2005), the first principle of multimedia design stated that learning can be enhanced when pictures are added to words rather than words alone. For instance, the scenarios of real world car problem rather than just scenarios written in text alone are presented for learners to understand the presented material.

Based on the modality principle, learners are found to learn better when words in a message are presented as spoken text rather than printed text. Hence, this learning environment provides feedback in the form of narration during a learner's exploration of the virtual car scenario. Meanwhile, feedback in the form of onscreen text is still remained. The exploration of the virtual environment is fully learner-controlled, and there is no additional visual load as the scene of the virtual environment is temporarily halted when any feedback (narration and onscreen text) is provided until the learner decides to proceed with the exploration.

Figure 2: A screenshot of the learning environment
CONCLUSION
The educational benefits offered by VR technology are widely recognised. However, as any other tools, VR is just a tool that has to be properly designed and used in order to best attain the educational objectives. As instructional design models prescribe methods with the aim to produce effective instruction, an instructional design model derived specifically for VR-based learning environment was chosen to guide the design of this VR learning system. This paper has provided a lengthy elaboration on how the learning system was designed in line with the strategies proposed by the chosen instructional design model.

REFERENCE