Evaluating the Effectiveness of Head-Mounted Display Virtual Reality (HMD VR) Environment on Students' Learning for a Virtual Collaborative Engineering Assembly Task

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Abstract

The emerging VR social networks (e.g., Facebook Spaces, Rec Room) provide opportunities for engineering faculties to design collaborative virtual engineering tasks in their classroom instruction with HMD VR system. However, we do not how this capacity will affect students' learning and their professional skills (e.g., communication and collaboration). The proposed study is expected to fill this research gap and will use a mixed-methods design to explore students' performance and learning outcomes in a virtual collaborative automotive assembly task. The quantitative data will be collected from the pre-and-post task survey and the task itself. This data will be used to analyze the differences among experiment and control groups. Students' responses to the open questions in the post-task survey will serve as triangulation and provide deep insight for the quantitative results. The study is expected to not only contribute to the research field but also benefit different stakeholders in the engineering education systems.

Keywords: head-mounted display, virtual reality, engineering education, collaborative learning.

1. Introduction

Previous research shows that HMD VR system has a moderate price but significant performance gains over desktop VR system and similar effectiveness as high-end VR products, such as CAVE [16]. These characteristics forebode that HMD VR system has broad application space in the engineering experiment field, which requires deep immersion, a high-fidelity simulation environment, and sometimes has a limited budget in equipment purchases. Furthermore, many emerging VR social networks (e.g., Facebook Spaces [8], Rec Room [17]) allow users to communicate and collaborate with others freely in a HMD-based shared virtual environment. This achievement provides opportunities for engineering faculties to design collaborative practices in their classroom instruction. However, how this capacity will affect engineering students' learning and cultivate their professional skills (e.g., communication and collaboration) have not been studied.

Most preceding research of collaborative learning under 3D VR environment focuses on either desktop or CAVE virtual environment. However, the effectiveness of different types of VR systems on users' learning are various [16]. The results of this research do not necessarily apply to the HMD VR system. On the other hand, the scenario design of the left small number of research which explored users' collaboration under HMD VR environment are mostly game based and unrelated with specific practice in school. This type of design partly weakens the practical value of the research in the educational field and may cause difficulties for faculties to connect the research results with their instruction [20].

The study I propose is expected to fill the gap. The research question that leads the study is: *What is the effectiveness of HMD VR environment on students' learning for a virtual collaborative engineering assembly task?*

An empirical investigation of the effectiveness of this simulated practical environment will add to the scarce knowledge on engineering learning under HMD-based 3D collaborative virtual environment in the research field. It is also expected to benefit different stakeholders in the engineering education systems. Simulated object assembly experiment (e.g., building, machine, and circuit assembly) is frequently used in engineering class. The results of this research are expected to serve as a practical guidance for engineering faculties on how to design a collaborative engineering task with the support of VR systems. Increased simulation practical experience will pave the path for students to smoothly transit from school to the workplace. Schools will also have a higher cost-effectiveness in teaching equipment.

2. Proposed Hypotheses

In this research, the lens of collaborative learning is: students in a team of two to six members synchronously work on a specific educational task. In the process, they mutually construct and maintain a shared knowledge for the success of the task. The focus will be at the individual unit, where the collaboration is an external intervention under a specific virtual context.

In general, there are two types of role settings for a collaborative task in an HMD-based 3D virtual collaborative learning environment. One is that all the members are in a shared virtual environment with HMDs (full-collaborative team); the other is that there is only one member in the HMD-based virtual environment, and the other members vocally direct this individual (semi-collaborative team). Besides these two settings for the experimental groups in the research, the setting of teams for the control group is that all the members in a team accomplish a 3D virtual assembly task together with their personal computers. This type of team is named desktop team. Based on literature, hypotheses that compare students in these three conditions are proposed.

2.1. Experience

Social presence (or co-presence) is defined as a person's sense of being in an environment together with other users [7], [14]. This sense is critical to promote collaborative learning and knowledge building [13]. Perception of being interdependent with others is the top level of social presence [6]. Due to the difference in role setting, ideally, there will be more frequent vocal communication among members in semi-collaborative teams than students in the full-collaborative teams, which indicates a higher level of interdependence. In addition, immediate interaction and communication among users enhances social presence [9]. HMD shields the unrelated visual influences from outside and concentrate users on the task under the VR environment [10]. This allows faster response to interaction than in a non-immersive condition.

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H1: Students in the semi-collaborative teams will have a higher level of social-presence than in the full-collaborative teams.

H2: Students in the full-collaborative teams will have a higher level of social-presence than in the desktop teams.

Compared with desktop VR, HMD VR has shown advantage in facilitating users continuously manipulating virtual 3D objects [4]. Moreover, when all students are in a shared virtual environment with HMDs, they can implement the same assembly task simultaneously. Therefore, the full-collaborative teams should have a better performance (less time spent) than the other two types of teams.

H3: The full-collaborative teams will spend less time to complete the virtual engineering assembly task than the other teams

2.2. Learning Outcomes

The evaluation of students' learning outcomes in this research follows the classification of learning outcomes proposed by Kraiger, Ford, and Salas [12], which includes three categories: cognitive, skill-based, and affective.

According to Sweller's Cognitive Load Theory [21], collaborative learning under VR environment includes two sub-tasks: one is constructing the knowledge and the other is controlling the learning environment [18], [21]. If the VR environment allows more efficient interaction, communication, and control, users will correspondingly focus more on learning itself, which will lead to better learning [15], [18].

H4: Students in the full-collaborative teams will have more knowledge gains in engineering assembly than in the other teams

A high level of realistic VR environment ensures good transfer of skills [15]. Students in the full-collaborative teams have a more similar role setting and implementation process to the real world practice than in other teams. This means that what they have experienced is closer to the collaborative assembly task in the physical environment than others. Therefore, they should have more skill gains.

H5: Students in the full-collaborative teams will have more skill gains in engineering assembly than in the other teams.

Self-efficacy is the most important measurement in the affective field [1]. It is related to the individual's beliefs in his or her performance for a specific task [2]. Past mastery experiences are the most important source of individual's self-efficacy [3]. More knowledge and skill gains ensure that students in the full-collaborative teams have more successful mastery experience and have a higher level of self-efficacy than in other teams when the intial level of self-efficacy for the assembling task is similar among all participants.

H6: Students in the full-collaborative teams will reach more self-efficacy in engineering assembly than in the other teams.

The unequal role setting in the semi-collaborative team may cause unequal access to the resource in the virtual task. In other words, the limited number of HMD headsets leads to a competition for the role of player [11]. Interactive competition generates negative attitudes among the group members [19].

H7: Students in the semi-collaborative teams have a higher level of negative attitude towards teamwork than students either in the full-collaborative teams or in the desktop teams.

Knowledge retention is also a critical factor to assess the value of VR in education [22]. Previous research indicates that there is no difference in knowledge retention either between students learning under 3D and 2D environment, or between students learning under VR and physical environment [22], [23].

H8: There is no significant difference in the retention rate of knowledge for students in these three types of groups.

3. Methods

This research will use the mixed-methods approach [5] to explore students' experience and learning outcomes for a virtual automotive assembly task under three conditions: full-collaborative team, semi-collaborative team, and desktop team. The quantitative data will be gathered from the closed questions in three surveys and the experiment itself; the qualitative data will be from the open-questions in the post-experiment survey. Once the initial results from the two sets of data are obtained, I will merge these results and create a better understanding for the overall research.

3.1. Instrument Development

Two questionnaires and one VR application are required for this research. The first questionnaire will be used for the pre-experiment survey, and the survey conducted one week after the experiment. The main content in the questionnaire will be demographic questions, instruments of self-efficacy in engineering assembly task and personal attitude towards teamwork, and a quiz of automotive assembly. The second questionnaire will be for the post-experiment survey. This questionnaire will include content from the first questionaire in addition to the instruments of social presence, and the supplementary open questions related to participants' experience in the collaborative virtual assembly task, their reflections, and feedbacks.

The topic of the VR application will be a virtual automotive assembly task. Its purpose is that players will be familiar with the internal structure of an automobile after the virtual task. The application has two modes: single player and team work. The team work mode supports three players wearing HMDs to assemble one virtual automobile simultaneously in a shared VR environment. The initial scenario of this application is that all the components (approximately 30 pieces) of an automobile are scattered on the floor. Users are required to assemble them as quickly as possible.

3.2. Data Collection

The participants of the experiment will be 60 undergraduate engineering students. They will be randomly assigned into three-member teams and all the teams will be evenly distributed into one of the three experimental conditions (full-collaborative, semi-collaborative, and desktop). After the members in a team have submitted their pre-experiment surveys, they will assemble a virtual automobile under the HMD VR environment together. When they successfully complete this, they will be given a post-experiment survey. After one week, these participants will complete the third survey with the first questionnaire.

3.3. Data Analysis

Quantitative Strand: Missing data will be examined first. Subsequently, one-way ANOVA method will be used to evaluate whether there are differences in pre-experiment scores among students assigned in different conditions. If the results indicate no significant difference, further hypotheses testing will be conducted; otherwise, experimental data will be collected again with a revised sampling method. Next, one-way ANOVA method will be employed in the hypotheses tests from H1 – H7 with students' scores in the post-experiment survey. A 3*3 repeated-measures MANOVA will be used to examine H8.

Qualitative Strand: Students' responses to the open questions in the post-experiment survey will be purposely coded around the themes of the examined hypotheses in the quantitative strand.

Mixed Analysis: The results of the two data sets will be merged, and how they converge and diverge from each other will be interpreted. This analysis will elaborate the initial findings of the quantitative strand.

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