
Kinesthetic Learning Potential in Mixed Reality

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ABSTRACT

Virtual Reality's recent commercialization has created a potential for its implementation into classroom and training environments. Past adoptions of this technology and their efficacy are explored in the literature review. This paper outlines the possibility of combining current VR technology with custom hardware allowing the user to interact with physical and mechanical object within virtual worlds and its implication on the future of kinesthetic learning and training in hazardous or expensive scenarios.

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KEYWORDS

Mixed / augmented reality; Usability testing

INTRODUCTION

Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) have been utilized in education and training activities since their inception. Their ability to combine kinesthetic interaction and hands-on activities with visualization of concepts not found in traditional learning environments without high cost and exposure to dangerous or toxic environments has elevated them as potential tools in both education and training. In this paper we explore the expanded tactile interaction and feedback combined with a VR environment and its effects on the training of physical skills.

VR has had many different academic definitions covering a wide range of theories and even its own reality—virtuality continuum [6]. The recent commercialization and popularization of VR technology by companies including Google, HTC, and Samsung have helped to simplify the definition for marketing to a general audience. For this paper, we will adopt a working definition of VR from these commercial applications by stating that VR is a computer-generated simulation in which the user may exist using a Head Mounted Display (HMD). HMDs are frequently described according to the way in which they operate, specifically, either three degrees of freedom (3DOF) or six degrees of freedom (6DOF). 3DOF being rotational movement in three dimensions (tilting the head left and right, tilting the head forward and backward, turning the head side to side) and 6DOF adding translational movement to these dimensions.

While VR places the user in a virtual environment, AR places virtual objects and information into the physical world using either transparent displays or pass-through video. This allows it to augment reality by analyzing and overlaying physical objects and scenarios with digital information. Much like the way AR augments reality, MR augments VR with the addition of physical objects and feedback from the natural world. MR's ability to augment a VR environment with kinesthetic feedback is an exciting concept and the focus of this paper.

LITERATURE REVIEW

While VR, AR, and MR applications and their ability to aid and augment learning has been studied for decades, little has been written about possible pedagogy within educational VR. To fill this gap [4] explored pedagogical capabilities of current VR applications. They evaluated 35 VR applications coming from private companies, public corporations, and universities or public foundations. The applications were investigated and placed into six categories based on their predominant and secondary pedagogies: direct instruction (2, 1), experiential learning (24, 5), discovery learning (4, 13), situated cognition (1, 4), constructivism (3, 10), and unclassified approaches (2, 0).

Kinesthetic learning has long ago been proven as a viable teaching approach and its use in MR-based education thoroughly studied. [1] developed an MR table to simulate chemical reactions. Using physical pieces deemed "totems" they allowed students to interact with chemicals by using

these totems to connect two chemicals and initiate a chemical reaction, giving the undergraduate chemistry students access to hands-on learning without expensive and hazardous real-world experiments.

Jang et al. [3] investigated the difference between passive and hands-on learning in medical students by studying their ability to learn the anatomical structure of the inner ear by viewing a 3D model for a short period of time. Both groups of students viewed a 3D model of the inner ear for a short period of time before being asked to draw and notate the structure and position of various parts. The control group was given a gyroscopic controller to manipulate the 3D model as if they were holding it in their hand and able to control the rotation and position with real-world movements. Each member of the control group was paired with a student from the test group and was only allowed to view the manipulated 3D model with no knowledge that it was being affected by another person. They found that the test group had greater success drawing the anatomical structure of the inner ear post-test. Students with lower spatial awareness were especially aided by manipulating the 3D model rather than relying strictly on observation.

To test the ability of students to relay newly gained knowledge through passive and hands-on learning, Guerrero et al. [2] employed the use of tangible user interfaces in a High School geometry class. They used two activities, each with their own test and control groups. The first, dubbed "PrimBox", paired students together who were tasked to replicate a geometrical figure given to one student of the pair. In the test group the first student was able to select objects by placing corresponding cards into a box equipped with RFID sensors which would then appear in a virtual world and could be manipulated with attribute cards (position, size, rotation, and color) and associated sliders to adjust these values and then could relay this information to their partner. The control group had to rely on the 2D printed image and their explanation of it to convey the information necessary for their partner to replicate it.

The second, dubbed "FlyStick", students were tasked with identifying four different curves created by bisecting a set of cones with a plane. The test group used a tangible user interface that can manipulate the plane bisecting the cones by sensing a controller's rotation and position. These attributes were replicated in a virtual world and transposed on a set of cones, one inverted on top of the other, in order to visualize various geometrical concepts. The control group relied on chalkboard instruction to understand the transition from 3D to 2D space.

The PrimBox activity was evaluated by the use of geometric language, orientation of the figure, and positioning of the geometric parts. The average score out of 100 for the test group was 100 and the control group scored an average score of 74.5.

The FlyStick activity used two competency tests. One given directly after the activity and the second given two weeks later. Evaluating the results with a paired t-test 84.6% of the students in the control group received worse scores in the second test, while there was no statistical difference within the test group.

Lahanas et al. [5] conducted a study in order to test the viability of MR simulations in replicating real-world laparoscopic surgery situations. Using two groups of surgeons (28 experts and 21 novices) they tested their ability to perform simulated laparoscopic surgery with physical replications of laparoscopic cameras and instruments in a VR environment. The expert surgeons scores were statistically higher ($p < 0.05$) in all three assessments: camera navigation, instrument navigation, and bimanual operation suggesting that an MR environment can sufficiently replicate physical scenarios in certain learning applications.

PROBLEM STATEMENT/RESEARCH QUESTION

Based on a review of Barrett et al. [1], Guerrero et al. [2], Jang et al. [3], and Johnston et al. [4] it is evident that learning can be enhanced by MR technology and integration of tactile activities. While this is the case, very little work has explored the use of actual mechanical manipulation and the visual feedback thereof of tools within a VR or MR environment and its impact on learning. This work explores increased physical interaction of objects via mechanical manipulation within an MR environment and its potential for learning by answering the following research question: What is the impact of additional visual and kinesthetic feedback on learning potential in an MR environment?

Key Variables

- Feedback level
- Learning potential
- Accuracy
- Comfort

RESEARCH DESIGN & METHODS

Description of Technology

Commonly used in commercial woodworking, the plunge router (shown in Fig. 1) is one of the most complicated and dangerous powered hand tools. Operating at up to 23,000 RPM with the capacity to fit a 3" diameter blade, it has a high potential to injure novice users. By virtualizing the actions of the plunge router, the user can have a safe and stress-free environment in which to practice using this tool. Using various sensors to relay information to the virtual environment we propose a 1-to-1 representation of a plunge router in virtual reality and the following actions:

- Simulation of on and off states
- Visualization of plunger depth in real time
- Manipulation of depth stops

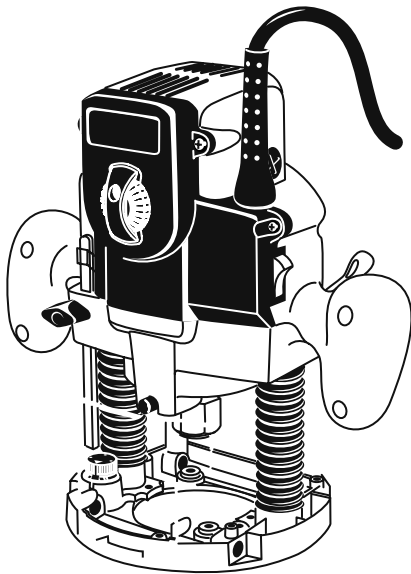


Figure 1: A plunge router

Previous studies of VR, AR, and MR technologies have focused on the use of tools within their respective environments, but none have delved into the possibilities of actual mechanical manipulation and representation in a virtual environment of such tools. Mechanical manipulation is defined as such: movement within an object other than the 6DOF movement defined earlier in this paper such as the plunging action of the plunge router where one or more parts of the tool move while other parts remain stationary.

The custom tool for this study will be built within the chassis of a traditional plunge router to create familiarity with the tool; the electronics replaced with an HTC Vive Tracker to detect the controller's position and rotation in space connected to an Arduino and resistance sensors to measure movement of separate parts within the controller. This set up will replicate the real-world and normally dangerous actions of the tool in a virtual environment.

METHODS

Participants randomly assigned to either a control or a research group will be required to complete tutorials to learn a variety of cuts using a plunge router with either the custom controller created for this study (research group) or traditional VR controllers (control group). Each group's method of participation will be broken down in the following subsections.

Control Group

The control group will use traditional HTC Vive controllers to interact with a virtual plunge router in each simulation. A trigger on the left and right controller allows the participant to manipulate the on-off switch and plunger locking mechanism, and pilot the virtual plunge router through a series of routing scenarios described later in this section.

Research Group

The research group will use the custom MR router controller by operating it as they would a plunge router in a physical space. Using the sensors described earlier they will be able to operate the MR plunge router controller as they would with the physical tool.

Each will navigate these common plunge routing scenarios:

- Plunge cut-out within a material
- Plunge trim cut
- Routed edge with profile router bit

And be evaluated by their ability to stay within a predetermined optimum path by the software. Because this study focuses on new technology and training methods it will be of a qualitative nature. To identify key themes, a think-aloud exercise (Nielsen, 2012 Jan) will be conducted with each participant. These themes will be used to design a future quantitative study of the topic.

ANALYSIS & RESULTS

Participants will take a pre-survey in order to determine demographic information. Each think-aloud exercise [7] will be analyzed for themes and codes based on the methods outlined in Ryan & Bernard's Techniques to Identify Themes [8]. These themes will be used to design a quantitative survey to be used in future studies.

CONCLUSION

With the commercialization of affordable VR HMD's, it is worth exploring the pedagogical possibilities of using custom hardware to interact with virtual realities. As mentioned in previous sections, the purpose of this study is to provide preliminary themes to be used in future studies. Not only using the controller designed for this study, but also as a potential guideline for other tangential work in this field.

REFERENCES

- [1] Barrett, R., Gandhi, H. A., Naganathan, A., Daniels, D., Zhang, Y., Onwunaka, C., . . . White, A. D. (2018). Social and tactile mixed reality increases student engagement in undergraduate lab activities. *Journal of Chemical Education*, doi:10.1021/acs.jchemed.8b00212
- [2] Guerrero, G., Ayala, A., Mateu, J., Casades, L., & Alamán, X. (2016). Integrating virtual worlds with tangible user interfaces for teaching mathematics: A pilot study. *Sensors (Basel, Switzerland)*, 16(11), 1775. doi:10.3390/s16111775
- [3] Jang, S., Vitale, J. M., Jyung, R. W., & Black, J. B. (2017). Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment. *Computers & Education*, 106, 150-165. doi:10.1016/j.compedu.2016.12.009
- [4] Johnston, E., Olivas, G., Steele, P., Smith, C., & Bailey, L. (2018a). Exploring pedagogical foundations of existing virtual reality educational applications: A content analysis study. *Journal of Educational Technology Systems*, 46(4), 414-439. doi:10.1177/0047239517745560
- [5] Lahanas, V., Loukas, C., Georgiou, K., Lababidi, H., & Al-Jaroudi, D. (2017). Virtual reality-based assessment of basic laparoscopic skills using the leap motion controller. *Surgical Endoscopy*, 31(12), 5012-5023. doi:10.1007/s00464-017-5503-3
- [6] Milgram P, Takemura H, Utsumi A, Kishino F (1995) Augmented reality: a class of displays on the reality-virtuality continuum. In: Proceedings of the SPIE conference on telemanipulator and telepresence technologies, Boston, MA, USA. Proceedings of SPIE, vol 2351, pp 282–292
- [7] Nielsen, J. (2012, June 4). How Many Test Users in a Usability Study? Retrieved October 29, 2018, from <https://www.nngroup.com/articles/how-many-test-users/>
- [8] Ryan, G. W., & Bernard, H. R. (2003). Techniques to identify themes. *Field Methods*, 15(1), 85-109. Retrieved from <https://journals-sagepub-com.proxy.libraries.uc.edu/doi/abs/10.1177/1525822X02239569>