



Evaluating the Use of Mixed Reality to Teach Gross and Microscopic Respiratory Anatomy

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Abstract

Advances in technology often evolve into instructional platforms. This study evaluated the applicability of mixed reality (MR) in anatomy instruction. First-year medical students were randomized into a control group using a cadaver and light microscopes, or an experimental group using HoloLens, to complete a learning activity on gross and microscopic respiratory anatomy. Compared with the control group, the experimental group reached an equivalent score on the post-activity knowledge assessment, performed better on follow-up assessment, had consistently higher perceived understanding, and rated the activity higher. Findings suggest MR is an effective teaching tool and provides a favorable learning experience.

Keywords Anatomy education · Mixed reality · HoloLens · Augmented reality

Background

Anatomy education plays a fundamental role in the training of physicians [1]. Anatomy instruction is traditionally accomplished through cadaveric dissection, but in the past decade new approaches have been evaluated [2, 3]. Novel instructional platforms include technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) [3].

Mixed reality is one of the newer technologies to be used in anatomy education [3]. On the continuum of VR and AR, MR blends the real and virtual worlds together to enable real-time interaction with displayed content [4]. Such technology has the potential to transform education, particularly how educators give, and learners receive, instruction. Although gross anatomy is of paramount importance to medical education, the anatomical sciences also include instruction on the structure of tissues and organs at the microscopic level (i.e., histology). To date, the authors have found no study evaluating the

use of MR to teach anatomy at both the gross and microscopic levels.

We examined the utility of MR in the instruction of gross and microscopic anatomy of the human respiratory tract. Medical students were assigned to a control group using a cadaver and light microscopes or an experimental group using HoloLens. Students completed pre-activity, post-activity, and follow-up assessments to evaluate improvements in knowledge and provided student feedback on each type of instruction.

Activity

Study Design

A total of 10 first-year medical students at Campbell University School of Osteopathic Medicine were recruited to participate in the study. Inclusion criteria were students who must be first-year medical students on their first attempt of the anatomy curriculum. All participating students had experience with cadaveric dissection but had yet to complete labs on respiratory gross anatomy and histology. A random number generator (GraphPad Software, San Diego, CA) evenly assigned the 10 recruited students to either control or experimental groups. Students who volunteered in the research activity were given a subscription to Complete Anatomy Student Edition (3D4Medical, Dublin, Ireland).

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This study was approved by the Campbell University Institutional Review Board by expedited review procedure as determined by 45 Code of Federal Regulations part 46.111, Categories 6 and 7. Informed consent was obtained by all participants in the study before commencement of research activities.

Anatomical Models and Histology Slides

The Microsoft HoloLens (1st generation) is a MR headset. The headsets were connected to the Internet using Campbell University's secure wireless network and the program HoloHuman (GIGXR, Venice, CA) was downloaded to each headset. HoloHuman was used to create MR anatomical models (Fig. 1a) used in the experimental group.

Histology slides used in this project came from normal organ teaching sets. Glass slides were scanned to permit virtual microscopy via Aperio ImageScope – Pathology Slide Viewing Software (Aperio, Buffalo Grove, IL). Digital photomicrographs of the desired histology were then imported out of the program as Joint Photographic Experts Group images and placed into a Microsoft PowerPoint (Redmond, WA) presentation. This PowerPoint presentation was uploaded to each HoloLens so participants of the experimental group could view histology in a MR environment (Fig. 1b). The control group viewed glass histology slides using light microscopes (Labomed Lx 400, 912601, Associated Microscope, Elon, NC).

Learning Activity

Students in each group completed a 30-min faculty-led learning activity on respiratory gross anatomy and histology. At the beginning of the learning activity, students completed a 14-question pre-activity assessment consisting of 12 multiple choice gross anatomy and histology questions and 2 self-perceived understanding rating scales.

In the control group, an anatomy faculty member demonstrated components of respiratory anatomy on a pre-dissected human cadaver, then a pathology faculty member used light microscopes and glass slides to teach respiratory histology. In the experimental group, an anatomy faculty member demonstrated components of respiratory anatomy on HoloHuman, an application for HoloLens, then a pathology faculty member used photomicrographs, viewed via PowerPoint on the HoloLens, to teach respiratory histology. Each faculty member followed a written script during their respective aspects of the learning activity. The same script and faculty members were used for both control and experimental learning activities.

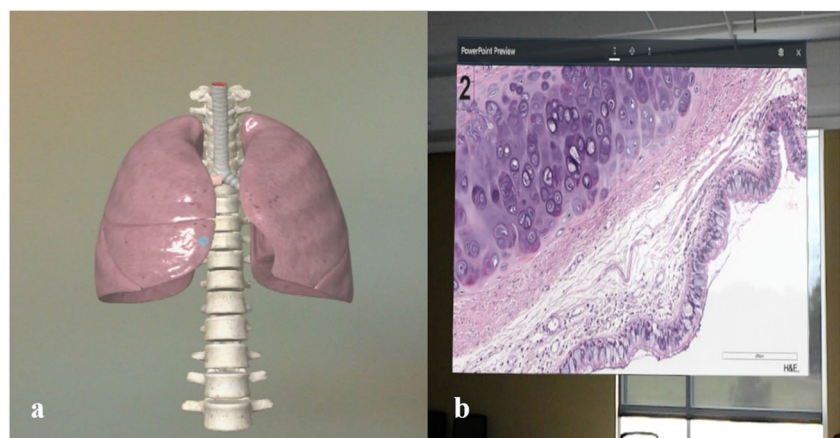
After completion of each learning activity, students completed a post-activity assessment. This assessment was the same as the pre-activity assessment with addition of a Likert scale. Students were also able to leave written feedback regarding their experience with the learning activity. Lastly, 7 days after the learning activity, participants completed a follow-up assessment. This assessment contained the same content as the pre-activity assessment. The self-perceived understanding rating scales in the pre- and post-activity assessments asked participants to rate their current understanding of respiratory gross and microscopic anatomy (1 for no understanding to 5 for very strong understanding). All assessments were developed and collected using the Qualtrics application (Qualtrics, Provo, UT).

Results

Limitations

In consideration to the pilot nature of this study, the small sample size restricted our ability to make statistically significant comparisons between groups. Presented data is limited to more superficial inquiry. All 10 participants completed the

Fig. 1 Mixed reality anatomy. **a** Gross anatomy. **b** Microscopic anatomy. Gross image from HoloHuman used with permission (GIGXR, Venice, CA)



pre-activity assessment, post-activity assessment, and follow-up assessment.

Anatomy Knowledge Assessments

The experimental group started at an average of 65.0% for the pre-activity assessment (versus 76.7% for the control) and ended at the same as the control (85.0%) on the post-activity assessment. Moreover, the experimental group performed better on the follow-up assessment compared with the control group, averages of 86.7% and 83.3%, respectively.

Self-Perceived Understanding of Anatomy

The control and experimental groups both reported improvement of anatomical and histological understanding after the learning activity. The experimental group averaged higher perceived understanding of both gross and microscopic

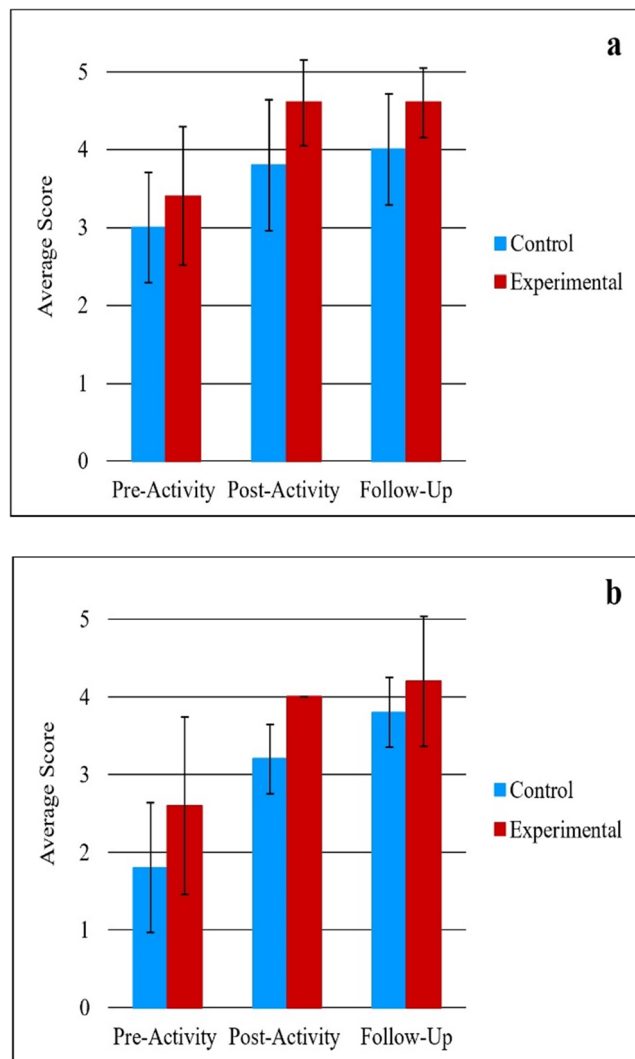


Fig. 2 Self-perceived understanding rating. **a** Gross anatomy. **b** Histology. Scores reported as mean ± SD

anatomy at each step of assessment compared with the control group (Fig. 2).

Student Feedback

The experimental group consistently reported higher scores on the post-activity Likert scale (1 for strongly disagree to 5 for strongly agree) that assessed students’ opinions of their assigned learning modality (Fig. 3).

In the control group, 2 of the 5 participants provided feedback. In the experimental group, all 5 participants chose to provide written feedback. Examples of participant feedback from the experimental group include: “This activity was very helpful to visualize both the histology and gross anatomy better. The HoloLens was interactive and engaging, helping to reinforce the learning.”; “Having a pointer during the PowerPoint presentation would have helped. Overall, a great way to learn!”; “Great learning experience for students.”

Discussion

This study demonstrates MR can be used to teach gross anatomy and histology in an efficient manner during a small group, faculty-directed learning session. Performance on the knowledge assessments was comparable between the two

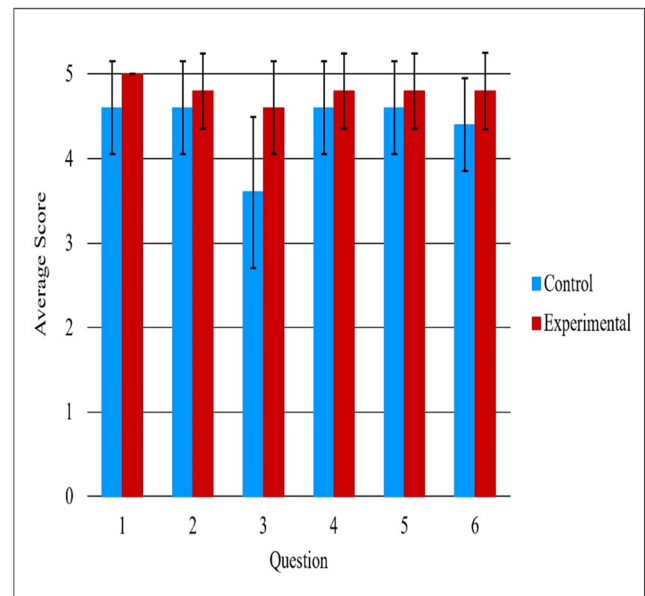


Fig. 3 Post-activity Likert scale results assessing students’ opinions of assigned learning modality. Scores reported as mean ± SD. 1, It is easy to learn anatomy from the assigned learning activity. 2, I enjoy learning anatomy from the assigned learning activity. 3, Learning anatomy from the assigned learning activity is engaging. 4, I would recommend the assigned learning activity to another student to learn anatomy. 5, I find it easy to identify spatial relationships from the assigned learning activity. 6, I find it easy to obtain factual knowledge from the assigned learning activity

groups; however, the experimental group demonstrated greater improvement from their pre-activity average to their post-activity average and performed higher on the follow-up assessment, compared with the control group. This finding suggests MR has the capacity to promote retention of anatomical knowledge. In addition to perceiving an increased understanding of gross anatomy and histology, participants in the experimental group reported MR to be an interactive and engaging way to learn anatomy. This finding supports the idea that favorable perceptions of a learning activity can produce better learning outcomes [5].

The application of multimodal teaching in anatomy education has been shown to increase student performance [6]. There are many instructional techniques currently used in anatomical pedagogy [7]. Mixed reality offers students an additional and unique way to visualize gross anatomy and histology. The present study used static photomicrographs placed into a PowerPoint presentation, which allowed for easy placement and use within the HoloLens. Of note, Hanna et al. demonstrated that virtual microscopy can be accomplished using the HoloLens by accessing web-based whole slide image viewing programs [8].

As we address the future of health sciences education, the current coronavirus pandemic emphasizes the need for exploration of distance learning resources. Mixed reality creates an environment where components of the digital world are perceived to exist in the real world and enables real-time interaction with displayed content. Mixed reality headsets are becoming more affordable and accessible to individuals [9]. A number of applications available for such devices are steadily increasing. These devices and programs can be used in almost any location to support self-directed learning and facilitate instructor-student engagement [9].

In conclusion, in evaluating MR to teach gross and microscopic anatomy, we found instruction via MR to be both feasible and effective. The findings of this study suggest MR is capable of producing knowledgeable, confident students while also providing positive learner experiences.

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Authors Contributions Robinson B., Mitchell T., Brenseke B.: Substantial contributions to the conception and design, acquisition, analysis, and interpretation of data; drafted the article and revised it critically for important intellectual content, approved the version to be published, agreed to be accountable for all aspects of the work

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Data Availability The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with Ethical Standards

Conflicts of Interest The authors declare that they have no conflict of interest.

Ethics Approval Approval was obtained from Campbell University's Institutional Review Board. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed Consent Informed consent was obtained from all participants included in the study.

Consent for Publication Participants signed informed consent regarding publishing their data and photographs.

Code Availability Not applicable

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