Scalable and Effective use of Immersive Virtual Reality for Physics Education

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We present work on the use of Highly Immersive Virtual Reality (VR) for correcting student misconceptions related to Newton's laws. Our in-house developed software runs on the latest generation of portable headsets, which has enabled us to easily scale VR experiences to entire classes. Since 2019, we have collected data from 156 students (little to no prior physics study) who have used VR as part of their foundational physics coursework at the Australian National University.

Inspired by multiple choice questions from Force Concept Inventory (FCI) [1], our VR experience asks students to play with a basketball and decide which forces act on the ball after it leaves their hand. The choice of forces includes gravity, the wind, and a force from their hand. They are then presented with the world that represents their choice, and therefore manifests any misconceptions giving them a world that behaves unphysical and causes cognitive dissonance. A narrator guides them with feedback to reconsider and reflect on their choices until they choose the correct answer, at which point they are free to experiment with turning different forces on and off.

The most common distractors targeted by our simulation are the misconceptions of impetus and active force [1] – essentially a 'force in the direction of motion' being required to keep an object moving. In this world view, because the ball is moving, a force from a student's hand must still be on the basketball after it leaves their hand. This is arguably the most prevalent misconception people studying Newton's laws need to correct. Eaton *et al.* [2], building on the work of others [3], uses factor analysis and over 19000 paired responses to identify correlations between question distractors on the FCI that relate to a variety of misconception categories. 'Factor-2' predominantly relates to the 'force in the direction of motion' misconception and encompasses 10 of the 30 FCI questions.

The FCI is administered twice during the course: prior to formal instruction, and then again after mechanics and the VR experience is (or isn't) undertaken. When we compare 156 VR students with 331 students who did not use VR but have undertaken the same course at ANU (over several years), there is a statistically significant improvement in FCI metrics. Applying a Repeated Measures Analysis of Variance (rANOVA), it is found that using VR is a significant predictor of improvement in score on the 10 questions of Factor-2 ($p < 0.01$). There is no statistically significant difference between the groups for the remaining 20 questions of the FCI. For Factor-2, both VR and non-VR students begin with statistically equivalent baseline scores of with an average of 23%. VR students improve their post-instruction score to an average of 53%, whereas non-VR students improve their average to 40%. We do not find cohort year to be a significant predictor of score variance.

We also present recent work on developing a multi-user, electromagnetism sandbox to allow for VR-based tutorials targeting EM visualisation and concepts.

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee (Protocol 2018/504).

[1] Hestenes, D., Wells, M., & Swackhamer, G., (1992) *The Physics Teacher.* **30**, p. 141.

[2] Philip Eaton, Kinsey Vavruska, and Shannon Willoughby, Phys. Rev. Phys. Educ. Res. **15**, 010123

[3] T. F. Scott and D. Schumayer, Phys. Rev. Phys. Educ. Res. **13**, 010126 (2017).