

Integrating Virtual Reality to Enhance Confidence in Anatomical Language

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Introduction

Mastery of anatomy as a language is fundamental to medical education, supporting precise communication, accurate interpretation of spatial relationships, and effective clinical reasoning. However, early medical learners often struggle to develop this proficiency due to limited prior exposure, reliance on rote memorization, and difficulty translating two-dimensional resources into three-dimensional understanding.¹ These challenges can hinder students' ability to integrate terminology with structural knowledge and apply anatomical concepts confidently in clinical contexts.

Emerging technologies such as virtual reality (VR) offer a potential solution by providing immersive, interactive environments that allow learners to manipulate structures and visualize spatial relationships in three dimensions. This approach has been shown to improve engagement, spatial understanding, and overall learning outcomes compared to traditional methods.²⁻⁴ Despite growing interest in VR as a supplemental tool in anatomy education, evidence specifically examining its impact on learners' confidence in using anatomical language remains limited.

This study evaluates whether a structured VR-based anatomy learning experience improves first-year medical students' confidence and understanding of anatomical language compared to unguided VR exposure. Using a mixed-methods design, quantitative changes in self-reported confidence were assessed alongside qualitative learner perceptions to better understand how immersive technology influences anatomical learning, engagement, and spatial reasoning.

Methods

Study Design and Participants: This mixed-methods study was conducted during a prematriculation anatomy bootcamp at Lincoln Memorial University–DeBusk College of Osteopathic Medicine. Seventeen first-year medical students volunteered to participate and completed both pre- and post-intervention assessments. Participants were divided into two groups: a control group (n = 9) and a module group (n = 8). (LMU IRB Approval #2025/04/15)

Intervention: The control group received 20 minutes of unguided exposure to a VR anatomy environment with minimal instructional direction using headsets and *Perspectus VR*⁵ software. The experimental group completed structured VR learning modules covering gastrointestinal anatomy, shoulder anatomy, and cerebrospinal fluid flow. These modules emphasized anatomical terminology, spatial relationships, and contextual identification of structures.

Quantitative Measures and Analysis: Participants completed pre- and post-intervention surveys containing six Likert-scale items assessing confidence and comprehension of anatomical language, including terminology understanding, interpretation of directional/relational language, spatial description, clinical application, terminology integration with structures, and independent learning confidence. Due to small sample size and ordinal data, non-parametric tests were used: Mann–Whitney U tests for between-group comparisons and Wilcoxon signed-rank tests for within-group pre–post changes. Combined cohort analyses evaluated overall intervention effects. Statistical significance was set at $\alpha < 0.05$ and all tests were completed in SPSS v31⁶.

Qualitative Measures and Analysis: Optional open-ended responses were collected before and after the intervention and analyzed using inductive thematic analysis, including familiarization, open coding, theme development, and investigator cross-validation.

Mixed-Methods Integration: Quantitative and qualitative findings were integrated during interpretation to contextualize statistical trends with learner experiences, particularly regarding spatial understanding, engagement, and learner autonomy.

Results



Figure 1. Representative images from *Perspectus VR* modules demonstrating user manipulation of three-dimensional brain and shoulder structures to enhance spatial understanding.

| Quantitative Analysis | | | | | | | |
|-------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|---|
| Comparison | Question 1: | Question 2: | Question 3: | Question 4: | Question 5: | Question 6: | Interpretation |
| Pre: Control Vs Experimental | 0.526 | 0.680 | 0.630 | 0.385 | 0.141 | 0.495 | No significant differences at baseline |
| Post: Control Vs Experimental | 0.299 | 0.715 | 0.896 | 1.000 | 0.778 | 0.153 | No significant differences after intervention |
| Control: Pre Vs Post | 0.010* | 0.017* | 0.006* | 0.011* | 0.042* | 0.201 | Significant improvement in Q1-5 only |
| Experimental: Pre Vs Post | 0.016* | 0.017* | 0.010* | 0.010* | 0.010* | 0.024* | Significant improvements across all questions |
| Combined: Pre Vs Post | <0.001* | <0.001* | <0.001* | <0.001* | <0.001* | 0.028* | Significant improvements across all questions |

Figure 2. Quantitative analysis of pre- and post-intervention survey responses. All values are p-values. * indicates statistical significance. No between-group differences at baseline or post-intervention. The VR group demonstrated significant improvements across all questions, while the control group showed limited gains; combined analysis revealed overall significant improvement.

| Qualitative Analysis | | | |
|----------------------|---|--|--|
| Phase | Emergent Themes | Representative Quotes | Interpretation |
| Pre- Intervention | <ul style="list-style-type: none"> Limited prior exposure to anatomy Reliance on memorization Confusion with terminology Need for repetition | <ul style="list-style-type: none"> "No prior experience." "I memorized then forgot rather than commit to memory." "Hearing a bunch of directional terms out of context is just confusing." | Students entered study with minimal anatomy background and difficulty connecting terminology to spatial concepts. |
| Post- Intervention | <ul style="list-style-type: none"> Enhanced visualization Increased engagement and enjoyment Desire for curricular integration Minor usability challenges | <ul style="list-style-type: none"> "Even using VR for that short amount of time was super helpful in understanding the anatomy and spatial relationships." "I truly enjoyed it and think it should be implemented as a tool for students." | Virtual Reality promoted 3D comprehension, engagement, and motivation; students viewed it as a valuable learning tool despite brief adjustments to controls. |

Figure 3. Qualitative thematic analysis of pre- and post-intervention responses. Pre-intervention themes reflected limited prior exposure, reliance on memorization, and difficulty with anatomical terminology. Post-intervention responses demonstrated improved spatial understanding, increased engagement, and positive perceptions of VR as a learning tool despite minor usability challenges.

Discussion

This study evaluated the impact of virtual reality–enhanced anatomy instruction on first-year medical students' confidence and understanding of anatomical language. Overall, both traditional exposure and structured VR modules were associated with significant improvements in students' self-reported comprehension, suggesting that early immersive anatomy experiences—regardless of format—may strengthen foundational anatomical literacy.

The absence of significant post-intervention differences between groups indicates that both learning approaches were effective in improving perceived competence. However, several findings suggest that VR modules may provide targeted educational advantages. Only students who completed structured VR modules demonstrated statistically significant gains in confidence related to independently learning anatomical language. This pattern suggests VR may enhance learner autonomy and self-efficacy, potentially by enabling students to actively explore anatomical relationships rather than passively memorizing terminology.

Qualitative findings reinforce this interpretation. Prior to the intervention, students described limited anatomy exposure, heavy reliance on memorization, and difficulty translating terminology into meaningful spatial understanding. Following VR exposure, students frequently reported improved three-dimensional visualization, clearer comprehension of spatial relationships, and stronger connections between anatomical structures and terminology. These perceptions align with the theoretical advantages of immersive learning environments, which allow learners to manipulate perspectives and interact with structures in ways not possible with static resources.

Additionally, VR was perceived as engaging and enjoyable. Participants expressed interest in broader curricular integration despite minor technical learning curves, suggesting that VR implementation is feasible and well accepted among early learners.

Limitations and Future Directions: The small sample size and reliance on self-reported outcomes limit generalizability. Future studies should include larger cohorts, objective assessments, and longitudinal follow-up to evaluate retention and clinical application, as well as comparisons with traditional anatomy learning methods.

Conclusion

A brief, structured virtual reality (VR) intervention improved first-year medical students' confidence and understanding of anatomical language, particularly in areas of spatial reasoning and terminology integration. While no significant differences were observed between groups, within-group and combined analyses demonstrated meaningful gains, with the VR group showing consistent improvement across all domains. Qualitative findings supported these results, highlighting enhanced visualization, engagement, and perceived learning value. These findings suggest that VR is a promising supplemental tool for anatomical education, particularly in helping students develop anatomy as a functional language rather than relying solely on memorization.

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