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Virtual Reality–Based Spatial Learning of Hemoglobin in Preclinical Medical Biochemistry

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Abstract

Preclinical mastery of protein structure supports later clinical training (hematology, physiology, pharmacology). Virtual reality provides stereoscopic, manipulable 3D visualization that may reduce spatial-conceptual load. Hemoglobin, central to oxygen transport and disorders such as sickle cell disease, offers a clinically anchored model.

We embedded a retrospective, within-session pre/post evaluation in a biochemical sciences course at Weill Cornell Medicine-Qatar. Students used Nanome on standalone headsets to explore hemoglobin's quaternary structure, heme coordination, and the T?R transition (preloaded PDB models included deoxyhemoglobin 1A3N). Primary outcome: conceptual understanding via three 1-10 Likert items. Secondary outcomes: engagement, perceived usefulness versus 2D, and qualitative reflections. Surveys were anonymous and paper-based; paired comparisons with thematic analysis were planned.

Fifty-four students participated. The proportion rating 9-10 rose from 15% to 63% for perceived usefulness (Q1), 9% to 66.7% for spatial understanding (Q2), and 5% to 70.5% for structural understanding (Q3). Endorsement was near-universal: 54/54 said VR improved understanding of biochemistry concepts and aided molecular learning beyond mental 3D imagination; 53/54 would join future sessions; 54/54 (would recommend VR. Prior VR use: 42/54; among them 35/42 rated this a "better" experience. Reported discomfort: 35 "no", 13 "at beginning", 6 "yes." Qualitative themes highlighted clearer subunit discrimination, heme-site clarity, and collaborative discussion.

Immersive virtual reality is a feasible, high acceptability complement to 2D resources in preclinical medical education. Embedded implementation, anonymous paper capture, and straightforward analyses support scalability. Next steps include incorporating delayed retention testing and expanding immersive modules across biochemical and preclinical topics.

Keywords: Virtual Reality; Preclinical Medical Education; Hemoglobin and Protein Structure;

Immersive Learning; Spatial Cognition; Clinical Models