Impact of 3D-printed molecular models on teaching – a compensatory research study

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Introduction

A strong understanding of molecular structure is key for mastering structure–function concepts in life-sciences and is based heavily on visualization of biomolecules. Object-based learning stands out as an approach that gives students a tangible way to view and manipulate physical structures in three dimensions, strengthening learning by providing a more complete sensorial experience and challenging students to engage with and interrogate the object. In this work, atomically accurate physical models of macromolecules generated from Protein Data Bank (PDB) data have been fabricated using cheap consumer grade 3D printers and integrated into two lectures. The impact of the models on students' ability of overcome some common misunderstandings related to proteins and DNA structures was evaluated in a randomized controlled experiment using a compensatory research design.

Methods

Models design and printing. Structural data was downloaded from RSCB PDB, rendered in USCF ChimeraX for improved printability and saved as .stl files. Models were sliced in Prusa Slicer and printed on cheap fused deposition modeling (FDM) printers (Creality Ender 5). All models, including printing and post-processing instructions were deposited to NIH 3D Print Exchange server and are available under a CC BY license.

Participants. Second year cohort on undergraduate degree programme in Biochemistry from Alexandru Ioan Cuza University, Iași, Romania tacking the Molecular Biology course. From a total cohort of 58 students, 48 students opted into the study and **39** finished all activities. At the beginning of the study, participants were assigned randomly to two groups labeled here Group A and Group B.

Intervention. The 3D printed models were used during lectures in front of the students, handed to students which were allowed 3-5 minutes to handle them individually or in small groups. While students were handling the models, animations and movies of the same models were projected on an overhead screen and the educator offered instructions on key aspects. In the **control condition**, same animations and movies were projected, same instructions were provided, but were not accompanied by any physical models.

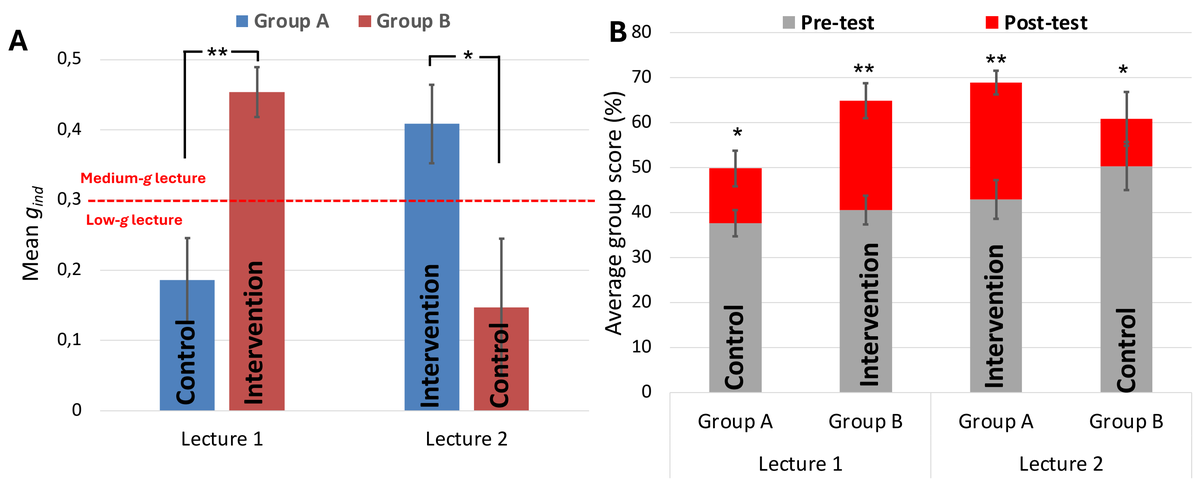
Implementation

	Week 1	Week 2			Week 3			Week 4 - Week 7
Group A	Announcement Recruitment Consent	Pre-test 1	Lecture 1 - Proteins Structure	Post-test 1	Pre-test 2	Lecture 2 - DNA structure	Post-test 2	Intervention and Feedback form
Group B		2 days before lecture, 30 minutes, 13 questions	**Intervention**	2 days after lecture, 30 minutes, 13 questions	2 days before lecture, 30 minutes, 10 questions	**Intervention**	2 days after lecture, 30 minutes, 10 questions	
			No intervention			No intervention		

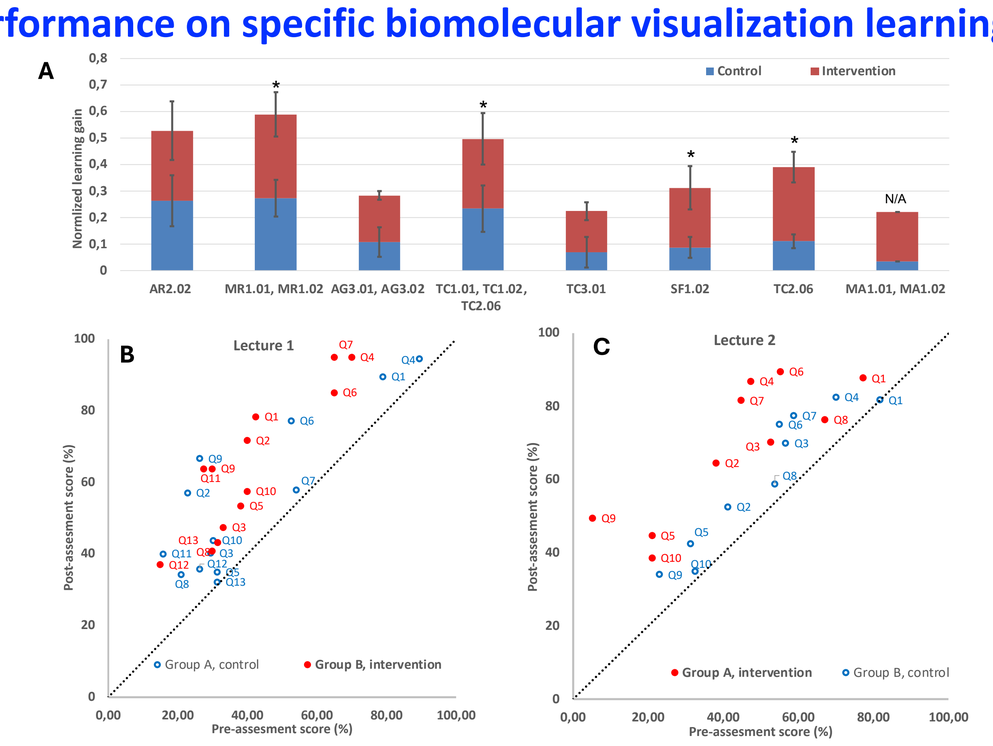
Ethical considerations. The project was approved by the ethics committee at Alexandru Ioan Cuza University of Iași (no 186/29.01.2024).

Results

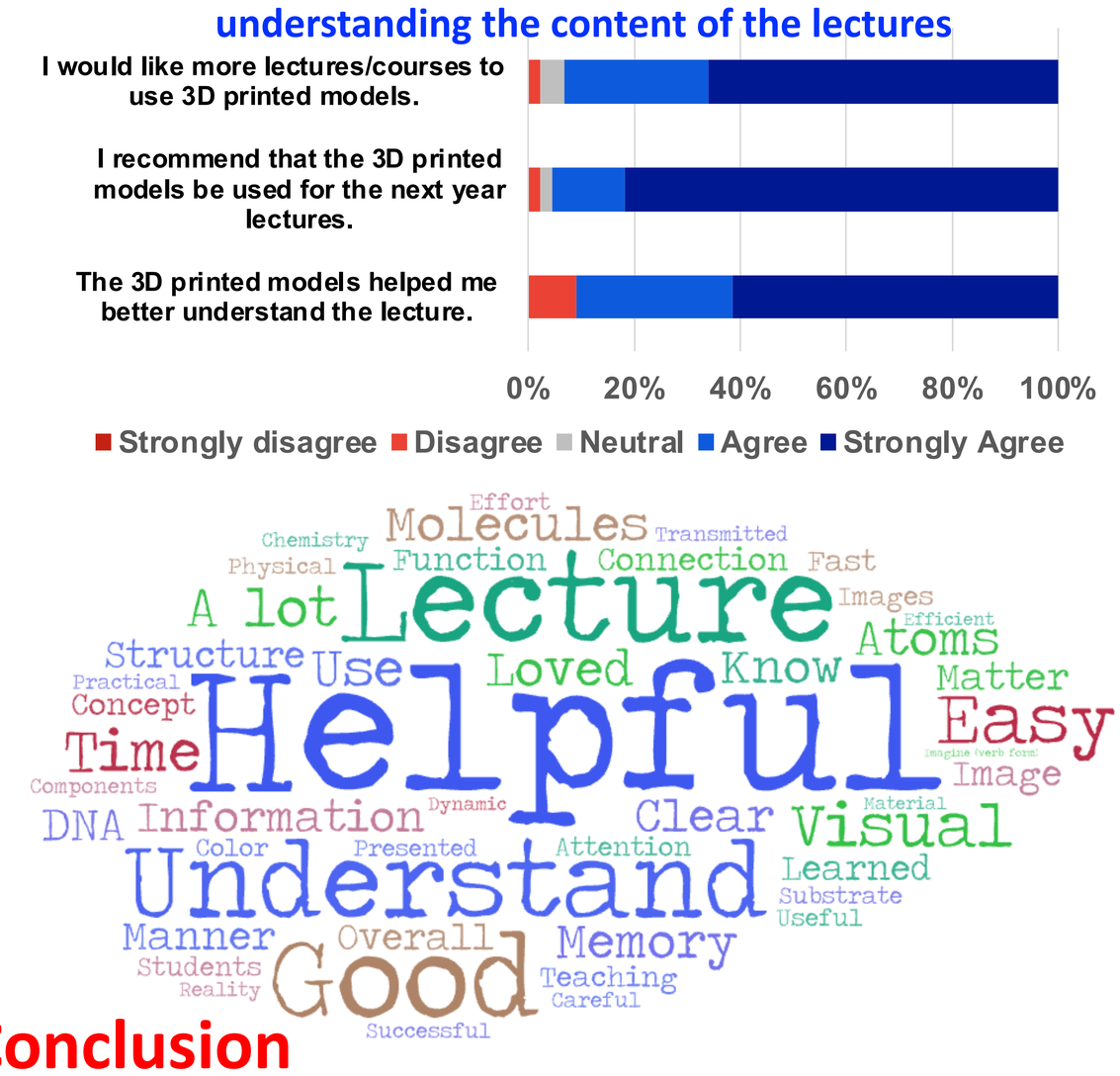
Handling 3D printed molecular models improved the average class learning gain



Usage of 3D printed molecular models significantly improved student performance on specific biomolecular visualization learning goals



Students appreciate the 3D-printed models as helpful for better understanding the content of the lectures



Conclusion

Presenting the models in the class and only allowing students 3-5 minutes to handle them individually or in small groups was shown to be enough to convert a low-g lecture into a medium-g lecture.

References:

Taber KS (2019) Experimental research into teaching innovations: responding to methodological and ethical challenges. *Stud Sci Educ* **55**, 69–119

Mihasan M (2021) A beginner's guideline for low-cost 3D printing of macromolecules usable for teaching and demonstration. *Biochemistry and Molecular Biology Education*, bmb.21493