The Efficacy of Virtual Reality Teaching Tools

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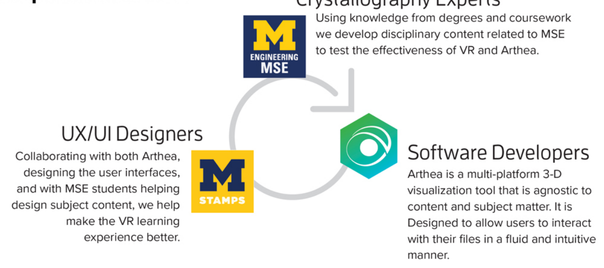
Introduction

Visualization is a key component for student understanding of three dimensional subject matter. Virtual Reality presents a unique opportunity for presenting 3D concepts in a 3D environment. Our research focuses on developing and testing VR tools to teach 3D concepts related to crystal structure. In this work, we examine student attitudes towards using VR tools for learning, and whether using VR representations of crystal structures can improve learning outcomes compared to 2D renderings.

Implementation



Student Have Little Experience With VR

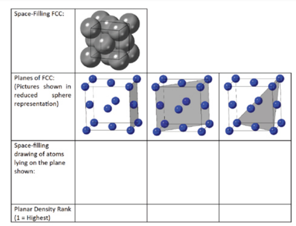
Students were asked to fill out a survey regarding their attitudes towards paper- and VR-based representations used to assist learning of 3D topics. It asked students about their familiarity with VR, and to describe what they liked most and least about using the different representation types (shown below).

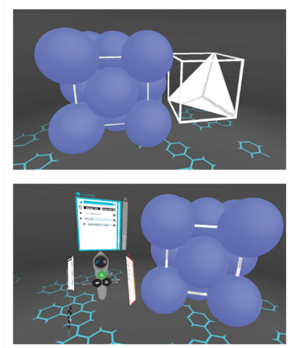
Most	%	Least	%
VR	N=62		N=59
New way to visualize	40.3	Usability	37.3
Interactive	17.7	Physiological effects	27.1
Never	16.1	Equipment/costs/access	18.6
Realistic	9.7	Never for engineering	11.9
Immersive	9.7	Nothing wrong with VR	5.1
Entertaining	6.5		
Paper	N=155		N=142
Ease of use	40.6	Limited	60.6
Assists learning	21.9	Keeping track of resources	21.1
Referenceable	15.5	Boring	9.9
Visualization	11.6	Bad for environment	4.9
Hands on	10.3	Reading	2.1
		Nothing	1.4

49.6% of the respondents have not used VR in any context. The majority of the students who have prior experience with VR have only used it once within the past year (44.7%), and never for a class assignment (99%). However, our survey results also show that students are positively disposed towards using VR-based representations as learning tools in engineering.

Student Learning is Improved

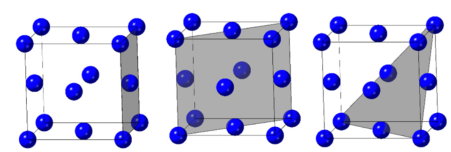
Students in an introductory materials science course (N=152) were given a variety of activities on crystalline structures. The first activity was a worksheet similar to that used in Gentry et al, that students completed individually. Students were provided illustrations of three crystal structures, asked to identify them, sketch the configuration of atoms on the shaded cross-sectional planes, and rank the structures according to the density of atoms in each plane (see below)





Above: Sample problem for the individual crystal structure activity.
Right: Example renderings of the VR environment for this activity.

The next activity was a similar crystal structures worksheet, but this time completed in pairs. A subset of students (N = 23) volunteered to complete the paired activity again using VR-based representations for extra credit.



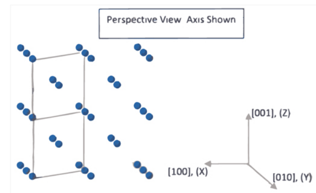
		(100)	(110)	(111)
Individual		52.2	60.9	4.3
Paired Paper	(22 pairs)	52.2	73.9	21.7
Paired VR	(13 pairs)	60.9	65.2	56.5

Comparisons of the correct response rates for the individual worksheet, paired worksheet with 2D renderings, and paired worksheet with illustrations in VR.

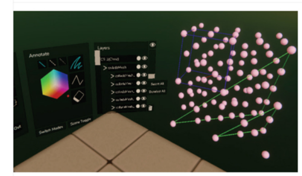
The results suggests that pairing students, regardless of rendering, leads to improvements in the correct response rates. The VR-based activities resulted in higher correct response rates compared to the individual paper-based activities for the responses for the (111) plane

Students Interact Differently in VR

Eight volunteers were compensated to participate in a pilot study. Each was randomly selected to complete an activity about crystal structures on paper or in VR. Audio was recorded as they completed the task. There weren't statistically significant differences found in accuracy between the paper and the VR based responses. However, we found that the participants' responses to the worksheets were different.



Paper-based Rendering



VR-based Rendering

Participants who completed the paper version commented on how they would try to answer the questions from memory, or recalled formulas.

> *I don't think I remember enough of this to answer these questions adequately*

On the other hand, participants who completed the VR version commented more about visualization of the problems.

> *The planes with closest packing are the same, ..., it's just FCC rotated!*

Next Steps

These results show that VR is a promising technology to improve learning outcomes, especially for inherently 3D concepts. Future work will be to increase the number of students using VR, implement a controlled experimental design, and creating additional activities in more complex crystal structures. As we learn how to best implement VR, we can expand to teach more advanced concepts and structures such as extended defects, which are difficult to visualize. Creating tools that more realistically represent structures and allow students to view them dynamically from multiple angles and magnifications may lead to better learning outcomes and deeper intuition. These gains are not limited to concepts within crystallography, but to any discipline that contains concepts with more than two dimensions.

References

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