The Use of Animated Visual Aids in the Education of Undergraduate Engineering Students

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WIP: The Use of Animated Visual Aids in the Education of Undergraduate Engineering Students

Introduction

A common issue in many classes, particularly in materials science courses, is the difficulty students face in visualizing the concepts being explained by the instructor [1,2]. From crystal structures to the movement of dislocations through a lattice, imagining the structure that the educator is trying to convey is by far one of the hardest educational challenges to tackle [3,4]. Every educator has addressed this problem differently, some draw sketches, some use physical models, and some might show a YouTube video. These methods all have limited success and while it may seem like students understand more than they previously did, there are few quantitative studies to show the true effects of these methods [2,4].

Makgato et al. [4], at Tshwane University of Technology, suggested that traditional teaching methods in the Engineering Graphics Design (EGD) course may not be entirely effective, particularly in addressing the identified difficulties faced by student teachers [4]. This assertion is implied through various observations and discussions within the study. For instance, during classroom observations, it was noted that lecturers often relied on abstract teaching approaches, lacking in concrete illustrations, simulations, and practical demonstrations that could enhance student understanding. Additionally, the study highlighted instances where students struggled to grasp sectional drawing concepts due to limited access to drawing models and insufficient explanations from the lecturers. Moreover, the emphasis on memorandums and the absence of tailored explanations to address student queries further indicate the limitations of traditional teaching methods in facilitating effective learning experiences. Overall, these observations suggest a need for more innovative and student-centered teaching approaches in the EGD course to better support student learning and address the identified difficulties [4].

There are many methods to enhance the learning of a student in the classroom. The methods range from visual animated aids and physical demonstrations to augmented reality models that the students can manipulate [5,6,7]. Each type of aid has its advantages and disadvantages, and some students may be more responsive to one type than another. McGrath et al., at the University of Iowa showed that integrating visual learning techniques into education brings many benefits. Students become more interested and engaged, often doing extra work. They also learnt better, showing improvement in their work and grades. Courses with visuals attracted a diverse group of students, including more women and minorities. Visual feedback also helped students quickly understand and correct mistakes. Studio classes were also implemented to encourage active learning, where students were more involved in their education. Furthermore, immersive experiences, combining sights, sounds, and emotions, helped students remember what they learned for longer. Overall, the study concluded that visuals in education made learning more interesting, effective, and inclusive. [6].

Aravinthan et al. [8], at the University of Queensland explored civil engineering courses and showed that the inclusion of animations in engineering courses has shown promising outcomes, indicating significant improvements in both student performance and engagement. In the field of

Public Health Engineering, the use of animations led to a noticeable rise in the number of students achieving higher grades. About 79.4% of students scored above a C grade, compared to 67.3% in previous years. Additionally, there was a decrease in the percentage of students failing the course, dropping from 16.3% to 11.7%. Feedback from students highlighted their increased interest and involvement with course material, especially praising the helpfulness of animations in understanding concepts. Similarly, in Geology and Geomechanics, animations were effective in improving learning outcomes, particularly in challenging topics. The addition of interactive quizzes and animations resulted in better comprehension and grades in assessments. Overall, incorporating animations positively impacted student learning experiences and achievements in both courses. [8].

Therefore, the solution that this paper focuses on is the development of animated visual aids for the subject of Materials science, specifically in the topic of strain hardening which involves strengthening metals through plastic deformation. The strengthening mechanism is directly related to the movement of dislocations within a metal. Investigations into previously administered exams and quizzes highlighted the fact that students are not able to make the connection between plastic deformation, dislocation movement, and metal strengthening. Students struggled to understand how dislocations interact and how they affect the metal structure (crystal lattice) on a micro-scale. The link between understanding how the movement of dislocations alters the mechanical properties of the metal is the focal point of the study. The understanding of this concept not only makes sure that the students understand the specific idea of how dislocations move but it also ensures that the students understand that dislocations are a driving force of many material properties. The link between how each dislocation moves and why it moves and the way that dislocations interact is all part of this understanding that students must attain. This is why visual aids seemed to be a necessity to enhance learning in the classroom.

Methods

Initially, a storyboard was created that expressed a simple but comprehensive storyline that explained the role of dislocations in the process of strain hardening. The purpose of this storyboard was to organize the effort of animating and to make sure students can easily follow the main storyline and that it is closely linked to the content covered in the lectures. In addition to this, the

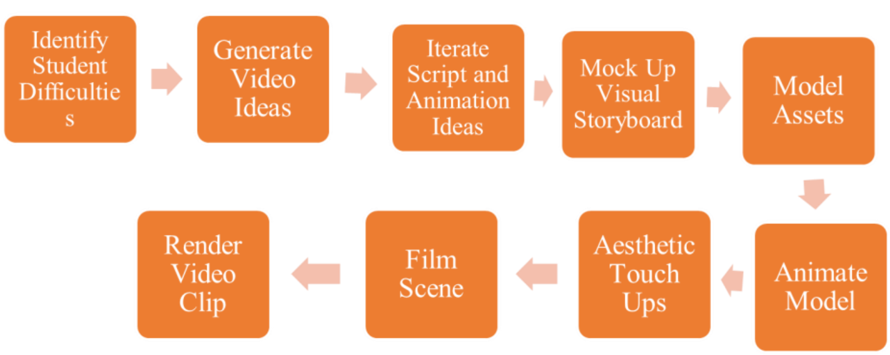

Figure 1: Plan for the current and future of the project

storyboard outlines the figures and animations that will need to be developed such that the project is done comprehensively as shown in **Figure (1)**.

The first step to producing an animation is selecting the tool that will be used to make the idea come to life. Since the animation was going to be made by undergraduate students with little to no prior experience, this selection had to be catered towards ease of use and animating prowess. The three main contenders for the animation software were Maya, Houdini, and Blender.

Each of the software had their respective strengths and weaknesses and all three software were explored extensively by the students to judge which one they preferred to use. Maya has been the industry standard in animation for a long time and hence has many plugins and resources to aid in the animation process. In addition to this, Maya is a very powerful animation software in general giving the user many tools to work with. However, since Maya has been around for so long the software has become reliant on third-party plugins to achieve its full potential. Furthermore, Maya is more of a modeling software than an animation one which didn't quite fit the scope of the project that was desired. Houdini is a very powerful software that is deeply rooted in the VFX industry and is highly utilized in the movie-making industry. Houdini is also extremely complicated and requires an experienced eye to fully be able to master its controls and tools. Blender is a newer software that has emerged on the scene recently, it is made for the more casual animator as opposed to industry veterans. Blender is a free software that has easy-to-use tools for beginners with decent animating power. The drawback of Blender is that the controls are not as optimized as one would hope, leading to some difficulty in the learning process. This caused lots of difficulty with the modeling of various aspects of the lattice structure since the software made the modeling process quite slow and complicated producing the model shown in **Figure (1)**. With this particular challenge, it was found that the 3D models could be made in external software such as SolidWorks and that the model could then be imported into Blender. This saved a lot of time and effort as the undergraduate students were much more familiar with modeling in Solidworks than in Blender as can be seen in **Figures (2 and 3)**.

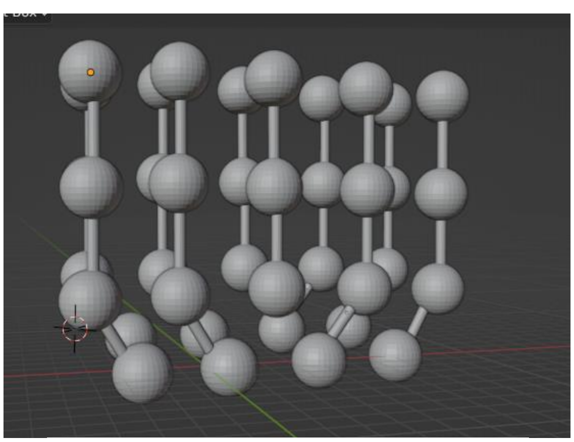

Figure 2: Initial model made in Blender

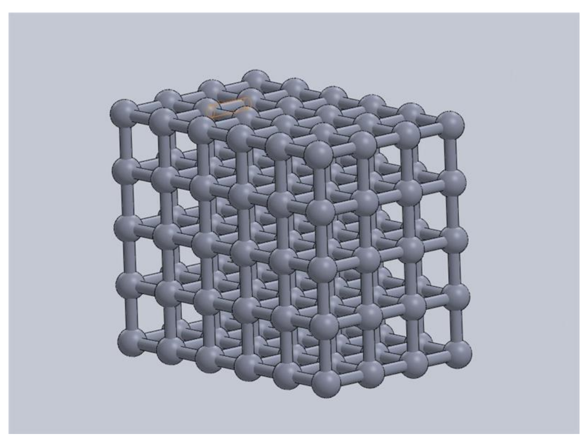

Figure 3: Secondary model made in SolidWorks

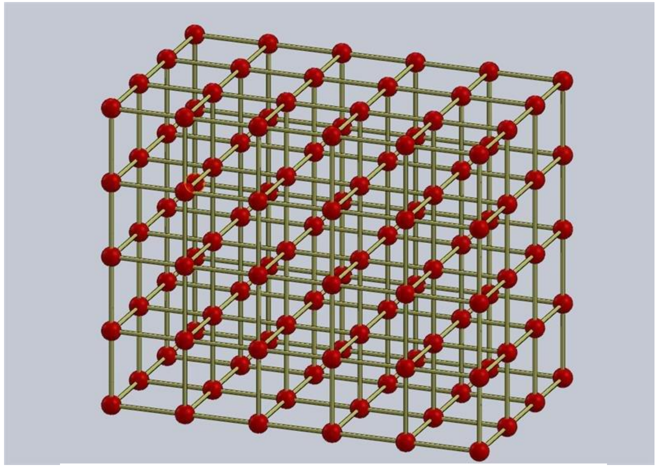

Figure 4: Final lattice made in SolidWorks

With this new development, the production rate of the animations increased and was on track with what was expected. The models created using SolidWorks made animating a lot easier. However, the animation part itself was challenging for undergraduate students due to the need to animate each link and atom individually. This was a very time-consuming process that forced a reduction of the scope in the expected year of the project. The newer scope focused on making a solo animation that was not accompanied by any commentary or description that can be used as a visual aid in a classroom.

Due to the time taken to develop the animations by the undergraduate students, the focus was shifted away from learning how to make the animation and instead, the animation was outsourced. The focus of the undergraduate students was then altered to learn how to communicate technical and scientific knowledge to the animators with no engineering and materials science background. This proved to be a large undertaking as the animators had little to no understanding or knowledge about the idea of dislocations or how they move. The students gained a lot of experience in handling the animators and in turn, deepened their understanding of the topic of dislocations as they navigated the challenges of communicating with the animators. The only thing left was to test the effectiveness of the animation on the class of students studying the topic.

Figure 5: Shot showing strain hardening from outsourced video

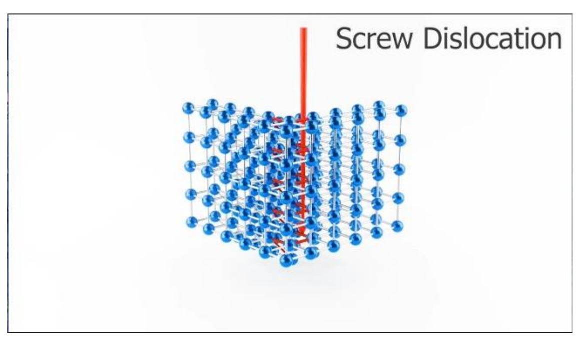

Figure 6: Shot of screw dislocation from outsourced video

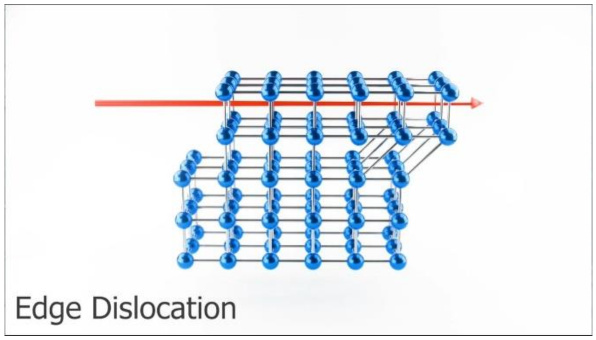

Figure 7: Shot of edge dislocation from outsourced video

Results

The methods selected to assess the understanding of the students with respect to their understanding of the content are preliminary and post-animation exposure quizzes. The purpose of this is to provide quantitative data to show the effect of the animation on the understanding of the students. The preliminary quiz served as a baseline test to evaluate the knowledge of the students in terms of the general understanding of the concepts presented in previous introductory materials science classes on the topic of dislocations and material properties. The same quiz will then be administered after the students watch the animation. This will give an accurate idea of the learning gains that were achieved by the students because of the exposure to the animation and test the effectiveness of the animation in improving students understanding of the topic.

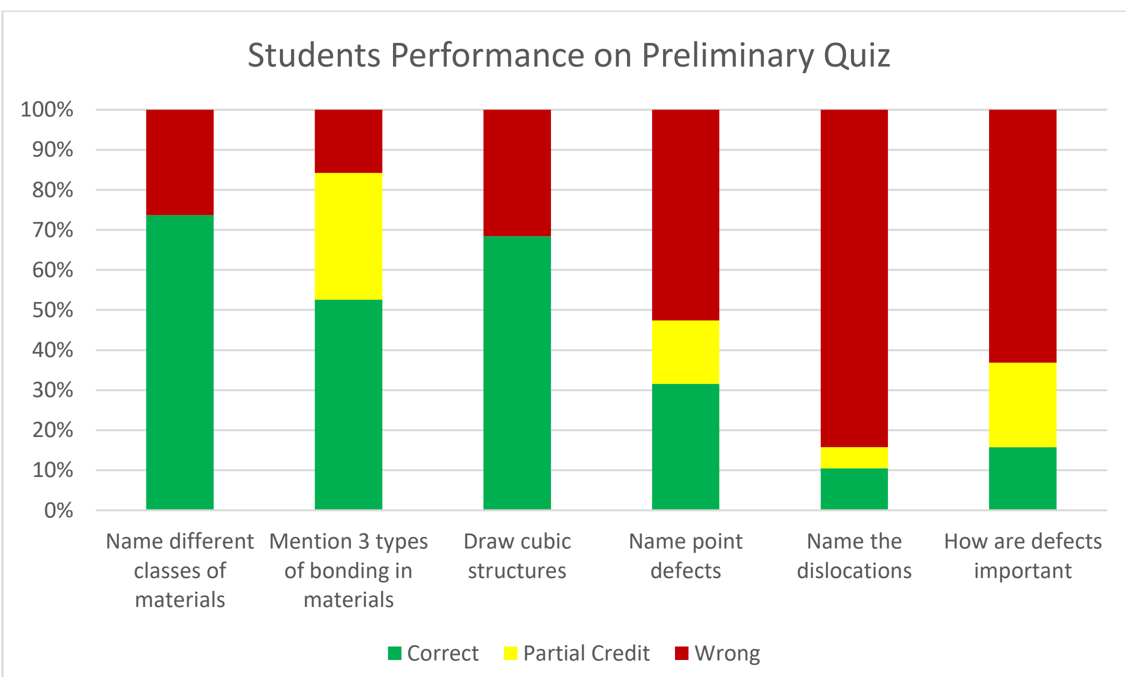

Figure 8: Preliminary Quiz Results

As shown in **Figure 8** the question that the students struggled the most with was the one where the dislocations had to be identified with so much as 85% of the class getting the question completely wrong or leaving it blank. This is interesting because other visualization questions where the students had to draw a cubic structure were answered with around 70% getting the question correct. This shows that the students faced incredible difficulty with the identification and retention of the shape of an edge and screw dislocation from the content in class while visualizing a simple cube that is a common shape was easily visualized. Therefore, the results of the quiz highlighted that the classical method used in class through the use of lecture slides and explanation/description was not very effective in explaining the concept of dislocations across to the students.

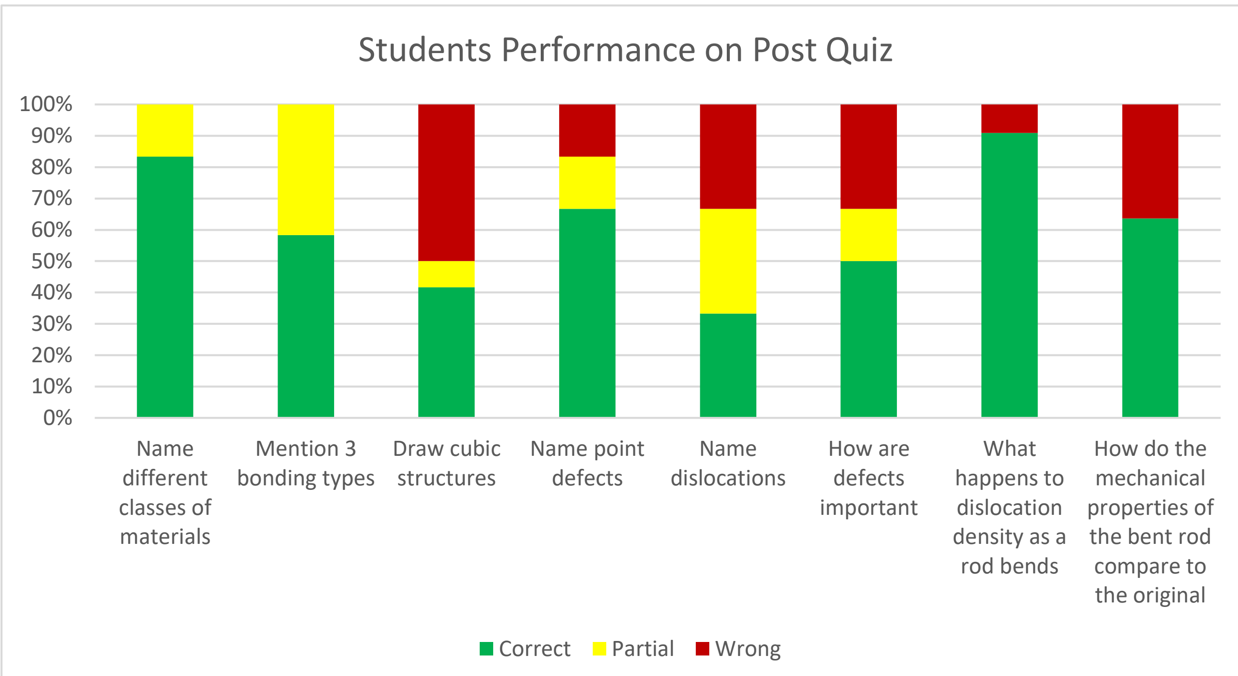

Figure 9: Post Quiz Results

In the assessment of student performance on naming dislocations, there was a notable improvement between the preliminary and post-quizzes. Initially, only about 17% of the responses were correct with a high of 83% incorrect, indicating a significant gap in understanding. By the time of the post-quiz, correct responses had impressively increased to 60%, and incorrect responses had decreased to 30 %. This overall improvement reflects positively on the effectiveness of the educational video applied between the assessments, particularly in enhancing the understanding of dislocations in materials science.

Conclusions

In conclusion, this paper highlights the significance of addressing the challenges students face in visualizing complex concepts in materials science education, particularly pertaining to dislocations and their influence on material properties. The development of animated visual aids emerged as a promising solution to enhance understanding and engagement in the classroom setting.

Through meticulous planning and collaboration, the animation project progressed, albeit with challenges such as software selection and animation complexity. Outsourcing animation production enabled students to focus on refining their communication skills while deepening their understanding of the subject matter. Preliminary assessment results underscore the limitations of traditional teaching methods, emphasizing the need for innovative approaches to enhance learning outcomes.

As we proceed with the project, future steps will involve administering post-animation exposure quizzes to gauge the effectiveness of the animated visual aid. Additionally, considering the evolving landscape of educational technology, we propose exploring augmented reality as a potential next step. Augmented reality offers immersive experiences that can further enhance students' comprehension and retention of complex material science concepts.

In summary, the development of animated visual aids represents a step towards addressing the visualization challenges in materials science education. By leveraging emerging technologies and continuous assessment, we aim to foster a deeper understanding of dislocations and their role in material behavior, ultimately enriching the learning experience for students.

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