REFLECTIONS ON PRACTICE

Going Beyond PowerPoint: Using 3D Printed Medical Device Prototypes to Promote 'Tactile' and 'Visual' Learning

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ABSTRACT

The purpose of this paper is to identify whether the use of 3D-printed medical device models and prototypes are beneficial in an educational setting to enable engineering students to acquire a better understanding of a specific subject or concept. A questionnaire was used to determine whether this approach is effective, novel and better than conventional teaching techniques such as PowerPoint. The responses obtained were analysed and elaborated on, based on the current usage of 3D printing as an educational tool in different pedagogical environments. The findings show positive effectiveness of using such teaching tools such as 3D printed models and that they facilitated visual, tactile and interactive learning.

Keywords: Visual learning, active learning, technology-enhanced learning, TEL, 3D printing, PowerPoint

INTRODUCTION

Due to the rapidly changing technology, teaching with the use of up-to-date tools and knowledge can be very challenging (Lara-Prieto et al., 2015). With the rising interest in mass-customised and personalised products in today's society, 3D printing or rapid prototyping (RP) has been much sought after from diverse stakeholders in the marketplace. RP is a technique used to create 3D-printed objects using computer-aided design parts utilising additive manufacturing (AM) (Kuang-Hua, 2015). This emergence of manufacturing and 3D printing technologies offers opportunities for educators to initiate new teaching practices in a range of subjects and educational settings. There are numerous examples of 3D printing being used to enhance student learning in schools and tertiary educational institutions, particularly in a medical setting. However, not many studies have looked into how this strategy may be implemented in Engineering to enhance long-term student learning, or how this approach can help explain complicated yet vital concepts which are difficult to comprehend visually using 2D PowerPoint presentations alone.

This Reflection focuses on the author's teaching experience of using a 3D-printed hip implant prototype to explain the mechanism of the wear of articulating surfaces in patients who have undergone total hip arthroplasty (THA) surgery. There are existing papers on using 3D printing to teach gross anatomy (Garas et al., 2018), but there is little in the literature on using this 3D printing technology as a teaching tool to describe and explain such complex engineering mechanisms.

The usage of 3D printing as an educational tool serves as an alternative teaching technique that emphasises the visual aspect of learning as compared to PowerPoint slides, which only offers 2D visual representation of objects. This technique leverages on its ability to provide 3D visualisation, which is important for students to build an accurate mental schema of a certain object or mechanism. In this Reflection, our objective is to identify the effectiveness of 3D-printed models and prototypes in education.

METHODS

This study involved 82 participants taking the module BN3301 "Introduction to Biomaterials". Students voluntarily filled up a questionnaire consisting of two parts: fifteen 5-point Likert scale choice questions (from 1= "Strongly Disagree" to 5= "Strongly Agree"), and eight open-ended questions, yielding both quantitative and qualitative data (go to the Appendix for the full questionnaire). Their responses were tabulated into an Excel spreadsheet for analysis. Charts were plotted to determine whether there are statistical differences between the choices in the closed-ended questions. Meanwhile, the open-ended questions were analysed by looking for similarities and patterns between students' responses, such as retrieving the most common words. All 82 participants completed the questionnaire.

RESULTS

Closed-ended questions

The following questionnaire items (Figures 1 to 8) seek to understand whether using appropriate prototypes or models of medical devices during lectures and tutorials have aided students' learning process (refer to the Appendix for the full questionnaire). A positive response was observed from most respondents for all the questions. Most were satisfied and responded favourably regarding the use of this teaching method, highlighting its overall effectiveness on the learning process.

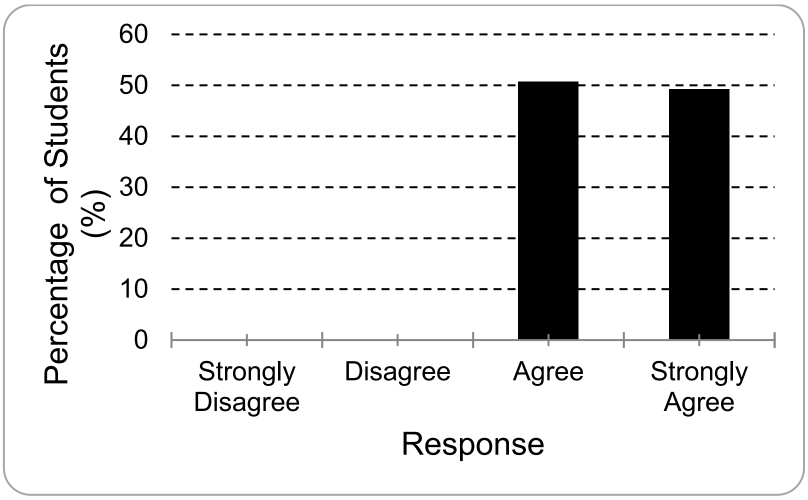

Figure 1. Students' responses to Question 1 "The use of prototypes/models of medical devices during lectures and tutorials aided my learning process".

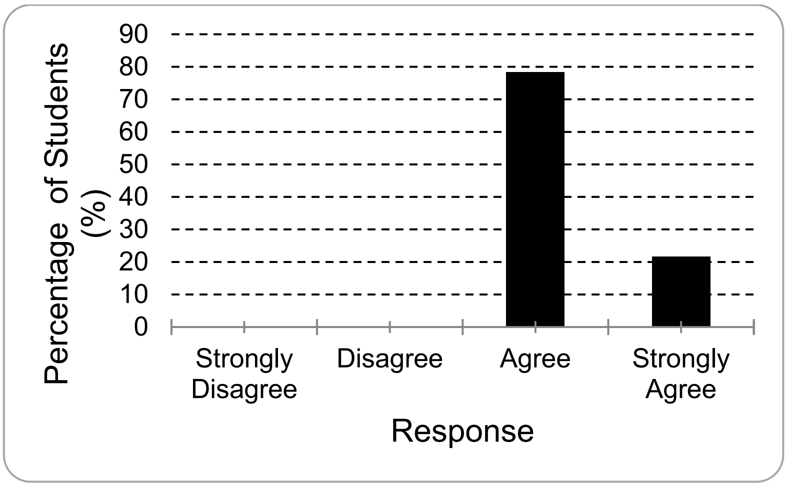

Figure 2. Students' responses to Question 2 "The elaboration and description provided by the lecturer using the real-life prototypes facilitated visual learning".

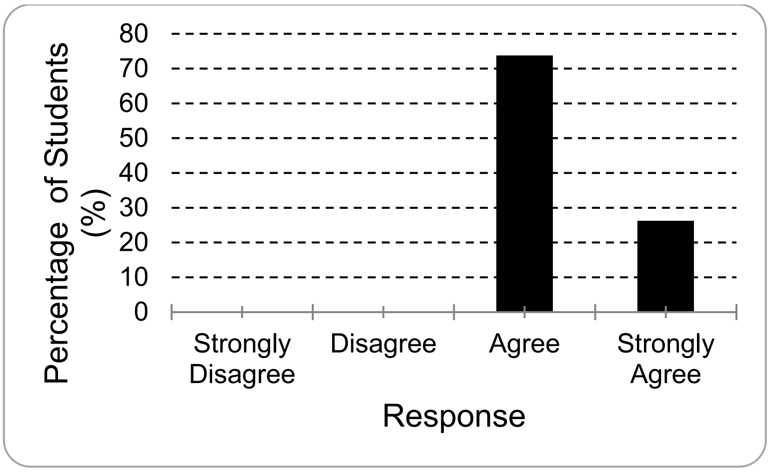

Figure 3. Students' responses to Question 3 "The explanations using the medical device prototypes was helpful in my learning process".

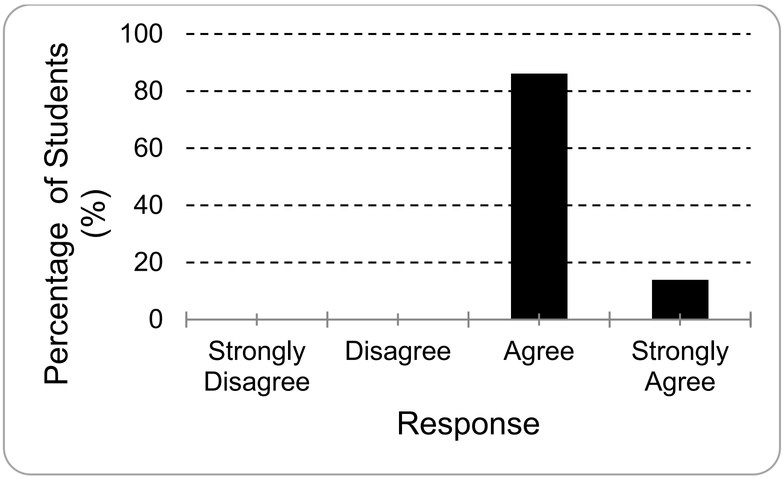

Figure 4. Students' responses to Question 4 "The med device prototypes helped me grasp how such devices are manufactured in a real industrial setting."

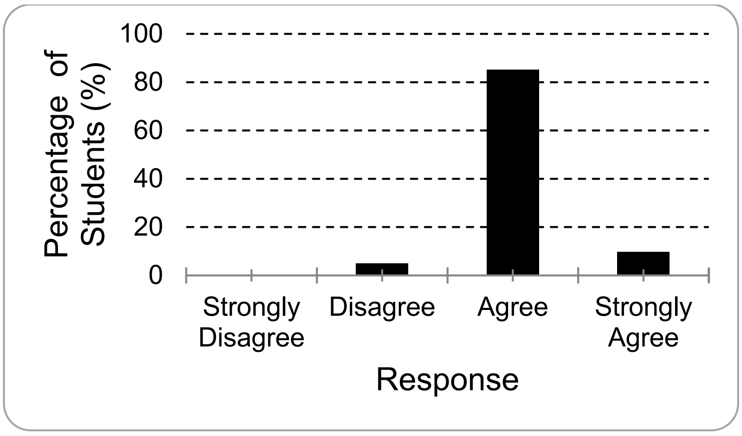

Figure 5. Students' responses to Question 6 "I would recommend continuing using such medical device prototypes to explain critical and fundamental concepts for future cohorts as well".

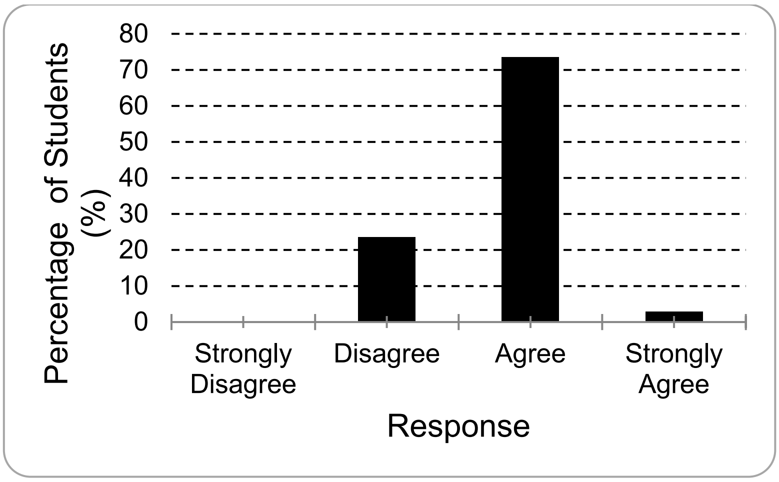

Figure 6. Students' responses to Question 10 "Such prototypes are more helpful in our understanding than PowerPoint slides."

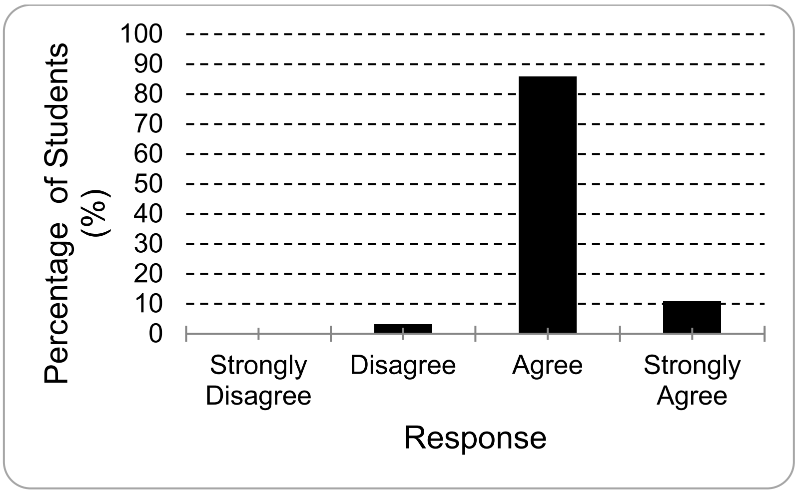

Figure 7. Students' responses to Question 11 "The lecturer has been proficient and very knowledgeable on medical devices and biomaterials and usage of such prototypes."

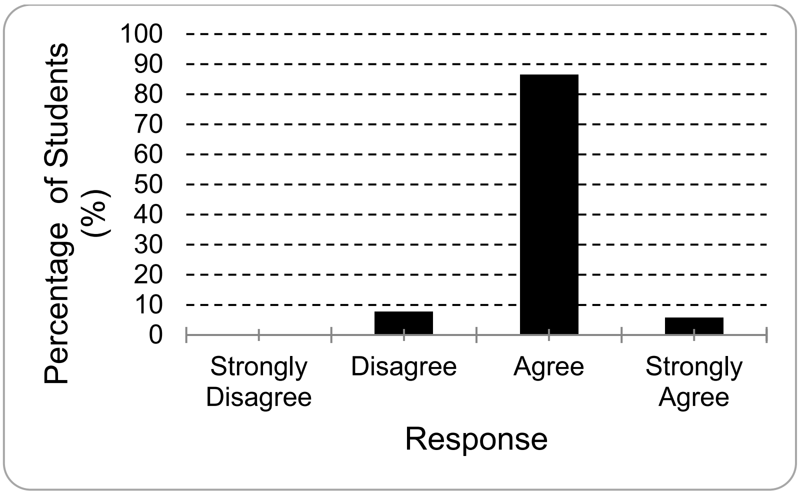

Figure 8. Students' responses to Question 13 "The student learning outcomes and module learning outcomes have been easily achieved using the medical device prototypes/models as a tool to explain critical concepts."

The survey findings indicate that the majority of respondents (>70 %) opined that the use of 3D-printed prototypes aided in their learning process compared to solely using PowerPoint slides. Such 3D printed prototypes allow students to 'visualise' and 'feel' the tangible and close-to-real medical devices. Thus, this may be considered a better teaching-learning strategy in the long run. This approach provides students with more realistic, industry-relevant exposure as well as more hands-on and active learning. This has positive implications for current and future cohorts as they can apply what they learnt to fields such as finite element modelling in the medical industry.

Open-ended questions

The qualitative data was analysed using the coding and categorising method (Wong, 2008). Students' responses were divided into abstract 'codes' by identifying and labelling recurrent words, themes, and concepts. This was done by scanning students' responses for the most commonly words and phrases, as well as words and phrases used with unusual emotions (see Figures 9 and 10).

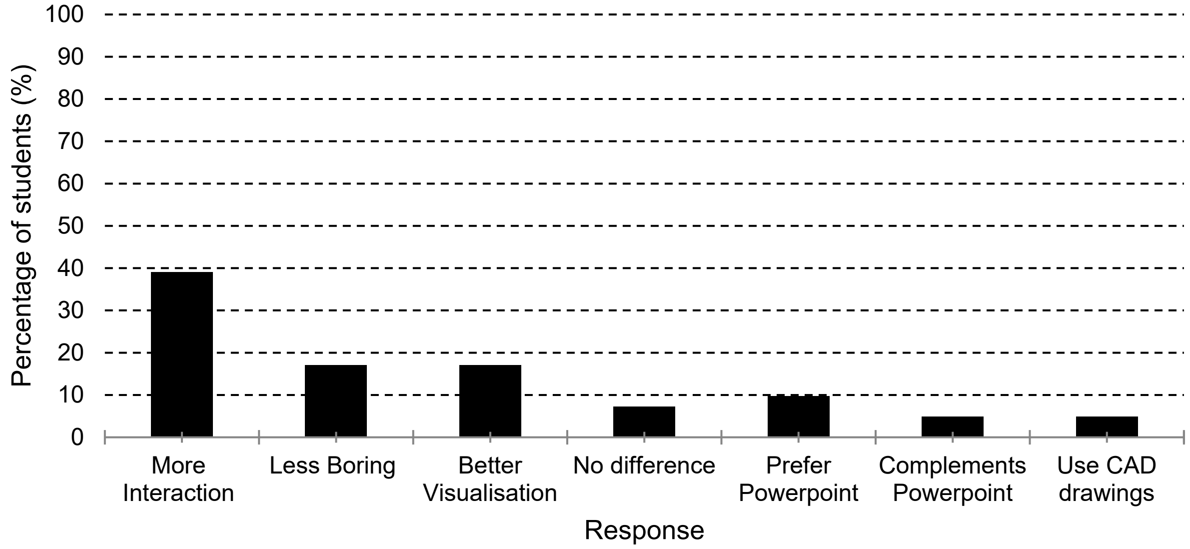

Figure 9. Students' responses to the open-ended question "How is such a novel technique better than PowerPoint slides?"

How is such a novel technique better than PowerPoint slides?

This question compares the effectiveness in teaching when using this technique with PowerPoint slides. This technique of using a 3D-printed prototype as a teaching tool, allows for greater interaction and discussion between students and the lecturer as stated by the majority of respondents (39%) and hence making the lesson less "boring" as told by 17% of them. A minority stated that there was no difference, while 9.7% preferred PowerPoint slides to 3D printed prototypes. Interestingly, roughly 5% of respondents stated that these prototypes and PowerPoint slides complement each other. According to research, it has been shown that interactions during class promotes student retention and achievement (Mohamed & Osama, 2007).

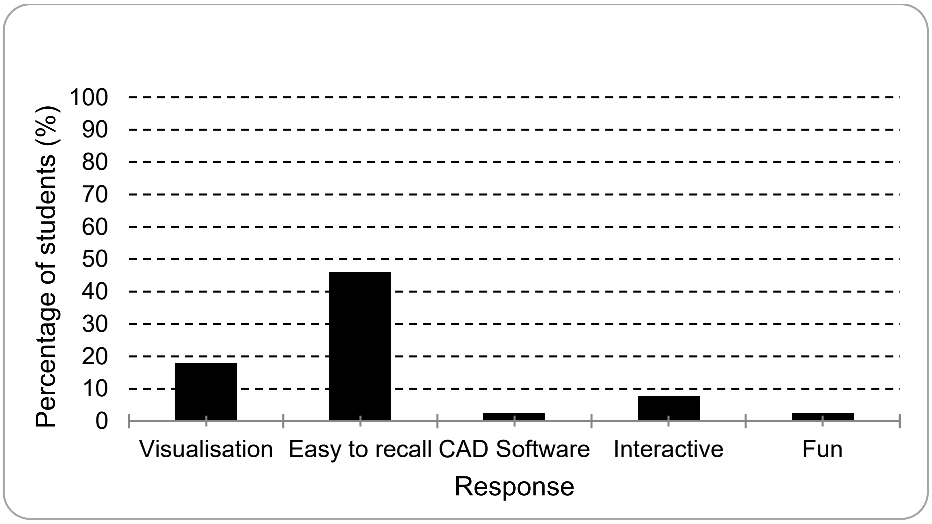

Figure 10. Students' responses to Question 10 "Explain in few sentences how this technique would help in your long-term learning process? Any other suggestions or recommendations?"

This question was intended to investigate how this technique helped in students' long-term learning. Majority of respondents opined that it has been easier for them to recall the information, followed by some stating that it aided their visualisation of the concepts. There are suggestions to improve on this technique, including Finite Element Modelling to emphasise on the load and pressure on the medical device i.e. hip prosthesis, so the students have a better understanding of which areas are more load-bearing and link it to material selection. Another suggestion is planned trips to a medical device company to better understand how the manufacture of such prototypes work.

DISCUSSION

Most students reported gaining a better understanding of the generation of wear particles caused by the articulation between the femoral head and the polyethylene liner attached to the acetabular cup, and also mentioned that without the use of 3D-printed models, it would be more difficult to comprehend the concept. Hence, the following technique used can be considered effective in helping to explain (bio) materials and their corresponding systemic interaction and associated engineering concepts of a complex nature.

Visual learning and tactile learning

The usage of such 3D-printed tools aided in the students' learning process, particularly facilitating the ability to visualise. Learning can be considered a two-step process (Byers, 2001) comprising the receiving and processing of information. The first step involves using external information accessible through the senses, and internal information available through introspection, and selectively selecting the information for further processing. The next step includes inductive or deductive reasoning, memorisation, introspection and interaction with others. The results can then be classified into two categories, namely 'learned' and 'not learned' (Felder & Silverman, 1988). There are various advantages to visual learning and can be considered as a way to create new ways of problem-solving, changing the education teaching style of science and engineering, and promoting a different way of thinking in this field (McGrath & Brown, 2005). Students may also touch and feel the model, and understand its surface characteristics including surface topography, roughness, dimensions and specifications etc. Application of this approach hence facilitates the learning process for a kinaesthetic learner who might prefer an active "hands-on" approach (Pourhosein Gilakjani, 2011).

3D printing versus PowerPoint

Many students mentioned that by having 3D-printed prototypes, their discussions and interactions between peers and their lecture were more active and engaging, making the learning more fun and efficient. This use of active learning has proven to be an effective learning strategy as it has successfully reduced failure rates in science, technology, engineering, and mathematics (STEM) courses (Freeman et al., 2014). The results illustrated that participants in general have acquired enhanced skills while working on 3D printing projects, which involves 3D modelling, technology literacy, problem solving, self-directed learning, perseverance, and critical thinking skills. Most teachers who participated in this study believed that such tools has a great capacity to promote learning in the 21st century (Trust & Maloy, 2017).

The introduction of 3D printing implies that students will become more interactive in the learning process. Using 3D printing, a physical object can be obtained thus, turning an idea into reality. The use of such a method forces the student to learn more skills such as utilising 3D modelling software and design skills. They are able to apply their knowledge gained in mathematics and engineering as well. 3D printed objects allow room for imagination and thus, the learning process becomes more fun (Marco, 2017).

When educators are able to supplement their course-related explanations using relevant 3D-printed prototypes with PowerPoint slides, the students' learning experience can become more meaningful, combining verbal and visual instruction (Mayer & Moreno, 2003), and can help sustain students' attention and focus (Hill et al., 2012).

Comparison between this study and previous studies

In this study, about 74% of respondents preferred using prototypes. This correlates with another study on using 3D models of hearts suffering from congenital heart disease for medical education, wherein 60% of nurses surveyed for the study indicated they agree or strongly agree that 3D models have enabled them to appreciate and understand the knowledge they acquired, thus improving their learning experiences and realising the effect of the usage of 3D models (Biglino et al., 2017). Using 3D models not only invokes fun in learning, but can also make learning more comfortable. Another study also indicated stated that students found it more comfortable handling 3D printed models over wet specimens. (Garas et al., 2018)

REFLECTION

Limitations of the study

It is to be noted that this study is based on a perception survey on student experience which may not necessarily translate to students' academic performance or learning gains. For a better indicator on whether using 3D printed models have aided students' learning, the class can be taught without the use of 3D printed models for a few weeks in the semester, and later incorporating the models into lessons. The lecturer can then compare the before and after effects of 3D printed prototypes. The marks obtained by students may also be compared to ascertain the effectiveness of this pedagogical strategy. Similarly, this year's student cohort who were taught using the models can be compared with the following year's cohort who will be taught without the models. Additionally, the knowledge of each student may not have been entirely homogeneous, which could have affected the stabilisation, validation, and generalisation of the final results.

Challenges involved in implementing 3D printing as an education tool

3D printed models are expensive due to the equipment required, including state-of-the-art 3D printers and printing materials. However, reproducibility and easy alterations of such models and effectiveness of using them to teach in classes will ultimately reduce the time taken and hence, reduce cost in the long run.

In addition, the current 3D printed models may not provide a completely realistic feel due to the difference in softness and ductility of the printing materials compared to actual human organs. As mentioned in the study by Shepherd et al., (2016), the Acrylonitrile Butadiene Styrene (ABS) material used for the mandible model was too soft to allow for tooth elevation and hence failed to provide ample resistance and may be deformed. However, the model still managed to offer teachings of elevator positioning and basic elevation attempt, deeming 3D printed models useful as a teaching tool. Further development of 3D printed models which mimic the haptic characteristics of specific tissue (i.e., nerves, arteries, muscles) should be carried out.

The steep learning curve for learning 3D modelling software may deter students and even teachers from actually creating their own 3D printed models. Another challenge is to design a collaborative learning system and incorporate model sharing to allow students to gain a better understanding of the object's physical and geometrical features, which is tangible and subsequently promotes interactive learning.

CONCLUSION

Modifying the traditional structures of learning is vital to enhance students' learning process, especially in today's era of constantly evolving technology. 3D printing has the potential to create a better learning environment in terms of both interactive learning and visual learning, being able to incorporate various types of learning styles and may also be easily integrated with active learning. However, given that using 3D-printed prototypes alone may not be sufficient to enhance students' learning, it may be integrated with traditional PowerPoint slides for maximum benefits. With the use of 3D printing as a teaching technique, educators can more easily apply the case-based learning approach; it will also allow students to understand possible manufacturing errors due to 3D printing glitches. Thus, using 3D printed models may be of utmost benefit when it comes to promoting students' learning of complex yet vital engineering concepts that may not be accomplished by PowerPoint slides alone.

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REFERENCES

Biglino, G., Capelli, C., Koniordou, D., Robertshaw, D., Leaver, L., Schievano, S., . . . Wray, J. (2017). Use of 3D models of congenital heart disease as an education tool for cardiac nurses. *Congenital Heart Disease, 12*(1), 113-118. http://dx.doi.org/10.1111/chd.12414

Byers, W. (2001). Using questions to promote active learning in lectures. *University Chemistry Education, 5,* 24-30.

Felder, R., & Silverman, L. (1988). Learning and teaching styles in engineering education. *Engineering Education, 78*(7), 674–681. http://dx.doi.org/10.1109/FIE.2008.4720326

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, USA, 111*(23), 8410–8415. http://dx.doi.org/10.1073/pnas.1319030111

Garas, M, Mauro, V., Newland, G., McVay-Doornbusch, K., Hasani, J. (2018). 3D-Printed specimens as a valuable tool in anatomy education: A pilot study. A*nnals of Anatomy - Anatomischer Anzeiger. 219,* 57-64. http://dx.doi.org/10.1016/j.aanat.2018.05.006

Gess-Newsome, J. (2001). The use and impact of explicit instruction about the nature of science and science inquiry in an elementary science methods course. *Science & Education, 11*(1), 55–67. http://dx.doi.org/10.1023/A:1013054823482

Hill, A., Arford, T., Lubitow, A., & Smollin, L. M. (2012). "I'm ambivalent about it": The dilemmas of PowerPoint. *Teaching Sociology, 40*, 242–256. https://doi.org/10.1177%2F0092055X12444071

Kazempour, M. (2014). I can't teach science! A case study of an elementary pre-service teacher's intersection of science experiences. *J Sci Educ Technol, 27*, 412–432.

Kuang-Hua, C. (2015). Chapter 14 - Rapid prototyping 431 beliefs, attitude, and self-efficacy. *International Journal of Environmental & Science Education, 9*, 77–96

Lara-Prieto, V., Bravo-Quirino, E., Rivera-Campa, M., & Gutiérrez-Arredondo, J. (2015). An innovative self-learning approach to 3D printing using multimedia and augmented reality on mobile devices. *Procedia Computer Science*, *75*, 59-65. http://dx.doi.org/10.1016/j.procs.2015.12.206

Marco. (2017). The benefits of 3D printing in education. *3devo Blog* [Blog post]. https://3devo.com/blog/education-benefits-using-3d-printing/.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*(1), 43–52. http://dx.doi.org/10.1207/S15326985EP3801_6

McGrath, M., & Brown, J. (2005). Visual learning for science and engineering. *IEE Computer Graphics and Applications, 25*(5), 56-63. http://dx.doi.org/10.1109/MCG.2005.117

Mohamed, I., & Osama, A. (2007). Impact of interactive learning on knowledge retention. *Human Interface 2007: Human Interface And The Management Of Information. Interacting In Information Environments*, *4558*, 347-355. http://dx.doi.org/10.1007/978-3-540-73354-6_38

Pandey, P., & Zimitat, C. (2007). Medical students' learning of anatomy: memorisation, understanding and visualisation. *Medical Education, 41*(1), 7-14. http://dx.doi.org/10.1111/j.1365-2929.2006.02643.x

Pourhosein Gilakjani, A. (2011). Visual, auditory, kinaesthetic learning styles and their impacts on English Language teaching. *Journal Of Studies In Education*, *2*(1), 104. http://dx.doi.org/10.5296/jse.v2i1.1007

Shepherd, S., Macluskey, M., Napier, A. & Jackson, R. (2016). Oral surgery simulated teaching; 3D model printing. *Oral Surgery, 10*(2), 80-85. http://dx.doi.org/10.1111/ors.12228

Trust, T., & Maloy, R. (2017). Why 3D print? The 21st-century skills students develop while engaging in 3D printing projects. *Computers In The Schools, 34*(4), 253-266. http://dx.doi.org/10.1080/07380569.2017.1384684

Wong, L. P. (2008). Data analysis in qualitative research: A brief guide to using Nvivo. *Malays Fam Physician, 3*(1), 14–20. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4267019/ ■

APPENDIX. QUESTIONNAIRE / FEEDBACK FORM