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VIRTUAL & AUGMENTED REALITY TECHNOLOGY HELP LEARNING OF BIOLOGY IN SECONDARY SCHOOLS

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Abstract

Some Science, Technology, Engineering, and Mathematics (STEM) subjects in secondary schools or high schools, such as biology, physics, or mathematics are considered tough to students. It is due to the lack of tools to visualise details or effects in the learning process, with traditional learning materials of textbooks, blackboards, and static models. The classroom education is evolving with the technology advancements. Development works in three-dimensional (3D) graphics rendering, virtual and augmented reality (VAR) have been reported to provide interactive visualisations for classroom education. Teaching of the subject of biology is one of such examples in the classroom education which could benefit to the emerging technologies with different types of supportive tools. This project is developed to apply virtual and augmented reality technology-enhanced learning (VARTEL) in biology education of secondary schools. Pilot study has been performed with the collaborating secondary schools. The VARTEL technologies developed in the research project can be rolled out to more mainstream schools in Singapore and other countries.

Keywords: Virtual Augmented Reality (VAR), Technology-enhanced Learning, Biology Education.

1 INTRODUCTION

Currently teaching-learning technologies of classroom education have progressed significantly from conventional learning with blackboards, visualizers, and computer-aided projectors [1]. Educators are exploring alternative educational technologies to provide active learning and technology-enhanced learning to students, that show more effectiveness according to research statistics [1]. It encourages the exploration of innovative educational approaches into teaching [2]. In the past years, many research activities have been reported to provide supports to various technology enabled learning in realistic scientific tasks. Some examples of educational technologies include the use of simulations [3], [4], [5]; augmented reality [6], [7], [8]; virtual reality [9], [10], [11], [12]; and modelling tools [13], etc. Different tasks and various learning environments could be created for students at mainstream schools.

There is a strong research base supporting that technology helps the involvement of students in learning tasks. Simulations and active learning are beneficial to learning [1]. Among these emerging educational technologies, virtual reality and augmented reality technologies exhibit promising to improve the efficiency of education [14]. It enables certain learning exercises and teaching activities which are usually difficult to be executed in traditional classroom education [15]. It also provides a safe learning environment for certain applications [16].

In this paper, we share our research works on the virtual and augmented reality technology-enhanced learning (VARTEL). It emphasizes on the use of existing teaching environment, built on top of the available textbooks, without introducing high-end VR/AR equipment and altering classroom setting. The research outcomes show feasibility to develop low-cost solutions assisting students in tackling difficult learning topics of biology subject in secondary schools.

The experiments have been conducted with several collaborating secondary schools in Singapore and internationally. The knowledge sharing has been organised jointly with these collaborating schools, each of which presents the biology topics enabled by VARTEL technologies with relevant case study results. The sharing sessions are informative and very helpful to illustrate the effectiveness of the VARTEL technologies for biology subject learning.

2 METHODOLOGY

The objectives of the research project are to develop VARTEL technologies for in-class and after-class learning of subjects in mainstream schools. The proposed VARTEL solutions can be implemented on mobile platforms, head-mounted display (HMD) or flipped classrooms which are already available in school educations. It would not be substantially altering the existing teaching environment of the classroom setting. The proposed solutions have been evaluated in one of the secondary school subjects, biology.

In biology subject, there are complex structures or dynamic transformations which are tough topics to some students. It is very difficult to visualise its internal structure by static 2D models or pictures. For example, an RNA polymerase shown in purple in Fig. 1 is a complex enzyme at the heart of transcription [17].

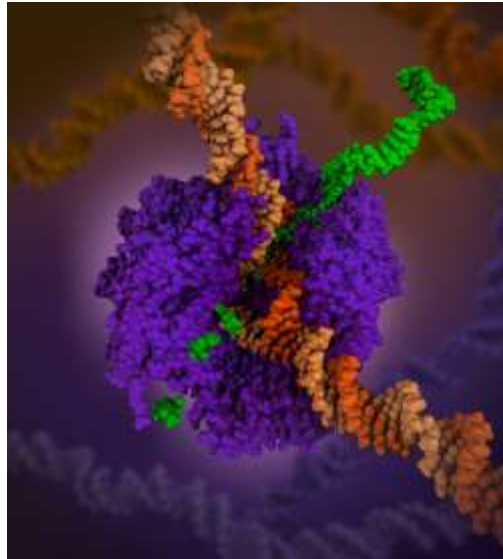


Figure 1: Structure of a complex enzyme (image courtesy of PDB)

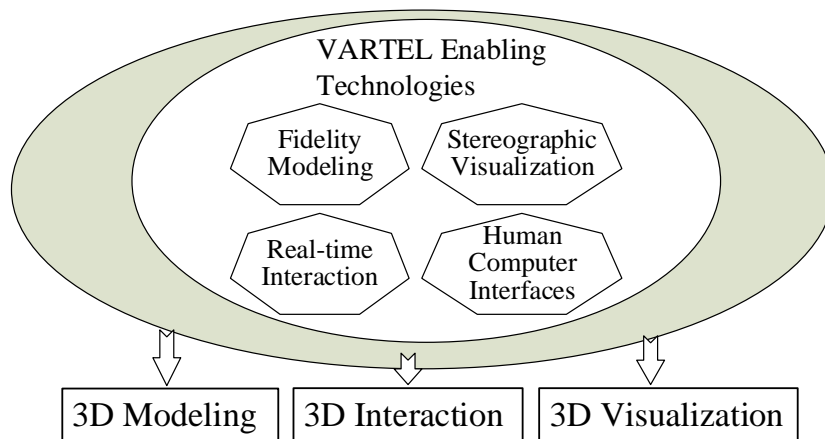


Figure 2: VARTEL enabling technologies for in-depth learning

The theory of in-depth learning paradigms has been proposed in [18]. It creates innovative approaches to engage learners in 3D immersive and interactive learning environments enabled by VARTEL approaches. Some features of VARTEL enabling technologies are shown in Fig. 2, such as fidelity modeling, stereographic visualization, real-time interaction, and human computer interfaces, etc. With the evolutionary of VARTEL technologies, it becomes more feasible and affordable to achieve high performance computation to overlay the reality with virtuality into smart phones, iPhones or tablets. The VARTEL technologies strengthens the 3D processing for developments of in-depth learning paradigms. Although the implementation of VARTEL technologies into education is challenging works, the in-depth learning paradigms are able to achieve advantages of other learning paradigms, including visual learning, simulation-based learning, constructivism learning, and engaged learning [18]. The in-depth learning can transform these learning paradigms into 3D-enabled learning methods.

3 LEARNING EXPERIENCE SHARING

In the project, VARTEL learning applications for biology have been developed for some topics in the biology subject of secondary schools. These VARTEL learning applications are available for both mobile devices (iPhone, iPad, smart phone, Android tablet) and Oculus HMD device to in-depth learning, shown in Fig. 3. The design of in-depth learning contents involves multiple stages from conceptualization, storyboarding, scripting, 3D implementation, trials, to experiments. Teachers can choose the platforms to conduct their teaching according to the curriculum requirements. Efforts have been made in design on the affordability, convenience, interactivity and scientific accuracy of the VARTEL learning applications.

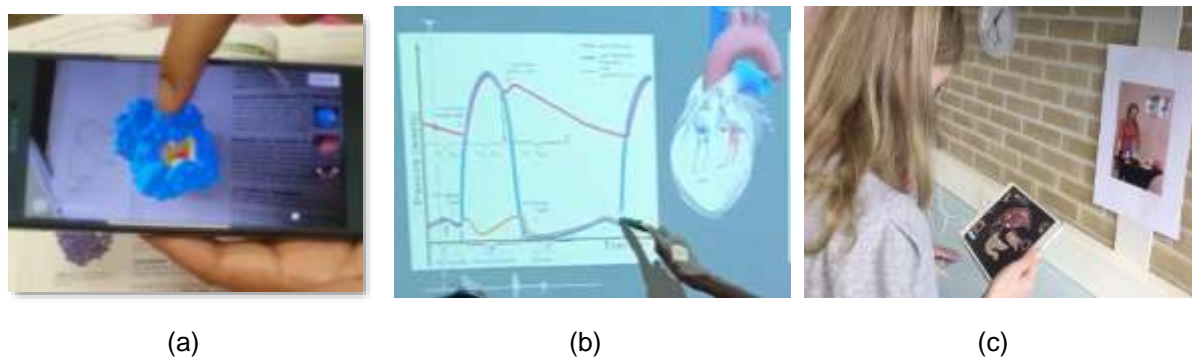


Figure 3. VARTEL Learning Applications for Biology: (a) Enzyme, (b) Cardiac Circulation, (c) Digestive System

In order to evaluate the effectiveness of the VARTEL learning applications in the biology subject, students from collaborating secondary schools in the project have participated in the trial runs. Data of learning outcomes are collected by these collaborating schools. Results are presented and shared during a joint symposium with local educators, researchers, developers, and international collaborators, shown in Fig. 4.



Figure 4. Sharing on VARTEL biology learning by: (a). Christ Church Secondary School (circulation system); (b). Riverside Secondary School (enzymes), (c). Gymnasium Novum School (digestion system)

This project mainly deals with content development for biology education in secondary schools. VARTEL learning applications are developed to assist students' learning in biology. Such learning is traditionally difficult to many students not only locally in Singapore, but also internationally. There are similar challenges in other Science, Technology, Engineering, and Mathematics (STEM) education. Thus the approaches developed in this project are applicable for other subjects in STEM education.

4 CONCLUSIONS

This research project aims to develop VARTEL enabled innovative education technology. One example solution is used for subject of biology learning in secondary schools. It is able to assist students to have a better understanding of difficult concepts, structures or processes in their learning. Such learnings are through cost-effective VARTEL learning applications for immersive real time interactions.

This project provides an avenue for technologists, developers and educators joining efforts to develop innovative educational solutions. The developed VARTEL learning applications enables for learning of

biology without imposing high-end VR systems and without altering existing classroom settings. There are good potentials to adopt the same strategy for VARTEL learning applications in preschools, special needs schools and vocational schools.

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REFERENCES

- [1] L. Coyne, T.A. Merritt, B.L. Parmentier, R.A. Sharpton, J.K. Takemoto, "The past, present, and future of virtual reality in pharmacy education", *American Journal of Pharmaceutical Education*, vol. 83, no. 3, pp. 281-290, 2019.
- [2] I. Horváth, "Evolution of teaching roles and tasks in VR / AR-based education", *IEEE International Conference on Cognitive Infocommunications*, Hungary, 2018.
- [3] Y., Cai, S.L. Goei, W. Trooster, "Simulation and serious games for education". Publisher: Springer Singapore. 2017. <https://doi.org/10.1007/978-981-10-0861-0>.
- [4] N. Rutten, W. van Joolingen, J. Veen, "The learning effects of computer simulations in science education". *Computers & Education*, vol. 58, pp. 136-153, 2012, <https://doi.org/10.1016/j.compedu.2011.07.017>.
- [5] Y Cai, W van Joolingen, K Veermans (Eds.), *Virtual & augmented reality, simulation and serious games for education*, Springer, 2021, ISBN 978-981-16-1361-6, <https://www.springer.com/gp/book/9789811613609>.
- [6] D.F. Tovar, V. Jonker, W. Hürst, "Virtual reality and augmented reality in education, a review". *Educate-it, Universiteit Utrecht*, 2020. https://educate-it.uu.nl/wp-content/uploads/2020/02/20200204_rapportage-literatuurstudie-AR-VR.pdf.
- [7] J. Garzón, J. Pavón, S. Baldiris, "Systematic review and meta-analysis of augmented reality in educational settings". *Virtual Reality*, pp. 1–13, 2019, <https://doi.org/10.1007/s10055-019-00379-9>.
- [8] G. Papanastasiou, A. Drigas, C. Skianis, M. Lytras, E. Papanastasiou, "Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills". *Virtual Reality*, vol. 23, no. 4, pp. 425–436, 2018. <https://doi.org/10.1007/s10055-018-0363-2>.
- [9] R. Ba, Y. Xie, Y. Zhang, SFBM. Taib, Y. Cai, Y, "VR enzymes: an interdisciplinary & international project towards an inquiry-based pedagogy", In Y. Cai, W. van Joolingen, K. Veermans (Eds), *Virtual & Augmented Reality, Simulation and Serious Games for Education*, Springer, 2021, ISBN 978-981-16-1361-6, <https://www.springer.com/gp/book/9789811613609>.
- [10] P. Chiang, J. Zheng, Y. Yu, K. Mak, C.K. Chui, Y. Cai, "A VR simulator for intracardiac intervention". *IEEE Computer Graphics and Applications*, vol. 33, no. 1, pp. 44-57, 2013. <https://doi.org/10.1109/MCG.2012.47>.
- [11] J. Radianti, T.A. Majchrzak, J. Fromm, et al., "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda". *Computers & Education*, vol. 147, 2020. <https://doi.org/10.1016/j.compedu.2019.103778>.
- [12] D. Hamilton, J. McKechnie, E. Edgerton, C. Wilson, "Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design". *Journal of Computers in Education*, 2020. <https://doi.org/10.1007/s40692-020-00169-2>.
- [13] A. Oliveira, F. B. Reza, L. Ni, A. Mohsinah, K. Burgess, L. Guo, "Emerging technologies as pedagogical tools for teaching and learning science: A literature review". *Human Behavior and Emerging Technologies*, vol. 1. Pp. 149-160, 2019. <https://doi.org/10.1002/hbe2.141>.
- [14] M. Garcia-Bonete, M. Jensen, G. Katona, "A practical guide to developing virtual and augmented reality exercises for teaching structural biology", *Biochemistry and Molecular Biology Education*, vol. 47, no. 1, pp. 16-24, 2018.

- [15] M. Krishna, S. Mehta, S. Verma, S. Rane, (2018). "Mixed reality in smart computing education system", *International Conference on Smart Systems and Inventive Technology*, India, 2018.
- [16] A. Bhargava, J.W. Bertrand, A.K. Gramopadhye, K.C. Madathil, S.V. Babu, (2018), "Evaluating multiple levels of an interaction fidelity continuum on performance and learning in near-field training simulations", *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 4, pp. 1418–1427, 2018.
- [17] Maria Voigt, "Award-winning RNA Polymerase Illustration", *Protein Data Bank (PDB)*, 2019, Retrieved from URL: <https://pdb101.rcsb.org/learn/flyers-posters-and-other-resources/poster/award-winning-rna-polymerase-illustration>.
- [18] Y. Cai, C.T. Tay, B.K. Ngo, "Introduction to 3D Immersive & Interactive Learning". In *3D Immersive and Interactive Learning*, Y. Cai (Editor), pp. 1 -16. Springer Singapore, 2012. <https://doi.org/10.1007/978-981-4021-90-6>.