VR Biology, an interdisciplinary and international student project towards an inquiry-based pedagogy

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Abstract

Education in Science, Technology, Engineering, and Mathematics (STEM) is moving towards a more inquiry-based, and creativity stimulating pedagogy. Part of a curriculum based on such pedagogies should be challenging learning activities that engage students in investigation. At the same time, it is imperative that such activities are developed and validated in collaboration with the teachers who should incorporate them in their lesson planning. In this contribution we propose to develop innovative lessons in which such learning activities are embedded via the professional development method of Lesson Study with teachers Biology in (initial) teacher training in the Netherlands in close collaboration with students Mechanical Engineering in Singapore. Within this project both student groups will be using a model-based and VR-enabled solution created through an interdisciplinary and international collaboration between the Netherlands and Singapore.

Keywords: Education in Science, Technology, Engineering, and Mathematics; Virtual Reality ; inquiry-based pedagogy for biology; Lesson Study; model based simulation; models in Biology

Concepts: • **Applied Computing** → Interactive learning environments

1 Introduction

There is a strong research base providing support for the argument that technology enables the involvement of students in realistic scientific tasks, for example by the use of virtual reality (Cai, Tay & Ngo, 2013; Tan & Waugh, 2013; Chow & So, 2012), simulations (Cai & Goei, 2013; Cai, Goei, & Trooster, 2016; Rutten et al., 2012; Shin, 2002; van Joolingen & de Jong, 2003), external data and laboratories (Cai, 2011 & 2013; van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005), as well as modelling tools (Blikstein, Abrahamson, & Wilensky, 2005; Louca & Zacharia, 2011) as to enhance and stimulate deeper learning. These tools allow for the creation of task environments in which realistic and authentic forms of inquiry are possible and within reach of students in secondary education. The beneficial effect of such a realistic context can be linked to the potential of technology to make students' learning experiences more authentic and to increase exposure and interaction. Authenticity is considered important, because more authentic learning experiences may lead to higher cognitive fidelity, which in turn could contribute to better learning outcomes.

A major goal of science education is to build students' skills and attitudes towards Science, Technology, Engineering, and Mathematics (STEM), which include views on the nature of science, the role of scientific representations and models, the processes of scientific inquiry, the creativity involved, as well as views on one's personal attitude and possible career in science or technology. The construction and evaluation of scientific models (Lohner, van Joolingen, Savelsbergh, & van Hout-Wolters, 2005; Minner, Levy, & Century, 2010) provide a means to offer students experience with scientific research, if only on a small scale and to learn about the model-based nature of scientific knowledge, especially about the relation between models and reality.

In STEM, the learning issue can be defined at two levels. At a domain generic level, students need to learn about the nature of scientific knowledge and the role of models as representation of that knowledge in particular. Within the specific domain, e.g. molecular and cell biology, that will be studied in this project, the relation between models and reality is particularly apparent (see below). It is important that students gain insight in both the explanatory powers of models and their limitations in understanding in this domain, and learn to see the added value of using multiple representations and multiple models.

2 Virtual Reality (VR) enabled teaching and learning: collaboration between Singapore and the Netherlands.

VR is widely considered as one of the most viable applications for use in education. A large number of research papers has been published over the last few years discussing VR in education (Freina & Ott, 2015; Merchant et al, 2014; Chow & So, 2011; Cai, 2013). Back in the mid of 2000s, the PI, and co-PIs Dr Sandra Tan and Mr BH Chow started doing VR technology development and education research for curriculum-based learning and teaching on molecular biology in Singapore (Cai, 2011; Cai, 2013) under supervision of professor Yiyu Cai, based at NTU Mechanical Engineering. In 2014 they were invited by professor Sui Lin Goei of Windesheim University of Applied Sciences to showcase their ideas on teaching and learning molecular biology using a VR-enabled solution in a Dutch National Conference. At that time professor Goei was a visiting professor at the National Institute of Education of NTU. They met professor Van Joolingen from Utrecht University and the Singapore team and the Dutch team explored potential

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collaboration in the area of Model-based and VR-enabled teaching and learning. This interdisciplinary and international project, in which students on both end of the pond will collaborate in developing VR-enabled solutions (Singapore students) to be used in innovative lessons for molecular biology (Dutch students) is, amongst others, a result of the many fruitful discussions. Its goal is to further the collaborative research in order to keep crafting pedagogy for VR-enabled learning and teaching as to add to the knowledge and evidence already available on VR education, model-based learning but also teachers' competencies to build innovative lessons for VR-enabled learning. The ultimate aim is of course that our pupils in the classroom will benefit. Our previous study through control and experiment shows our pupils indeed have benefits from the use of VR technology in molecular learning (Tan & Waugh, 2013) which is a strong justification supporting this project.

Lastly, the project outlined is an attempt to bring together teacher educators, researchers, and (student) teachers using a cross-cultural partnership not only to develop effective and validated pedagogies for inquiry-based learning, but also to model and stimulate skills and attitudes in our students and student teachers that are relevant for functioning in high complex and fast changing 21st century working environments, in which professional teams need to collaborate, cross boundaries in activity systems, and therefore need to develop and speak a common professional language.

3 The Domain: models in Biology

As said, the focus is on models in Biology. In this domain, textbooks typically depict molecular and cellular processes such as enzyme operation and protein synthesis with iconic representations of macro-molecules. Whereas this representation is useful to obtain a global view of the processes there are aspects that are not covered but are important for understanding the essence of the processes involved. For example, apart from the 'lock and key' idea of enzyme that is involved in order for molecules to 'snap' into each other, the molecules themselves are dynamic structures and their movement within the cells adds to the dynamics. Whereas the textbook representation may give rise to the misconception that molecules display purposeful behavior, a representation that incorporates dynamics can give rise to a more accurate 'mechanistic way' of reasoning that is capable of explaining the effects of external factors such as temperature and pH value in the cell. The project aims to develop models and modeling environments in which students can create and play with such multiple representations, as well as lesson plans to support learning in these environments. In this way pupils can learn concepts, processes and functions within the domain of molecular and cell biology and develop 21st century skills related to the understanding of science and scientific knowledge.

4 Lesson Study for Design of Innovative VR-enabled teaching and learning

In the design, implementation, and evaluation of the modelling activities teachers will be actively involved using Lesson Study (Lewis, Perry, & Murata, 2006). Lesson study is a collaboration-based teacher professional development approach that originated in Japan (Fernandez & Yoshida, 2004). In this approach, teachers collaboratively engage in research inside their classrooms using a design cycle: prepare and design lessons, perform the designed lesson as a research lesson and evaluate them in order to feed into the next cycle (Cerbin, 2011). Teachers collaboratively design one or more research lessons in which they attempt to adjust to varying educational and instructional needs of their students (Goei, 2013). Great thought is devoted to predicting how the students may react. Important in the Lesson Study cycle is that teachers as Lesson Study team members observe the students when the research lesson is enacted in the classroom, and have special attention to the learning activities and behavior undertaken by the students. Immediately after the lesson, it is evaluated with the focus on the learning activity, rather than on the performance by the teacher who executed the lesson (Becker, Ghenciu, Horak, & Schroeder, 2008; Oshimaa, Horinoa, Oshimab, Yamamotoc, Inagakid, Takenakae, Yamaguchif, Murayamaa, & Nakayamaf, 2006). Observations are shared, ways of refining and improving are discussed and the subsequent review of the lesson is planned. In most cases the research lesson is thereafter enacted in another classroom.

5 An interdisciplinary and international student project towards an inquiry-based pedagogy for Biology

This is an interdisciplinary and international effort in which researchers, developers, educators, and students engineering from Singapore collaborate with researchers, teacher educators, and (student) teachers in Biology from the Netherlands. Students from both countries will work closely under supervision of their teacher educators and researchers to develop innovative VR-enabled solutions and pedagogies for learning and teaching molecular biology. The project has just started and we aim to be in full swing once we have recruited the students from all the universities.

The Singapore students will develop simulations and visualizations for VR-applications, and the Dutch students will integrate these in lesson plans that employ the features of modeling and simulation in teaching molecular biology. The Dutch students will validate and fine-tune the developed lesson plans via Lesson Study. The delivered and tested lesson plans will also be tested out by teachers in Singapore, i.c. Sandra Tan and Ban Hoo Chow, and by subject matter specialists in the Netherlands.

The VR-enabled solutions will draw on the work of Professor Yiyu Cai from the College of Engineering, NTU, Singapore. The team with NTU is specialized in biology modelling with several Ph.Ds developed over the past decades. With the VT tool, students can deal with 2D drawings, 3D graphics of molecular structure and 4D (3D + time) simulation of dynamic functions. The pedagogy will be based on Inquiry-based Learning and Modeling using the approach of "Drawing-based Modeling" developed by the team of Professor Wouter van Joolingen of Utrecht University, the Netherlands (Bollen & Van Joolingen, 2013). The novelty of the development is its embracing of more general concepts of models in multiple levels and with multiple variables for teaching and learning. The models include simulation and 2D/3D visualizations. The validation of the designed pedagogies and lesson plans will be done via the Lesson Study method as developed by Professor Sui Lin Goei of Windesheim University, the Netherlands, implementing this method widely in Dutch schools in the Netherlands. Lesson Study

is also applied as a professional development method in Singapore schools. The content will be designed by Biochemistry students, teachers, and teacher educators from both Singapore and the Netherlands. At Windesheim University professor Teresa Dias Pedro Gomes will be leading her student teachers into this project. The student teams will meet using videoconferences and once a year face-to-face during conferences and workshops to discuss the design of the lessons.

6 Conclusion

This project has the timeliness to explore the application of VR technology in education, especially STEM education, aiming to help pupils in better understanding of scientific concepts through model-based simulation for interactive Learning. Last but not least, one of the existing challenges for higher education is to internationalize its programs and to make students more globally competent. Although teaching is often tailored to local contexts, international collaboration can be important for educators as they grow professionally through exposure to innovative ideas and best practices in other settings. It may be expected that in the two countries, teaching traditions, learner and teacher dispositions are different, providing teachers on both sides of the collaboration with fresh insights.

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