Exploiting augmented reality based technology for contextualized experiential and authentic learning in mainstream schools - A dream or a reality?

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ABSTRACT
Contextualized experiential and authentic learning can be situated within augmented-reality (AR)-enhanced learning environments involving inter-disciplinary academic domains such as physical education, physics, mathematics and biology. However, AR technology-based learning tools are mainly exploited in tertiary institutions such as universities and polytechnics as they are costly and sometimes bulky. A national initiative funded by the National Research Foundation (Singapore) has made the development of such a tool affordable and mobile. This tool has the ability to automatically analyze physical scenes captured by video devices in terms of kinematic characteristics. Essentially, multiple segments/rigid bodies can be tracked automatically. Thus, mainstream schools now have the opportunity to exploit this AR technology-based scaffolding learning tool in an inquiry-based learning environment as it (the tool) potentially frees up more time (as compared to traditionally available frame-by-frame multiple-mouse-clicking video analysis tools for mainstream schools) for more questions to be asked and options to be explored during empowered self-directed learning sessions. Practical examples are highlighted in adapting these AR scaffold learning tools for activities in physics and physical education in the hope that the readers can perceive the potential pervasive exploitation of these tools in a multiple disciplinary learning space beyond the two mentioned subjects situated in mainstream school as well as tertiary education.

Keywords: Augmented reality, Authentic, Interdisciplinary, Experiential and Scaffolding.

1. INTRODUCTION
In traditional physics lessons, it is typical that problems be given to students in class, or as homework assignments, and again in tests that require students to calculate a precise quantitative solution (Briscoe & Prayaga, 2004). When solving these problems, students tend to focus on finding the right equations, manipulating them, and calculating an answer (Redish, Saul, & Steinberg, 1998). The focus on equations and calculations often results in students failing to understand the deeper conceptual relationships present in the problems, which encourages poor problem-solving strategies (e.g. Larkin, McDermott, Simon, & Simon, 1980).

Although various efforts have been successful in improving student motivation, problem solving, and achievement when compared to traditional physics instruction, many researchers feel that the context in such approaches remains implicit (see Finkelstein, 2005; Glynn & Koballa, 2005). Although students may become more reflective, active, and involved in what they are learning, they may still not have an understanding of how they can apply their newly learned skills and knowledge outside of the classroom, limiting the authenticity of instruction. For this reason, it is expected that contextualizing instruction so that it is applicable to students’ everyday lives is a much more effective way to improve student motivation, understanding, and achievement (Glynn & Koballa, 2005).

2. A CASE FOR INTER-DISCIPLINARY AND EXPERIENTIAL LEARNING IN PHYSICS?
Additionally, the learning of academic subjects such as physics, mathematics, biology, physical education and the coaching of sports skills are usually taught predominantly within each discipline’s domain. There are common inter-related concepts like mechanics in physics, mensuration in mathematics, kinesiology in biology and simple technique analysis in physical education or sports coaching which can be learnt within a common educational framework. The relevant connectedness between these academic and sports coaching domains are usually not perceived by the learner.

To develop the holistic thinking student, one of the potential strategies is to have the connectedness between these domains, which forms a significant part of formal mainstream school curriculum, located within the learner. The learning of interdisciplinary academic concepts, incorporating experiential physical activities in realistic conditions, provides a potential platform for establishing the connectedness. Traditional classroom or laboratory strategies have their limitations in that the concepts taught are usually not fully contextualized to real situations involving actual activities. Therefore, this may not facilitate deep learning. However, through interactive digital media (IDM) technology, we may now have a very attractive learning tool to address this problem by providing contextualized augmented feedback, infused with interdisciplinary information, in activities performed in real settings. Such situations and activities are best facilitated using imaging technologies. Objective and augmented feedback through interactive video-based approaches using augmented reality (AR) technologies, where virtual objects such as pictures, tables and graphs can be displayed and be interacted in a real environment, may be used to enhance the teaching and learning processes (see Kaufman, 2004). For example, a class of students may analyze their classmate performing a golf club swinging action where this performance, captured with video devices, is play-back real-time on a display screen augmented with feedback on the musculoskeletal structures that are involved as well as speed of the golf club displayed in digital and graphical format on the screen. The action can be ‘freezed’, played forward and backwards in fast and
slow motion at the will of the students analyzing the context of golf, the anatomical structures (eg. prime movers and synergists) involved that control the movement (eg. speed and acceleration) of the club head as well as

3. SCAFFOLDS IN TECHNOLOGY-BASED CONTEXTUALIZED EXPERIENTIAL LEARNING

The importance of learning incorporating scaffolds has been emphasised by Bottge and colleagues (2009). In a technology-supported environment, students may potentially make use of four kinds of scaffolds: (a) conceptual, (b) metacognitive, (c) procedural, and (d) strategic (see Hamafin et al., 1999). Conceptual scaffolds help students determine what to consider when solving a problem, metacognitive scaffolds support students’ self-regulation or self-management, procedural scaffolds assist students with learning how to use resources or tools built into an environment, and strategic scaffolds help make students aware of different approaches and techniques for solving problems (see Brush & Saye, 2001). Thus, using the above golf example again, the students may choose to use technology-based AR learning tools to look at the problem from a mathematical and/or physics perspective (conceptual). The learning tools available are just merely tools but the students will have to learn to use them in the right context and optimal combinations to solve the problem, say, ‘How to improve the golf swing’ (procedural). With the advancement in technology, the students can appreciate the various protocols available at their disposal for analysis in groups or as individuals and even deliberate on the equipment setup; indoors or outdoors (strategic). Throughout the analysis, they can reflect and examine on their learning processes and experiences at various intervals (metacognition) before proceeding further.

Tasooobshirazi and Martha Carr (2008) stated the need for contextualised learning in physics. Additionally, the reasoning process is another important element in inquiry-based learning. Learning in such an environment is no longer as simple as fact-collecting. Instead, inquiry-based learners have to engage in inquiry processes in which critical and creative thinking skills are the key for the learners to accomplish the problem solving tasks imposed upon them (Hung, 2009).

Using IDM in learning within a common theme may involve various inter-related academic disciplines. For example, in the example of the golf swing, the angles, speed, time concepts in mathematics can be explored together with physics principles like kinetic energy, potential energy and momentum under the domain of skills acquisition or physiology focusing on the musculoskeletal forces and moment arms. Also, these concepts can be taught experientially whilst the students actually perform the swing in actual realistic environment. Benefits of experiential and interdisciplinary learning environment using IDM has been described (Jarmom et al., 2009).

Additionally, as computing hardware—both wired and wireless—approaches ubiquity, new opportunities emerge to use technology to enrich individuals’ experiences of objects and places. Because all areas of academic inquiry potentially benefit from background and context, AR has performance. They will be able to investigate, in the evaluating the interplay between the different energy systems (eg. kinetic, potential energy and total energy).

the possibility of enhancing education across the curriculum. By holistically exposing students to an experiential, explorative, and authentic model of learning early in their education experience, AR has the potential to help shift modes of learning from students’ simply being recipients of content to their taking an active role in gathering and processing information, thereby creating effective knowledge (Educause Learning Initiative, 2005).

Thus, there is a potential need for the use of a scaffolding learning tool in a contextualized inquiry-based learning that encourages experiential, realistic and interdisciplinary learning. Within the framework of a typical academic curriculum like in Singapore, the many activities within a physical education curriculum can present themselves as contextualized topics for learning. How can we improve our run or jump? How can we smash (in racket games) more effectively? Is energy conserved when we are performing a high jump? How can we field more effectively in fielding and batting games? How can we drive a golf club optimally? The activities can be performed by the students themselves and captured in video formatted scenes for immediate analysis and learning evoking, arguably, the experiential and authentic ‘Kodak moment’. Potentially, these activities allow simultaneous learning opportunities in physics, mathematics, biology and physical education. The students can investigate the major muscle groups that control the physical movements which can be examined using mathematical concepts in time, distance, speed and angles using, say, motion tracking devices.

Logical associations can be made with kinematics and energy systems in physics topics such as the velocity, potential and kinetic energy of the centre of mass. All these can be fused together to give a better understanding of executing fundamental movements such as jumping, running and smashing (in racket games) within the physical education curriculum. In fact, such learning opportunities are pervasive in learning sessions within the discipline of Sports Biomechanics (see Hamill & Knutzen, 2003) as the discipline is fundamentally underpinned by concepts from the mentioned core academic topics. Such lesson typically involves sophisticated equipment setups and arguably, predominantly students from tertiary or specialized institutions have the opportunity to experience such an innovative contextualized learning environment (Ong & Ho, 2006). The equipment used are costly and bulky rendering the deployment of such technological infrastructure in main stream school a challenge. A, seemingly far-fetched, suggestion may be to converge this equipment into something mobile and affordable so that main stream schools may have the opportunities to be immersed in such learning activities. In fact, a project has been initiated and funded by the National Research Foundation in Singapore where two neighborhood schools (one primary and one secondary) are being piloted. In this project, a learning tool is developed to effectively and automatically track any moving object/s in 2D space as well as computing and displaying the instantaneous time, distance, speed, displacement, velocity and angles in digital or graphical format augmented in real scenes as captured by video devices (see Figure 1).
4. A SCAFFOLD LEARNING TOOL USING AUGMENTED REALITY TECHNOLOGIES - A REALITY OR A DREAM?

Although the abovementioned AR tool is limited to observable and measurable activities (as it tracks what is visible), there are numerous opportunities to exploit it. For instance, through a simple ball tossing and catching activity (in hand-eye coordination) where students, say, will not only get feedback on the vertical displacement and the velocity of the centre of mass of the ball but they will also have to calculate the potential energy and kinetic energy as well as the total energy by means of an MS EXCEL spreadsheet that incorporates the data that is derived from the video analysis. In so doing, they will be actively involved in the learning process (through calculation of the energy quantities) as well as receiving augmented feedback on selected information such as the displacement and the velocity. Through this, the students will potentially and simultaneously incorporate knowledge from mathematics, physics, information technology (IT) that is realistic and experiential in the context of a throw-and-catch activity. This is in contrast to a worked problem from a textbook or a flash-based simulated programme such as a trajectory of a missile (see http://www.math.tamu.edu/~dallen/physics/).

Consider another example, that of a physical education lesson. Through the AR technology, students will be able to track themselves running across a field or hall and derive their speeds, distances and times to be displayed automatically on the computer screen (see Figure 1) to enable comparisons to take place. With the given information, students may plot ‘distance vs time’ graphs, derive their speed of movement over various sections of the run and consider where they may improve on their performances. Additionally, the teacher may introduce concepts of angles of depressions/elevations for further analysis to consider the angular relationship with the projection of the takeoff in the run. Extending further from these learning opportunities, deep and inquiry-based learning can take place using the scaffolding educational tool to solve a simple contextualised problem such as “how can I run faster?” The experienced teacher will be able to suggest meaningful combinations of activities to facilitate deeper learning.

Thus far, the above-mentioned participating piloted primary and secondary schools are positive and have indicated their desire to integrate the AR tools into their curriculum in the following year. Throughout the piloting experience, we have learnt that the schools have indicated two key themes for discussion: Conceptual and Instrumental learning.

5. CONCEPTUAL AND INSTRUMENTAL LEARNING REVISITED IN PHYSICS

Conceptual understanding implies knowledge of the idea, how it relates to already acquired ideas, the contexts in which it is applicable and its limitations (McIntosh, 2002).
Skemp (1978) described it as ‘relational understanding’ in that one knows “both what to do and why” (p. 9). He differentiated between this and ‘instrumental understanding’ which he described as ‘rules without reasons’ (p. 9).

A perennial problem is that the end product for students (and a measure of their teacher’s success) is often an externally set assessment which focuses on the doing, and less so on the conceptual understanding and broader perspective. These problems are often reinforced by typical assessment questions that ask students to ‘solve, sketch, find, graph, evaluate, determine, differentiate, integrate’, etc (see Ferrini-Mundy & Guether-Graham, 1991). With the availability of technology (graphical calculators, data logging equipment, computer algebra systems), there is the opportunity to free students from the drudgery of algebraic manipulation and calculation by supporting the learning of fundamental ideas. Koirala (1997) sets the teaching of calculus for students’ conceptual understanding in the framework of Skemp’s (1976) instrumental and relational understanding. Students can do well on traditional examinations and in an environment of international comparisons and short modular courses, such an approach appears successful to the teacher, learner, government and educational authorities. Teaching that develops relational understanding not only provides students with knowledge of what to do and how to do it, but they can also explain what they are doing and why. Students can demonstrate an understanding of the concepts underlying the rules. Koirala prefers to call this conceptual understanding. Schwalbach and Dosemagen (2000) reported on the practice of one high school teacher who provided students with concrete examples from their physics class to give them a contextually rich environment in which to explore the abstraction of calculus. They made use of data logging equipment and graphic calculators to provide an environment to explore displacement–time, velocity–time and acceleration–time graphs. The authors commented that many calculus students are gifted in mathematics yet rely on memorising formulas and applying them in rote manner. Their study suggests that making connections for students between disciplines, in this case mathematics and science, can develop richer understandings of semantic (knowing facts and concepts and how they connect) as well as procedural knowledge.

6. REAL-LIFE IMPLEMENTATION

The big question is always, “Will it work at the ground?” Here we will describe more specific applications using the scaffold learning tool within a school setting. In schools, arguably, the primary concern is to ascertain if such pedagogical scaffold tools do indeed improve academic results in addition, to enhancing higher levels of learning. We did a pilot study in a secondary school on two classes (1 experimental and 1 control), where the students were mainly mixed fifteen year olds, in physics. The experimental class essentially used the above-mentioned scaffold learning tool to facilitate the understanding of energy systems using a real person performing a vertical sargent jump as well as a tennis ball dropped from head height. A pre-test and post-test was conducted. In the main, no significant difference was found (p>0.01). The questions were a mixture of conceptual with predominantly instrumental-learning-based calculation-typed ones. However, there were 2 conceptual questions where one derived almost 1.6 times more correct responses from the experimental group. As this was just one question and the other did not show any marked difference, no statistical conclusion can be stated. However, it must be noted that contextualised studies in physics have mixed conclusions as mentioned earlier and the criticisms are mainly on the methodology such as non-standardised tests, small sample size and no control group being used (see Taasoobshirazi & Carr, 2008). These results can only be interpreted within their contextualised settings. To address such concerns requires significant resources and may not be practical. In fact, there are many practitioners who advocate interpreting learning experiences situated within contextualised environment.

The AR tool acts as a scaffold for learning by measuring authentic real-life physical performances, augmenting feedback in acceleration, velocity/speed angles, timings and distances/displacements. It therefore encourages inquiry as the students can now search and discuss for inter-connections of the relationships of known measured quantities and published knowledge. They can formulate their own conclusions, derive recommendations (and testing their recommendations) and rationalise future studies. Incidentally, scientific inquiry is explicitly defined and described in the Singapore’s science curriculum (see http://www.moe.edu.sg /education/syllabuses/sciences/). Thus, this experience in learning may be seen in the context of health and fitness lifestyle activities within physical education curriculum where the pedagogical framework is embraced within the Singapore science curriculum (see http://www.moe.edu.sg/education/syllabuses/sciences/).

Additionally, within the science inquiry-based learning, it encourages students to see activities as inter-connected. Similar, philosophy is stated in the mathematics and physical education curriculum (see http://www.moe.edu.sg/education/syllabuses/). The broad spectrum of activities essentially involve concepts found in Singapore national curriculum concepts such as time, distance, speed, angles, energy, kinematics, mechanics and moments from upper primary to ‘A’ levels as well as tertiary level. The problem can be ‘How can I improve my performance in a meaningful activity’. Thus, at primary level, students may be involved in simple vertical jumping activities where the scaffolding tool facilitates learning activities that measures the maximum height jumped, speed at lift-off and angles at the knee joint. At secondary level, students may investigate the standing forward jump, where they may measure the trajectory variables such as velocity, height and elevation angle at take-off en-route to solving the problem. At tertiary level, the students may investigate the relationship between take-off and landing strategies such as the coordination of the hip, knee and ankle angles over time during the process to solve the research question. Such activities may be standalone to sum up a topical concept or they may allow progressive learning that is constructive and spiral such as the learning of time,
distance, speed and then acceleration concepts in a chronological sequence.

These possibilities are typically shared with teachers in the participating piloting schools. The breadth (as in the wide spectrum of activities within the physical education and beyond as well as the many concepts within the science and mathematics syllabus) as well as the depth (in terms of the concurrent inter-disciplinary learning opportunities using of physics, mathematics, and physical education concepts) will be impressed upon them. Ultimately, they are left to decide upon how they may want to proceed. These schools have shown great interest in wanting to implement this AR tool into their curriculum. They have requested for more features and have initiated meetings with the developers. However, there have been concerns in that there are similar software modules commercially available. In mainstream school education, there is java or flash-based simulation software but not real-life video based software. Non-video-based simulated software modules allow limited scenarios and it requires the developers to laboriously write the scripts to simulate the various new situations. Video-based ones potentially capture almost any observable situation to be analyzed authentically (not simulated) once downloaded to the laptop or computer.

Thus, based on my experience during the piloting process while interacting with the various stakeholders such as the students, teachers, principals and parents, to see a pervasive integration into main-stream schools, the breadth and depth as well as where in particular the national academic curriculum can be specifically situated, must be impressed, at a level relevant, upon them. However, the exact execution will have to be left to the customization of each school as the implementation must be contextualized and situated at each location. Only those at the ground will have the ability to adopt and adapt the pedagogical changes more effectively. Additionally, as the principals of each school is the gate-keeper of pedagogical policies and changes, they must first be convinced that this AR scaffold learning tool is beneficial and can value-add to the student’s learning as compared to other time-tested traditional pedagogical methods. There are principals who explicitly state that they will like to hop on this bandwagon much later. For those who are keen to hop on immediately, the implementation and adaptation in the schools were swift and the results were positive. This, in my opinion, is due largely to the fact that the earlier-described AR learning tool was built from scratch to be user-friendly and contextualized to be situated within mainstream academic curriculum interacting with students who are novices as well as conversant with digital media technologies.

7. CONCLUSION

From the Singapore experience, AR is an ally to facilitate conceptual learning in physics and potentially in inter-disciplinary learning within in mathematics, physics and IT domains in contextualised situations derived from the PE curriculum. It goes beyond standardised testings (which are just tools to inform us). In reality, schools at the ground, arguably, see the value of such a scaffold and today’s technology allows such affordable and mobile scaffold learning tools to be situated in main stream classroom from primary to tertiary levels. This is becoming a reality but more studies are needed to provide better in-depth insights to various contextualised learning environment using these AR learning scaffold tools in main stream education.

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9. REFERENCES


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