The Epistemic Platform for Science Learning with a Computer Game for High School Students in Learning Fundamental Nanoscience and Nanotechnology

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Abstract

Teaching and learning of the emerging fields of nanoscience and nanotechnology at high school level is not simply bringing concepts to students but also providing them with authentic learning experiences which can lead to deeper understandings, both conceptual and procedural knowledge. As computer game technologies are considered as multiple-representation system, it is believed that using computer games as a framework to develop an epistemic platform, a novel science learning experience, is promising for science education. Engaging students in the rich context of science learning is central to the study. This can help students learn more effectively by immersing them into authentic situations, the simulated world where they can play and learn collaboratively. This research study is to develop an epistemic platform for science learning with a computer game and to investigate the impact of the epistemic platform on high school students. The integrated science learning units of nanoscience and nanotechnology have been developed using computer game technologies. Design based research are employed as the large framework for this study. The data from first round of implementation was obtained by using conceptual understanding test administered to all six students, focus group discussion and individual interview technique. The results indicated that the epistemic platform for science learning with a computer game is positive in term of students’ conceptual understanding increment and motivation. It is also found that the ability to engage in inquiry in an authentic setting was powerful for students. However, some modifications are needed on computer game interfaces.

Keywords: Nanoscience and nanotechnology, computer game technologies, epistemic platform, science learning

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บทคัดย่อ

การจัดการเรียนการสอนเนื้อหาวิทยาศาสตร์นาโนและนาโนเทคโนโลยีสำหรับผู้เรียนชั้นสี่ มีการใช้แบบเรียนเพื่อเน้นท่าทางการเรียนรู้ที่นำไปสู่การเข้าใจอย่างลึกซึ้งทั้งตัวความคิดรวบยอดและกระบวนการทางด้านวิทยาศาสตร์นาโนและนาโนเทคโนโลยี เทคโนโลยีของเกมคอมพิวเตอร์ที่มีจุดเด่นการนำเสนอเพื่อหลากหลายและสามารถนำไปใช้เป็นรูปแบบในการออกแบบและพัฒนาระบบการเรียนรู้วิทยาศาสตร์แบบใหม่ที่เหมาะสมได้ การวิจัยครั้งนี้ทำาการศึกษาเกี่ยวกับการออกแบบและพัฒนาแบบการเรียนรู้วิทยาศาสตร์เนื้อหาวิทยาศาสตร์นาโนและนาโนเทคโนโลยีด้วยเกมคอมพิวเตอร์และศึกษาผลกระทบของรูปแบบการเรียนรู้ดังกล่าวที่มีต่อผู้เรียนในชั้นสี่ นอกจากนี้ผู้วิจัยได้ใช้รูปแบบการวิจัยที่เรียกว่า การวิจัยที่มีการออกแบบเป็นฐาน (Design Based Research) ในการศึกษาครั้งนี้ ผลการวิจัยจากการทดลองครั้งแรกโดยใช้หน่วยการเรียนรู้ที่หนึ่ง พบว่า รูปแบบการเรียนรู้วิทยาศาสตร์ที่ใช้เกมคอมพิวเตอร์ร่วม (the Epistemic Platform of Science Learning with a Computer Game) ช่วยให้ผู้เรียนที่หลากหลายที่เข้าร่วมสามารถพัฒนาความเข้าใจเกี่ยวกับความรู้พื้นฐานทางด้านวิทยาศาสตร์นาโนและนาโนเทคโนโลยีได้ และส่งเสริมแรงจูงใจในการเรียนรู้อย่างไรก็ตาม ผู้วิจัยยังพบว่า ตัวเกมคอมพิวเตอร์ยังมีจุดบกพร่องที่ต้องปรับปรุงและแก้ไข เพื่อใช้ในขั้นต่อไป

คำสำคัญ: วิทยาศาสตร์นาโนและนาโนเทคโนโลยี, เทคโนโลยีเกมคอมพิวเตอร์, การเรียนรู้วิทยาศาสตร์, รูปแบบการเรียนรู้ (The Epistemic platform)
Introduction

Background and Rationale

Nanotechnology is concerned with the fabrication and use of devices so small that the convenient unit of measurement is the nanometer (a billionth of a meter) (Tegart, G., 2002). Coming before nanotechnology is nanoscience that deals with studies of behaviors and properties of materials or devices/system having size at nanometer scale. Similar to the relation between science and technology, both nanoscience and nanotechnology are closely related to each other and inseparable. As such, nanoscience can be defined as fundamental study of materials' behaviors and properties and nanotechnology as applied fields of direct control of materials and devices on a molecular and atomic scale. Nanotechnology thus covers a wide range including fabrication of functional nanostructures with engineered properties, synthesis and processing of nanoparticles, supramolecular chemistry, self-assembly and replication techniques, sintering of nanostructured metallic alloys, use of quantum effects, creation of chemical and biological templates and sensors, surface modification and films (Tegart, G., 2002).

As a sequence of the fast growing studies of the cutting edge nanoscience and nanotechnology which have been impacting on our daily lives and a very little understanding of these core concepts public has, there are different ideas people have in whether or not we should develop these ideas. This can be very useful for better lives in the near future as well as very dangerous and risky for public health and our environment. This ambiguity can be blurred by developing our understanding of basic science concepts of nanoscience and nanotechnology. Thus, it is required that the educational community has to have a commensurate response in increasing students' understanding of core concepts in the field. Many universities and academic institutes across the globe are now increasingly offering nanotechnology courses and degree at undergraduate and graduate level, including Thailand. One of the first nanotechnology undergraduate degrees in the world, for instance, was established at Flinder University, Australia in 2000 (Shapter et al, 2003).

Whereas numerous nano-scale science and engineering programs exist at the undergraduate and graduate levels, there is a strong need for nanoscience education in earlier grades, both to increase students' scientific literacy and to prepare them for further study in the field. High school or pre-college students are targeted for the goal of preparing work forces for the cutting edge of scientific research and applications.

Teaching and learning of the emerging fields of nanoscience and nanotechnology at high school level is not simply bringing concepts to students but also providing them with authentic learning experiences which can lead to deeper understandings, both conceptual and procedural knowledge. A computer game and its association are the latest technology that has received attention from educators Gilbert, J.,2004: 9). Many learning scientists are also now increasingly turning to computer and video games as tools for learning (Squire, K., 2003). Shaffer and his colleagues (2004) argued that for a particular view of games—and of learning—as activities that are most powerful when they are personally meaningful, experiential, social, and epistemological all at the same time. As thus, it is believed that computer/video game pedagogies bear considerable potential for science education in particular and the larger field of education more generally. From the perspectives of science teaching and learning, computer game technologies can provide students with the real world experiences in authentic situations where they are motivated and engaged to learn in meaningful learning environment.

Literature Review

A new mode of ICT use in learning, commonly called digital game-based learning, is emerging as alternative vision for digital age of learning. It is believed that digital game technology can provide students with the real world experiences in authentic situations where they are motivated and engaged to learn in meaningful learning environment. In digital game based learning, learners, or namely players, are required to play an active role to complete various kinds
of puzzle and task to accomplish the goal of that game and their own goal of gameplay. Given puzzles and tasks in gameplay, particularly in project creation or management games, players are required to use higher order thinking skills and develop various strategies to reach the goal (Bell, P.; Davis, E. A.; & Linn, M. C. 1996, Schlechty, P. C. 1990).

There are a quite number of research studies on using computer games and their associated technologies in education and training but few have been conducted in science education. One example of research on gaming in science education is the work by Kurt Squire and his colleagues (2004) who have worked on a computer game called “Supercharged!” to help students learn physics. They reported some results that are part of a larger design experiment examining the pedagogical potential of Supercharged in three urban middle school science classrooms with a good deal of cultural diversity. The results show that the experimental group outperformed the control group on conceptual exam questions. Post-interviews revealed that both experimental and control students had improved their understanding of basic electrostatics. However, there were some qualitative differences between the two groups. The most striking differences were in students’ descriptions of electric fields and the influence of distance on the forces that charges experience. In the report, they concluded that these initial findings suggest that the primary affordances of games as instructional tools may be their power for eliciting students’ alternative misconceptions and then providing a context for thinking through problems. An adept game players appropriate game representations as tools for thinking, which were later taken up in solving other physics problems (p 510).

Dede and Ketlehut, (2003, April) another example, have been developing and researching River City, which uses a Multiuser Virtual Environment Experiential Simulator (MUVEES) to introduce an engaging multi-user virtual environment that teaches science concepts in a way that draws on curiosity and play (http://www.virtual.gmu.edu/muvees). Similarly, Quest Atlantis (QA) is a learning and teaching project that uses a 3D multi-user environment to immerse children, ages 9-12, in educational tasks (http://questatlantis.org). This project is built on strategies from online role-playing games, QA combines strategies used in the commercial gaming environment with lessons from educational research on learning and motivation ( Barab, S. A.; et al., 2002). The series of research investigating the effects of these kinds of learning environment are still being undertaken. Some released show positive results of engagement and meaningful learning. By taking a closer look at this project study, the researcher found that this project integrates principles underlying the development of entertaining games (play, challenge, curiosity, and control) into the design of a learning environment, a practice frequently absent from textbooks and school-based activities. The project also entails a rich meta-game context through which children perceive their participation as meaningful and engaging.

The research studies mentioned previously show promising results for science education. However, a particular form of game uses as learning tools for science teaching and learning in classroom setting has been studied in very few numbers. Thus, it is worth investigating computer games and their associated technologies in the roles as learning tools in the learning system of classroom. As a result, creating such an immersive science learning environment using computer game technologies is central to this study. This study will obtain additional useful information concerning strategy using and incorporating digital game technologies into science teaching and learning. The result of this study will increase understanding on the use of game technologies in education in general and science education in particular. Besides that, this is very useful for participants in developing their own learning process. In this study, the effective epistemic platform for science learning with a computer game on the concepts of nanoscience and nanotechnology using the concepts of nanomaterial in particular will also be obtained. The learning units of the epistemic platform are expected to be adapted to other science classes.
The Aims of the Study

The aims of this study are summarized as follows: 1) To develop the epistemic platform for science learning with a computer game on the content of nanoscience and nanotechnology, using nanomaterial in particular, for high school science students, and 2) To examine the effect of the epistemic platform on students’ science learning achievement. The main research questions were:

1) What are effects of the epistemic platform on students’ science learning achievement?
2) Is there any advantage in the use of the epistemic platform in the view of students and teachers?
3) Is there any difference in science achievement between male and female students?

Research Materials and Method

The focus of this study is placed on developing a novel strategy for science teaching and learning called an epistemic platform for science learning with a computer game to enhance level 4 (High School) students’ science achievement by incorporating the educationally potential elements and devices of game technologies and gameplay into the design of the epistemic platform. The epistemic platform has been developed and set as learning units using the content of nanoscience and nanotechnology, nanomaterial in particular. The selected concepts of nanoscience and nanotechnology are in line with national science curriculum standards. As this research involves an innovative development for teaching and learning, the researcher employs design-based research as a large framework for the study (Collins, A., 1992; Barab S. & Squire K., 2004; Brown, A. L., 1992). Barab and Squire (2004) clarified that design based-research involves introducing innovations into the booming, buzzing confusion of real-world practice, not as that in laboratory context, and examining the impact of those designs on learning process. The DBR collective (2003) suggested that design based research approach is the continuous cycle consisting of design, enactment, analyses and redesign. This cycle is shown as follows:

![Design-Based Research Cycle](image)

As a result, the researcher uses multiple methods, both qualitative and quantitative, as a part of a larger design-based research study. According to the structure of the research study mentioned previously, the research study consists of two main phases:

Phase I Development of the epistemic platform for science learning with a computer game.

Phase II Implementation of the epistemic platform.

Phase I: Development of the epistemic platform for science learning with a computer game

In this phase, there are 3 stages in developing the epistemic platform and its related materials. These are stage 1) Analysis, stage 2) design, and stage 3) developing the epistemic platform and each of them are detailed as follows:

Stage 1) In the analysis stage, the researcher start with brainstorming with the participating teacher researchers. The researcher and participating science teacher researchers together studied and frame science content, here using nanotechnology which consists of basic science concepts of chemistry, physics, and biology of nanomaterial. We then studied and analyzed the national science curriculum standards to manage science content and learning objectives for level 4 students. In the next step, we continued to study about designing and integrating computer and computer game technologies for learning science. In each of this step, the researcher has documented and
consulted with experts and specialist from different disciplines. In developing nanoscience and nanotechnology content, the researcher selected and analyzed the important concepts of nanomaterial and then has nanoscientist or nanotechnologist checked for the correction of the concepts. After that, the researcher has developed science learning objectives for the curriculum unit which is divided into three different science learning units under consulting with experts in this field. The results of this stage are the main concepts of nanomaterial and learning objectives.

Stage 2) In this step, the researcher and other two science teachers have worked closely with gamers and game designers in order to design a computer game and its related materials for science learning activities of the epistemic platform. The process of game design and development consists of many steps: story design, graphic design, narrative design, and interactive design. In order to engage students with compelling story, we choose the scenarios of research competition of the project management in developing nano-superclothes for military purpose. From the game designer perspectives, we put learners into the state of player to play a role as a research project team leader to develop the superclothes for protecting future soldiers by utilizing the unique properties of nanomaterial for this purpose. We then developed the graphic, narrative and interactive system of game interface simultaneously. The result of this stage is the plan of computer game development that are: script and story broad of the game scenarios and related learning materials.

Stage 3) After we have all kinds of information, we have created the game interface by working with computer programmers. Using Adobe Macro Media Flash™ software, we obtained the computer game that engages students in simulated real world practice which is authentic and meaningful for them in science learning. We also developed related learning materials as well as research instruments and tools. The back-story of game scenarios is described below.

**The Description of Back-Story of Game**

The story design of the computer game used in this study is set as scientific research competition. The two research teams, one of those has to be leaded by students as players and another team is computerized, will be selected from the agents of the Ministry of Military to develop superclothes for soldiers’ use in the future war using nanomaterials.

In the scenarios of computer game, players as a leading scientist will be called for duty from the government to be the leader of the team to develop new material that can be used for military purpose. Players need to form his/her team by selecting computerized agents who will help and consult with throughout the game. Player will receive a limited budget and time. He/she needs to think carefully and plan everything about this to get his/her job done right on time. At the same time, the government also has another team do the same thing as your team. This means that the government assigns the same project to two development teams. Therefore, both teams have to compete with each other to win the contract from the government. For the project management of developing superclothes using nanomaterial for military purpose, players have to work smartly to compete with another team. As such, students as players need to think strategically and creatively for their final product to convince the government to select them as the winner.

Throughout the epistemic platform for science learning with a computer game, students will encounter various kinds of problem which require them to use various kinds of problem solving strategy, knowledge and thinking skills. As thus, they will also simultaneously develop their conceptual and procedural knowledge through interaction with computerized agents, their peers, and teachers who play a role as a facilitator both in gameplay and social context outside the gameplay.
Phase II Implementation of the Learning Units of the Epistemic Platform: Population and Samples (Targeted Group)

The population of this study is the high school students studying in science program in level 4 (high school), and already completed two semesters of biology, physics, and chemistry, at Piyachart Pattana School in Nakhonnayok, Thailand. The school site is equipped with microcomputers with the Internet connection. The samples of this study are students who are studying in science program in level 4, and already completed two semesters of biology, physics, and chemistry, at the Piyachart Pattana School in Nakhonnayok, Thailand. This study does not use sampling technique but asks for volunteering by students to choose to study in the epistemic platform. The samples of 54 students are volunteers screened by the test developed by the researcher to test basic knowledge of using computer program such as the Internet explorer, Microsoft Word, Excel, and PowerPoint. The samples are divided into three groups. The first group of six students is set for first round of implementation and the second group of nine students is set for second round of implementation known as small group implementation. In the third and final round of implementation, 39 students are set as the main phase of class implementation.

The First Round of Implementation of One Learning Unit with Six Students

In this first round of implementation, two groups of three high school students, totally six students, were implemented with the developed learning unit of the epistemic platform called Learning Unit One: Introduction to Nanoscience and Nanotechnology. In this round, the researcher also worked as a teacher to help the six students in the learning activities.

In this implementation of the learning unit one: Introduction to Nanoscience and Nanotechnology with two groups of three high school students, the researcher examined usability, student motivation, student learning in term of conceptual understanding, and small group implementation. Using design-based research methods, the researcher collected both qualitative and quantitative data from students, before-during and -after three hours of implementation period. The conceptual understanding tests developed by the researcher were administered to all six students, pre- and post-intervention. In addition, the researcher had a focus group discussion with selected three students and individual interview with two selected students after implementation. Besides this, the researcher also observed students learning activities.

The researcher used this data, plus the researcher own observations, to analyze the learning outcomes for students and to inform the understanding of how this kind of learning worked, in order to refine the design of the next iteration and to reflect on the theoretical foundations underlying the design.

The Second Round of Implementation of One Learning Unit with Nine Students

In this round, all research activities are the same as the first round of implementation but other nine high school students will be instead set in this round. The improved learning unit one from the first round will be used.

The Third Round of Implementation of the Three Learning Units in Classroom Setting

In the class implementation phase, a group of 39 students is set as the targeted group for the third round of implementation of the study. The all three learning units of the epistemic platform will be set as 10 period long learning activities and implemented with those students. In this final round of implementation, the researcher will do as follows: 1) doing workshop with science teachers who will use the epistemic platform, 2) implementing the learning units with a class of 39 level 4 students, and 3) following and evaluating the implementation and evaluating the learning units. For this main round of implementation, all the developed and improved learning materials will be implemented and all research tools will be employed.
Results and Discussion

Initial Findings

Presented here are only the results from the first round of implementation. Overall, results indicated that the epistemic platform for science learning with a computer game is positive in terms of students’ conceptual understanding increment and motivation. It is also found that the ability to engage in inquiry in an authentic setting was powerful for students. According to the results from pre-and post-conceptual understanding test, all six students showed the improvement in conceptual understandings of basic concepts of nanoscience and nanotechnology. Plus, the results from focus group discussion and individual interview indicated that this kind of learning was motivating for all six students. Three issues from the first round of implementation are discussed as follows:

Students’ increased conceptual understanding

After they learned and discovered many fundamental concepts of nanoscience and nanotechnology through the learning unit one by interacting with computer game, they have increased conceptual understandings of the key concepts such as size and scale, meaning of nanoscience and nanotechnology, tools of nanoscience and nanotechnology, historical perspectives of nanoscience and nanotechnology according to pre- and post-conceptual understanding test. However, they unclearly expressed some qualitative explanation in their writings due to their writing ability.

Motivation and Engagement

Results from focus group discussion and individual interview indicated that learning with the computer game called Nano-X Project was motivating for all students. It was also found that the ability to engage in inquiry in an authentic setting was powerful for students.

Design and Usability

Through interaction with computer game, students were engaged in this kind of learning experiences. However, there are needs for modifications of interface design, according to students’ response from focus group discussion and interview. Here are some needed modifications suggested by the six participating students:

- Long sentences on the interface should be shorten and made easier for students to grasp.
- Some parts of game interface are not related and could be cut off.
- There are confusing part on the game interface should be fixed.

As a result, the epistemic platform seemed to have positive effects for students with high perceptions of learning experiences that they had and the concepts of nanoscience and nanotechnology. Focused analysis on these six students led to an interesting discovery of the effect of the epistemic platform. Interaction with computer game interface and collaborative work in small group are key activities for the epistemic platform. However, the researcher did find that there were some needed modifications on computer game interface. The computer game interfaces are now modified accordingly to students responses.

Conclusion and Implication

Based on this implementation, it is concluded that the design of the computer game and associated learning activities had been positive and should be kept, but additional modifications are needed. Overall, these findings encouraged further refinement and experimentation with the learning unit of the epistemic platform to help students increase more motivation and conceptual knowledge.

By examining recorded and observed student interactions with the learning unit, the researcher saw ways to strengthen the content and pedagogy of the epistemic platform. Although students found the learning unit readily usable and the learning experiences motivating, the researcher found weaknesses in this design, both from a graphical and curricular perspective. From a theoretical perspective, all these were ways of increasing students’ psychological immersion in the learning experiences of the epistemic platform, through adding new types of actions, social situations, and participation in the learning environment.
References


