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Augmented Learning with Serious Game Character Design

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Abstract: This study addresses the learning of the elements in energy saving and CO_2 reduction education and their relevant properties by using augmented learning based on character design. This study uses technologies that include character design, interactive game cards, augmented reality technology, and interactive multimedia design to create "Kung Fu Chemistry Family" game. This game is designed to make learners learn the formulae of H_2O, CO_2 and H_2CO_3. This study uses the properties of the three chemical elements to design 2D/3D characters to make learning more fun and meet the goal of "learning by playing", as serious games. Every chemical element in the game has been personalized to fulfill a different role in the family, and each element's character corresponds to its properties as a chemical element. A prototype of a multimodal digital learning serious game to chemistry elements had been developed. Forty elementary students participated in the assessment of the designed materials. The results show that the extent to which users are engaged in innovative interaction digital learning, determines the success rate. However, learning can be affected when information displayed on the screen is not significant enough. The user experiences and a usability test will necessitate a follow-up study.

Keywords: interaction design, augmented learning, character design, serious game, joyful learning

1. Introduction

The development of new technologies not only influences the ways teachers teach, but also provide learners with more interactive ways to learn. Digital technology promotes the advancement of learning and its applications by means of information technology, which enables widespread teaching contents and accessible learning resources. In addition, multimedia design diversifies E-learning so that learning becomes livelier and interactive compared to traditional learning. It is also more efficient (Shetty & Kolur, 2011). However, science and technology are unable to solve all the problems in learning. Thus, how to design and develop appropriate instructional strategies is the key to the quality of E-learning. As a result, unlike the traditional way to prepare lecture materials for learning chemistry elements and reactions, this study focuses on designing and developing a curriculum and its platform for E-learning. Under this premise, the study uses a design of role playing which combines role, professional knowledge, augmented reality and user interface design to develop a multimodal digital learning serious game and further to assess its effectiveness from user experience.

This study addresses the learning of the core elements - carbon (C), hydrogen (H) and oxygen (O_2) - and their effect on chemical reactions. Based on these issues, this study uses different technologies which include role playing design, interactive games cards design, augmented reality technology, and interactive multimedia design to develop a serious game called "Kung Fu Chemistry Family." According to the definition by Botte and Sponsiello, a "Serious Game" is designed by incorporating a specialized discipline of knowledge into video or online games for the purpose of training and learning . Therefore, the study collates knowledge and incorporates it into the design of a role playing serious game for chemistry elements augmented learning . Learners are expected to learn the properties of the elements - carbon (C), hydrogen (H), and oxygen (O_2) and the formula of water H_2O, carbon dioxide CO_2 and carbonic acid H_2CO_3 after playing the "Kung Fu Chemistry Family" serious game.

In order to make learning much more fun and meet the goal of "learning by playing", emphasized by serious games, 2D/3D images are designed in this study by using the properties of the three chemical elements. Every chemical

element in "Kung Fu Chemistry Family" is personalized into different roles in a family, and each family member's character corresponds to its properties as a chemical element. In accordance with the properties of each element, the chemical elements'2D/3D images and E-learning cards are designed with augmented reality.

The results of this study show that the prototype of the role playing serious game is effective in fostering students' learning ability. Aside from traditional reading of game cards, the serious game via mobile devices guides learners through 3D images to intensify what they have read. Furthermore, through the multimedia design of "participating" and "triggering", learners demonstrate a wide range of achievements. The results also show the extent users are engaged in digital learning, and where innovative interaction design facilitates learning. However, learning can be affected when information displayed on the screen is not significant enough. The user experiences and feedback will facilitate a follow-up study. In the future, different issues of energy saving and CO_2 reduction will be introduced to the subsequent design of the digital learning serious game, and the result of the study will be used to amend and intensify the subsequent development of the current design and scheme. In a future study, more systematically approach tools and promotion events, based on the results of this study, will be implemented to lay a foundation for the related research on augmented learning serious games development.

2. Literature Review

Augmented learning focuses on augmented realities (AR) for learning that utilize mobile, context-aware technologies, which enable participants to interact with digital contents embedded within the physical environment(Dunleavy & Dede, 2014). This research employed the technology in the study to develop a serious game on the issue of energy saving and CO2 reduction. Augmented reality calculates the position of an image in real time (from the camera's angle), and places and displays it in a virtual world on a screen. In other words, the technology combines virtual and real objects on the same interface so that virtual objects look as if they exist in the real world (Kaufmann & Csisinko, 2011). As a matter of fact, augmented reality has been widely applied especially in digital learning. Shetty and Kolur(2011)pointed out that augmented reality combined with image recognition has brought about a diversified development in digital learning, including a more interactive learning environment and diverse learning modes. Furthermore, when augmented reality connected with mobile devices is applied in digital learning (Kaufmann & Csisinko, 2011), learning modes become more interactive and diversified owing to the assistance of motion detection and image learning. In this way, knowledge exploration can be more interactive and entertaining as well as effective.

Basically, augmented reality applied in digital learning is based on the mechanism of image learning and context awareness. In respect of image learning, 3D modeling through augmented reality makes what is to be learned more complete than 2D drawings. For example, Shetty and Kolur (2011) designed an augmented reality aid to textbooks. By means of image recognition and 3D modeling, the technology builds up a three-dimensional model of eight planets in accordance with the textbooks. This leads to more effective study on the knowledge of content since children not only find learning more interesting, but also are able to come up with a variety of creative ideas. As for context awareness, augmented reality can filter and display the information needed by users by establishing space, location, direction, flowing lines, objects, timeline, etc. in the context of games (Lee, Seo, & Rhee, 2011; Uchiyama, Saito, Servières, & Moreau, 2011).

The other concept that is used in this study is the development of a "Serious Game". The task that challenges digital learning is how to develop and improve instructional methods (Martin et al., 2011). As far as teaching materials are concerned, the number of digital materials that are implemented by multimedia applications are currently increasing more than that of the traditional ones (Nilsson & Jakobsson, 2011). Young learners also have a variety of choices when provided with these games which have been prevalent in education (Liarokapis & De Freitas, 2010; Manlow, 2010). Regarding the research of video games and online games, many studies have investigated the socio-cultural effects that video games and online games may bring about. On the other hand, a number of researches have explored the

application of video games and online games in education and training, which further entitles the term "Serious Games" (Botte et al., 2009; Pandeliev & Baecker, 2010).

Serious games are categorized in traditional video games and simulation programs. In essence, serious games are designed for educational rather than entertaining purposes; they originated from the "War Game" for military use. Unlike traditional video games, serious games contribute to enhance training in medical education and disaster management by integrating information technology, intelligent software and physical models. Moreover, a British company, Red Redemption, has used serious games in advocating energy saving and CO2 reduction since 2007. Targeting a population of 20 to 35 year-old professionals, the project combined role-playing and strategy decision and developed a small online game, "Climate Change". This is an example of using a serious game to make people aware of the correlation of CO2 emission and environmental resources, and to advocate the government's relevant policies.

3. Method and Role Playing Serious Game Design

The purpose of this study is to design a multi-modal serious game based on energy saving and CO_2 reduction. The design starts from writing a script and incorporates the issue knowledge the study addresses to. Next, interaction design is used to devise an overall scheme combining the issue knowledge, aesthetics, technologies and interface design towards the goal of creating user experiences. The final step is to develop a serious game with multiple learning modes like traditional game cards, augmented reality, and interaction design, and move forward to assess the properties and differences of these interaction modes. The research framework is shown in Figure 1.

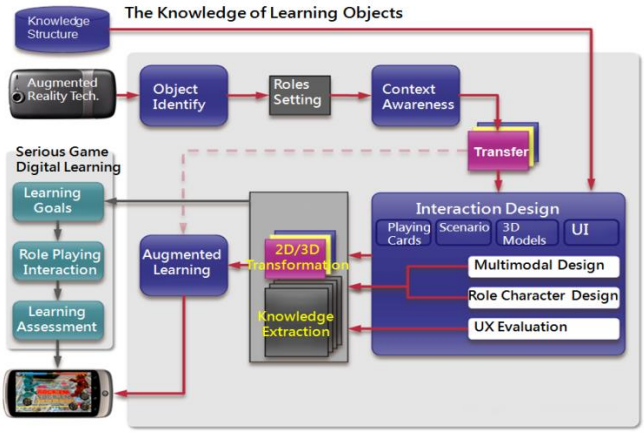

Figure 1. The research framework.

The study addresses the following issue: the learning of the core chemistry elements in energy saving and CO_2reductionin education - carbon (C), hydrogen (H), oxygen (O_2) - and their relevant characteristics. Based on the issue, the study uses technologies such as interactive games cards, augmented reality, and interactive multimedia design to entitle a "serious game." The following are the specifications of the scheme for this study:

a. Scheme for the learning of the core elements in energy saving and CO_2 reduction education - carbon (C), hydrogen (H), oxygen (O_2) - and their relevant knowledge.

One of the two main topics in energy saving and CO_2 reduction education is to reduce the waste of energy, and the energy resource that is most directly and closely related to learners' daily lives, is water. The other issue is to reduce carbon dioxide emissions. The serious game, "Kung Fu Chemical Family," is designed to make learners learn the formulae of water (H_2O) and carbon dioxide (CO_2). By studying the formula provided by the serious game, learners are expected to learn the properties of the elements: carbon (C), hydrogen (H), and oxygen (O_2); that are closely related to energy saving and CO_2 reduction, and the relevant knowledge derived from the chemical equations. The chemical equations used in the framework are as follows:

$2H_2+O_2 \rightarrow 2H_2O$（water）（I）

$C + O_2 \rightarrow CO_2$（carbon dioxide）（II）

$H_2O + CO_2 \rightarrow H_2CO_3$（carbonic acid）（III）

b. Scheme for the role playing serious game and augmented learning

On the issue of energy saving and CO_2 reduction, the design is developed by analyzing the attributes of a serious game from the perspectives of pedagogy, the elements of a game, and authentic elements existing in our daily lives. In addition, the design adheres to a four phases structure that are described as follows:

Phase 1 Scenarios: The learning knowledge is collected and storytelling methods are used to propose the scenario of the augmented learning serious game.

Phase 2 Character: Role playing design is implemented for designing the roles that will be used in the serious game. The 2D/3D graphics are then used to design the visual elements of each role.

Phase 3 Gamification: Augmented reality technology and a game engine are used to develop the augmented learning serious game of this study.

Phase 4 Achievements: Augmented learning mechanism is planned and implemented with learning.

c. The application of augmented reality technology.

The augmented learning serious game design in this study uses augmented reality in establishing the user interface and system. Augmented reality integrates video streaming and images to show close-to-real-images in a virtual reality, and therefor is a higher technology than "data mash-up". A lot of studies (Kaufmann & Csisinko, 2011; Lee et al., 2011; Martin et al., 2011) have shown that augmented reality has been widely used in digital learning for various purposes, for example in: architecture, arts, medicine, language, designing, etc. The use of simulation or three-dimensional models can effectively improve learning outcomes. In addition, the technology, when integrated with books and pictures, can make teaching and learning more diversified. Therefore, the study combines augmented reality and game cards to expand the interaction modes in the digital learning serious game.

There are many application tools to use for augmented reality. However, due to numerous limitations on the tools such as a high technical threshold set by software companies and cost for commercial purposes, the study uses the augmented reality tool Vuforia SDK, which was launched by Qualcomm. Furthermore, the tool is combined with Unity 3D, a game development tool, and Android to develop its mobile device version.

4. "Kung Fu Chemical Family" Augmented Learning Serious Game Development

According to the methods and serious game design proposed in the last session, an augmented learning serious game had been developed. In phase one, the knowledge that will be embedded in the augmented learning serious game are the three core chemical elements for energy saving: carbon (C), hydrogen (H), and oxygen(O_2). Additionally, water (H_2O), carbon dioxide(CO_2)and carbonic acid (H_2CO_3), which are created from the core elements by chemical reactions, are also included. In order to meet the goal of "role playing design", emphasized in phase two and gamification in phase three, a game call "Kung Fu Chemical Family", was developed in which every chemical element is personalized into different roles in a family, and each family member's character corresponds to its properties as a chemical element. In accordance with the properties of each element's role, the chemical elements' 2D/3D images and learning cards for augmented reality application were designed. Table 1 shows the roles, characteristics and 2D/3D images of the chemical elements used in the augmented learning serious game "Kung Fu Chemical Family". Table 3 shows all the elements contained in the materials of "Kung Fu Chemical Family."

Learning through playing a serious game needs to be both informative and entertaining, so the characteristics of each element's role need to be incorporated into the scenario of interaction design. The following is the scenario of interaction design for "Kung Fu Chemical Family":

(1) When Twin Sons, Hydrogen (H) and loving Mother, Oxygen (O_2), hug each other, chemical equation (I) is introduced with the image of gurgling water moisturizing the Earth.

(2) When Father, Carbon (C), and Mother Oxygen (O_2) have a quarrel, chemical equation (II) is introduced with a

hideous face representing carbon dioxide and the image of the suffering Earth from the impact of greenhouse effects.

(3) When the family members are joyously walking hand in hand, chemical equation (III) is introduced with the image in which the family members are happily drinking soft drinks under the stars.

Table 1. The roles, characteristics and 2D/3D images of chemical elements for serious game development.

Chemical Elements	Roles and Characteristics	2D Game Cards	3D Images	Learning Cards
Carbon (C)	• Strict Father, a rigorous master of the family • Resolute, kind-hearted but looks ferocious, consistent with the properties of carbon (C) • Carbon dioxide is produced when a quarrel with the wife, oxygen (O_2)			
Hydrogen(H)	• Twin Sons • Naughty, energetic, tricky, consistent with the properties of hydrogen (H) • Spoiled boys, likes to form water with Mother (O_2) and play around			
Oxygen (O_2)	• Loving Mother, a kind housewife of the family • Beautiful, affable, consistent with the properties of oxygen (O_2) • Likes to hug with Twin Sons(H) and becomes water			

In addition, there are four interaction modes for augmented learning:

(1) *Traditional game cards* (M1): This is a mode in which learning takes place through the design of game cards. Provided with images and texts on the game cards, learners study the chemical elements, but the study is limited only to the three elements - carbon (C), hydrogen (H), and oxygen (O_2).

(2) *Single element with augmented reality* (M2): In this mode the game cards learning is extended by the use of augmented reality (Figure 3). Unlike M1, this mode uses augmented reality and displays the 3D images of the chemical elements, which increases the amusement of learning. In M2, however, the study on the chemical elements is limited only to the three elements - carbon (C), hydrogen (H), and oxygen (O_2).

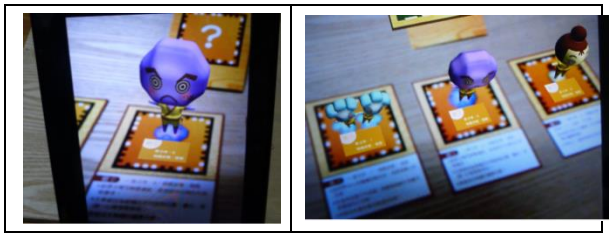

Figure 3. Single elements with augmented reality.

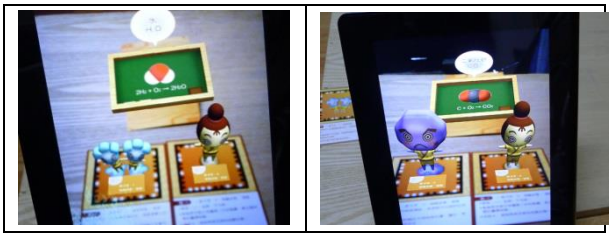

Figure 4. Multiple elements with augmented reality.

(3) *Multiple elements with augmented reality* (M3): The chemical equations are added into this mode. Again, augmented reality is used to show the chemical equations and the corresponding molecular structures. In Figure 4, the left-hand side shows an augmented reality system in which the chemical equation and its corresponding molecular structure appear on top of the screen when the identification cards - hydrogen (H) and oxygen (O2) are inserted. Augmented reality constructs an interface for multiple knowledge learning. The right-hand side illustrates the chemical equation of carbon (C) and oxygen (O_2) and its corresponding molecular structures.

(4) *Multiple elements with augmented reality and interactive multimedia* (M4): The interactive multimedia design is added into this mode. In addition to displaying the 3D digital models of carbon (C), hydrogen (H), and oxygen (O_2) as well as the chemical equations and their corresponding molecular structures, this mode also shows the properties of the elements' compositions. In Figure 5, the left-hand side shows an augmented reality system in which the chemical equation and its corresponding molecular structure appear on top of the screen when the identification cards - carbon (C), hydrogen (H) and oxygen (O_2) - are inserted. In this mode the properties of the elements' composition also appears on top of the screen. The right shows the animation of the three elements'

composition in its liquid and gaseous forms when carbon (C), hydrogen (H), and oxygen (O_2) meet and react with one another to form carbonic acid.

Figure 5. Multiple elements with augmented reality and interactive multimedia.

5. Experiment Results and Discussions

According to the above design, the study accomplishes the prototype of a multi-modal augmented learning serious game on the issue of energy saving and CO_2 reduction. Forty elementary students with interactive media design background participated in the assessment of the augmented learning. They used Android-operating tablet PCs to demonstrate the issue knowledge learning in the "Kung Fu Chemical Family" serious game. Observations and interviews with users were also carried out to understand the effectiveness of this design.

This study uses the Likert scale to analyze the user experiences with regards to it being entertaining, informative, interactive, accurate, immersive and friendly. Likewise, the study also evaluates the effectiveness of the four interaction modes by asking the subjects to fulfill the following tasks:

(1) Subjects were asked to describe the properties of carbon (C), hydrogen (H), and oxygen(O_2) respectively.

(2) Subjects were asked to write down as many chemical equations as they can.

(3) Subjects were asked to describe the animations they have observed in the multiple elements with augmented reality and interactive multimedia mode (M4).

(4) Subjects were asked to draw the molecular structure of carbonic acid from their concept images.

Figure 6 shows the assessment of user experience in the serious game, "Kung Fu Chemical Family". First of all, there is no significant difference among the four interaction modes in respect to being entertaining. Generally speaking, users were interested in using game cards to learn chemical elements. Some think it innovative to learn the chemical elements'3D images, their equations and molecular structures by the design of augmented reality; learners can easily overcome difficult lessons in this way. In addition, a majority of users stated that this was the first time they find it so much fun to learn chemical elements and their relevant knowledge.

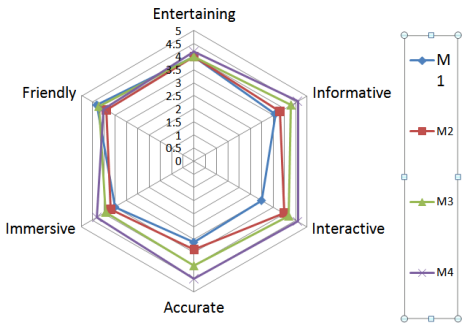

Figure 6. The user experience assessment of "Kung Fu Chemical Family" serious game.

In the aspect of being informative, *multiple elements with augmented reality and interactive multimedia mode (M4)* and *multiple elements with augmented reality (M3),*are better in the richness of knowledge introduced than *single element with augmented reality mode (M2) and game cards mode (M1)*. In other words, users experienced more knowledge conveyance in both multiple elements with augmented reality modes. In particular, M4 performs better with regards to in the chemical elements'properties owing to the incorporation of both augmented reality and interactive multimedia design. This, according to users'interviews, greatly improves learning effectiveness.

On the other hand, M1 obviously performs the worst with respect to being interactive since the interaction in M1 mainly comes from the physical game cards. Learning with the game cards is not so innovative and interactive though images from the cards benefit learning to some extent. Of the four interaction modes, nevertheless, M1 is the highest praised for being user friendly. According to users' interviews, transforming the learning of chemical elements into a playing cards game is very creative. It is also helpful in reducing the barriers that exists in the learning of chemical elements. Compared with augmented-reality-built, M2, M3 and M4, M1 makes what is to be learned more accessible in the absence of any mobile devices. Therefore M1 is the most user-friendly of all. Furthermore, some users suggested that the game cards design can be extended to make M1 more informative, for example, by increasing the number of chemical elements into learning, or by replacing the card game with a bridge game.

With respect to being accurate and immersive, M4 is significantly superior to the others. Being accurate refers to the completeness of the knowledge incorporated into the game while being immersive means the extent the users are engaged in the augmented learning. In M4, the knowledge incorporated is complete and interactive multimedia design is added to assist in the learning. So M4 scores the highest from user experience in this regard. According to the interviewees, M4 captures the essence of serious games better than the other modes i.e. learning by playing. Most agree that they did not feel they were "studying"; they were more like in the middle of "a real game" with augmented reality as the augmented learning occurs. Consequently, the extent users are engaged in the augmented learning is considerable and this was effective in improving the learning outcomes.

Aside from the user experience, the study also evaluates the effectiveness of the interaction modes by asking the users to fulfill tasks planned in phase four: interaction design and user feedback. The result shows that approximately 90% of the learners of "Kung Fu Chemical Family" were able to describe the properties of carbon (C), hydrogen (H), and oxygen (O_2) respectively. In addition, approximately 90% of learners were able to correctly write down the chemical equations of water (H_2O) and carbon dioxide (CO_2), while only 60% of learners could correctly write down the chemical equation of carbonic acid (H_2CO_3). Despite this, 60% of learners were capable of vividly describing the animations that render the gaseous and liquid properties of carbonic acid (H_2CO_3). They could also extend this knowledge to carbonated beverages (soft drinks). However, only 30% of the learners could draw the molecular structure of carbonic acid H_2CO_3) from their concept images. According to the interviews, this may result from the insignificant display ofcarbonic acid (H_2CO_3) in M4 and M3; some learners might not have been aware of its existence on the screen. The user experiences and feedback facilitates a follow-up study in the future. The above is the result of a preliminary investigation and analysis on the serious game prototype developed in the study. When the follow-up serious game becomes more, complete, a more systematic approach to the user experience and the assessment of learning outcomes will follow.

6. Conclusions

This study addresses the issue of energy saving and CO_2 reduction by learning its core chemical elements - carbon (C), hydrogen (H) and oxygen (O_2) and their relevant knowledge. Based on the issue, the study focuses on designing an augmented learning interface. Combining the issue knowledge, aesthetics, technology and interface design, the study aims to develop a multi-modal augmented learning serious game based on the issue of energy saving , and further to assess its effectiveness from user experiences. In accordance with the research framework, augmented reality technology is applied to develop a multi-modal augmented learning serious game, called "Kung Fu Chemical Family." According to user experience, the result shows that this serious game establishes its dominance in the aspect of being informative and accurate owing to the richness of the issue knowledge and interfaces introduced. In addition, the four interaction modes developed from the serious game do not show significant difference with regard to being entertaining. In the aspect of being informative, multiple element with augmented reality and interactive multimedia (M4) and multi element with augmented reality (M3) perform better than single element with augmented reality (M2) and traditional

game cards (M1). In respect to being interactive, M1, limited by the traditional game card interface, performs the worst. However, it is the most user-friendly because there are not any other mobile devices. When it comes to being accurate and immersive, M4 is significantly superior to the others since the knowledge incorporated is more complete and interactive multimedia design is added to assist the learning. Moreover, learners generally think it is innovative to learn the 3D images of the elements, their equations and molecular structures by the design of augmented reality; learners can easily overcome difficult lessons in this way. Aside from the user experience, the study also evaluates the effectiveness of the interaction modes by asking the users to fulfill tasks planned in the phase four of interaction design and user feedback. The results show the extent users are engaged in augmented learning with innovative interaction modes facilitating the learning. However, learning can be affected when information displayed on the screen is not significant enough. The user experience and usability test will necessitate a follow-up study. In the future, different chemical elements will be introduced to the subsequent design of the augmented learning serious game, and the result of the study will be used to amend and intensify the subsequent development of the current design and scheme. Eventually, a more systematically approach to and a promotion of the study result will be implemented to lay a foundation for related research on multi-modal augmented learning serious games.

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