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스마트폰의 센서를 이용한 가상 실험 콘텐츠의 개발 및 설계

정광식*, 권수열**, 웬하오 후앙***

요 약

자연과학에 있어서 실험실습은 중요한 과정이다. 그러나 실험 과정에 대한 선행학습을 통해 자연과학 전공자들은 위험한 실험을 인지할 수 있고, 이를 통해 실제 실험에서의 위험을 피할 수 있다. 모바일 어플리케이션인 가상 실험 콘텐츠는 학습자에게 안드로이드 스마트폰이 가지고 있는 다양한 센서를 통해 상호작용을 제공한다. 그리고 본 논문에서 개발한 가상 실험 콘텐츠를 통해 학습자들은 화학 실험실습 도구를 다룰 수 있는 선행 학습을 수행하게 된다. 본 논문은 학습자들의 실험 능력을 향상시키기 위한 가상 실험 콘텐츠를 설계하고 개발하였다.

키워드 : 가상 실험, 스마트폰, 이러닝, 모바일 러닝

Design and Development of Sensor-based Virtual Experiment Contents for Smart Phone

Kwang Sik Chung*, Sooyoul Kwon**, Wen-Hao Huang***

Abstract

Experiments and practices are critical instructional activities for teaching and learning natural sciences. However, by learning the experimental procedures in advance with the help of Virtual Experiments, natural science majors may address danger of handling chemicals before carrying out experiments in the laboratories. Virtual Experiments, a mobile learning app, provides learners with interactions between the learners and the contents by using the sensor built-in Android-platform smart phones. With the app, learners may handle the chemicals and experiment apparatuses, verify the reactions and assembly of the chemicals and instruments in advance. This paper describes the design and development of the Virtual Experiments in hope to promote the integration of mobile learning apps in order to better engage learners in the laboratories.

Keywords : virtual experiments, smart phones, e-learning, mobile learning

1. Introduction

E-learning was developed rapidly along with the development of information and communication technology. Due to its economical advantage over existing face-to-face learning environment, E-learning was spread among businesses and many formal education institutions to be used in forms of blended learning. This new learning environment is appropriate where knowledge transmission is required, such as lifelong educations, job trainings, etc. E-learning enables learners' autonomous learning as they take the control over time and range of

※ 교신저자(Corresponding Author: Kwang Sik Chung
접수일:2013년 06월 04일, 수정일:2013년 06월 11일
완료일:2013년 06월 13일
* 한국방송통신대학교, 컴퓨터과학과
Tel: +82-2-3668-4654, FAX:+82-2-3673-2384
email: kchung0825@knou.ac.kr
** 한국방송통신대학교, 환경보건학과
Tel: +82-2-3668-4701, FAX:+82-2-3668-4701
email: sykwon@knou.ac.kr
*** University Illinois at Urbana-Champaign, EPOL
Tel: +1-217-333-0807 , Fax: +1-217-333-0807
email: wdhuang@dcs.ac.kr

his/her learning. Along with the growing application of E-Learning is the spread of the smart phones and mobile device technology in recent years. Among various contents delivered by smart phones, educational contents are becoming more and more attractive to learners across contexts with many advantages. First, using smart phones enables the access to learning contents regardless of place and time. Second, smart phones provide user-friendly learning contents with the use of various built-in sensors, which could consolidate the cost and usage of infrastructures for providing laboratory instructions to natural sciences or engineering students. Generally, experiments and practices provided to natural science or engineering majors in offline environment require numbers of tools and materials, testing ground, and subsidiary facilities. But these requirements cost big amount of investment and maintenance. The capacity of experiments is often limited by the constraints of space, hazards of carelessly handling tools and materials, and the lack of proper safety education.

Delivering laboratory contents in E-learning environment can be highly effective in terms of improving pedagogical outcomes. But until recent years, most of experimental contents were developed with Flashes or script programming language based on desktop personal computers (PCs). These applications only allowed simple forms of input with mouse or keyboard, thus the contents were often shorter than needed in order to engage learners with higher levels of learning, which to certain extent, explains why the fields of natural sciences and engineering were pessimistic to establishing E-learning environments.

To address the aforementioned issues, this paper embodies the design and development of Virtual Experiments mobile app contents based on smart phone sensors. These contents are expected to overcome the constraints of space, to reduce cost of tools and materials, to allow more learners to participate, and to avoid the danger. Virtual Experiments contents are developed for smart phones based on Android platform, and to generate interactions between the learner and the contents by using built-in sensors. The contents also take the advantage of GUI for users to understand their tasks easily. Following sections will first discuss current literature related to the efficacy and development of simulation-based learning. Second, we will describe the design and developmental processes of Virtual Experiments. Finally we will conclude the paper by providing insights and future research and development agenda derived from the Virtual Experiments mobile application.

2. Relevant Research

2.1 Established Classification and Characteristics of Learning by Simulations

The Virtual Experiment contents allow the learners to have experience of experiments and practices through appropriate online alternatives, rather than through offline experiments and practices. In order to establish this new learning environment, virtual experiment model should be designed and developed by emulating systems or procedures of using experiment instruments. From the perspective of continuously improving laboratory instruction, the virtual experiments model may be used to explain and predict learning activities and learning behaviors in the actual experiment. The simulated learning environments may also be adjusted to given instructional variables and enable the learner to interact to the circumstances according to the feedback from instructors. In other words, learning with simulations fully makes use of functions of computers to develop unique learning conditions, to manipulate instructional variables, and allow learners to solve problems autonomously upon interacting with the simulated scenarios. The simulations may provide learners with not only the virtual learning environment, but also conceptual understanding of the underlying theories or models. In the context of teaching and learning, simulations may be classified into three categories:

1) Replicable performance simulations are used in the case that the aim of the learning is to repeatedly perform a series of learning behaviors. The performance, in general, is clearly and previously defined, and the main purpose of this type of simulations is to build a close connection between the actual learning activity and simulated learning activity. 2) In information Retrieval Simulations, learners can acquire information or knowledge, such as concepts or fundamentals. From simple facts to complicated cause and effects, various types of information may be provided. These kinds of simulations are made of muscular motion, physical experiment, chemical reaction experiment, environmental pollution, progress simulation, etc.. 3) Encounter simulations are to help learners experience learning environment through unpredictable situations or without previous concrete definitions, and to let learners search the effects of other selective methods or to provide learners with the opportunity to play other roles, rather than to perform certain functions.

Our proposed virtual experiments contents are classified as encounter simulations. Learners read experimental goals and apparatuses explanations. After that, learners assemble experiments tools and apparatuses as like off-line experiments class and operate experimental tools in virtual experimental environment of a smart phone.

2.2 Proofs of Concepts

Prior research and development efforts have acquired some success in integrating laboratory instruction with simulation learning, which provide numerous proofs of concept as the foundation of our design on Virtual Experiments.

In Fig. 1, Virtual Chemistry is an example of virtual experiment learning module managed by the Department of Chemistry in Oxford University. It provides learners with online virtual contents with 10 categories on their webpage and developed based on desktop PC. This site is developed and managed by Oxford VR Group and consists of digital movie file, animations, 3D animations, and Q&A board.

(Figure 1) Virtual Chemistry of Oxford University

Another example, Online ChemLabs, is managed by Oregon State University targeting freshmen on the subject of general chemistry. The content is hosted on a website and downloadable on leaners' computer. On this site, usage descriptions of chemical experiment tools, liquids, measurement tools are explained and learners can play and watch video files for usage of them. And explanation windows can help learner understand course of experiments and experiments theories.

(Figure 2) Online ChemLab of Oregon State University

Kongju University Digital Experiments Lab in South Korea also delivers digital virtual experiments from a website (http://princess.kongju.ac.kr/digitalmain/framekor.htm). See Fig. 3 for the screenshot. It mainly covers engineering related subjects and was funded by Korea National Research Funds.

(Figure 3) Kongju University Digital Experiments Lab.

Previous virtual experiment learning contents based on desktop computers have only restricted input devices (i.e., keyboard, mouse) so that interactions of learners are flat and simple. As a result learners could easily lose their learning interests toward the intended contents. Furthermore, the location-dependency of desktop computers poses challenges to allow learners to access virtual experiments contents anytime from anywhere. To address both issues, this study developed the Virtual Experiments learning module for the smart phone, which can provide a high level interaction between learners and the content, to increase and maintain the learning flows.

3. The smart phone Sensors-based Virtual Experiments Learning Module Design and Development

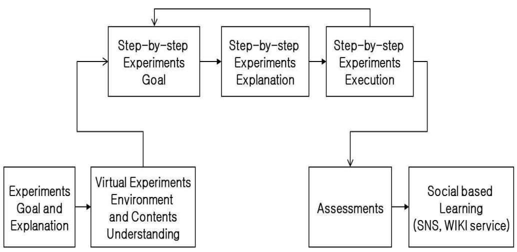
3.1 Classification and definition of virtual experiments learning contents

Virtual Experiments' intends to realize the objective of delivering laboratory instructions in virtual environments. Virtual Experiments was designed using comprehensive multimedia features to simulate the actual experiments and practice environments. In simulation-based Virtual Experiments, learners will be able to develop indirect experiences by interacting with concepts, principles, mutual relations, machine's operating procedures, instructions, and changing processes of circumstances in realistic learning situations. The Virtual Experiments also utilizes sensors-based simulation on certain aspects of the learning tasks, to mimic the authentic laboratory situations. As a result, learners may perceive increased motivation through interacting with simulated high-fidelity problem-solving tasks. Specific to laboratory instruction, with Virtual Experiments learners can safely experience the experiment procedures through simulated learning situations, which enables the full activation of cognitive, affective, and psychomotor learning during the interaction.

Virtual experiments contents for e-learning has classification matrix as like dimensionality, learner motion, frame of reference, multimodal interaction, and virtual experiment contents driving person. Our virtual experiment contents has characteristics of 2D dimensionality, dynamic learners motion, inside-out of references, multimodal interactions between learners and learning contents, and learner driving virtual experience. And our virtual experiments contents are similar with tutorial learning model. But our virtual experiment contents provide interactions with learners, and according to learner's reactions, and immediate feedback.

3.2 Learning Scenario Sequence Design for Virtual Experiments

Learning sequence for Virtual Experiments learning contents is developed based on the tutorial learning. The learning aim of virtual experiment scenario is a chemical experiments experience, and each experimental event becomes each virtual experimental stage that is needed to be completed successfully by learners. Each experimental stage consists of step-by-step learning content of virtual experiments including objectives and descriptions for each stage. Furthermore, each virtual experiments stage can be repeatedly accessed by learners in various ways of experimental explanations, step-by-step experimental apparatus explanations. Virtual Experiments contents are progressed as follows according to learning sequence.



(Figure 4) The process of scenario tracking

Virtual Experiments scenario sequence is divided into suggestions of experimental learning goal explanation, virtual experiments environment and contents understanding, step-by-step experiment presentations, step-by-step experiment explanations, step-by-step experiment executions, assessments, and social networks service(SNS) based experiment result sharing, feedback and wiki services as line in fig. 4. The step-by-step experiment presentations, step-by-step experiment explanations and step-by-step experiment executions can be conducted repeatedly by learners and instructors can decide how many times to repeat the steps and when learners can skip the step. The SNS-based learning feedback of the last stage of the scenario tracking tutorial learning model is supported among learners and between learners and instructors, to guide learners' study and sustain their interests. Finally the experiments results reports are shared with other learners through SNS-based wiki service to take the advantage of peer learning.

3.3 Development Method of Virtual Experiments

The Virtual Experiments was developed with a systematic approach according to the following stages: Analysis stage, planning stage, Development stage, and Formative Evaluation and Improvements stage.

At Analysis stage, we analyzed virtual experiment contents' goal and needs of instructors and learners. From those results, we extracted learners' learning interests and learning interactions. The virtual experiments contents were divided into several bite-size and bite-time contents. Even though virtual experiments contents should be divided into bite-size, the bite-size content should be logically independent with others and have their own quizzes and feedback. In this stage, we had much discussion with virtual contents development team who has experienced virtual e-learning contents and smart phone based e-learning contents. The content development team consisted of writers, content specialists (instructors), instructional design specialists, programmers and editors who provided development guideline and development instructions for content developers.

At Plan stage, instructors whose major is chemistry developed the first sample scenario. Virtual contents development team discussed the sample scenario and modified the sample scenario according to developers' input. In particular the sample scenario should be followed programming guideline so that the modified sample scenario could be useful and helpful for developers to program codes for the virtual contents.

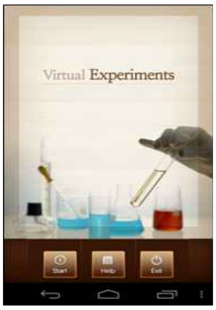
At Development stage, based on development and programming guidelines, virtual contents developers and programmers developed the sample contents and discussed the sample contents with instructors and coordinators. If instructors and instructional design specialists request the sample contents to be modified and changed, the virtual contents development team decided modifications of the sample contents. And if the developers and programmers request the scenario to be modified and changed, the virtual contents development team discussed and decided modifications of the sample scenario.

At Formative Evaluation and Improvements stage, the developed Virtual Experiments prototype was evaluated by a small group of potential users in terms of its usability and feasibility.

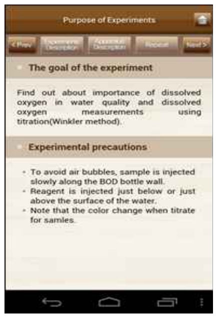
3.4 Developed Virtual Learning Contents

Based on the forementioned learning model and development method, we developed virtual experiments learning contents on a smart phone that stimulates learners' interactions with the intended laboratory instruction. Several important concepts on effective learning were considered when designing the virtual experiments content for chemistry experiments. Design factors such as experiment tools manipulation feasibility, experiments scenarios, especially the relation among sensors were taken into account to enhance the interactions between learners and the contents. The following section describes the steps learners should take in order to interact with the Virtual Experiments.

After the Start page, leaners should read and keep in mind the goal of experiments and experimental precautions that should be warned about at off-line experiment class in (Figure. 5 and 6.)

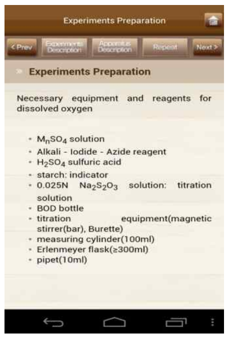


(Figure 5) Main Screen



(Figure 6) Purpose of The Experiment

(Figure 7) Explanation of The Experiments



(Figure 8) Experiments Preparation

At Experiment Preparation page, in order to start experiments, experiment apparatuses that should be prepared for experiments are introduced to learners. After that, learners can start conducting virtual experiments on their smart phones. Learners should assemble experiment apparatuses so that learners can finish individual experiment steps. From Fig. 9 to 11, a learner needs to assemble the apparatus first by dragging and dropping corresponding items on top of the page; then the learner tilts his/her smart phone so the liquid in a beaker is poured into the apparatus.

(Figure 9) Apparatus list

(Figure 10) Assembled Apparatus

(Figure 11) Pouring Action

At Precipitation stage, as the learner shakes his/her smart phone, the precipitation of the liquid gets thickening and changes color as the result of this experiment. See (Figure 12, 13, and 14.)

(Figure 12) Precipitation (1)

(Figure 13) Precipitation (2)

Figure 14) Precipitation (3)

After completing all step-by-step virtual experiments, learners should take three quizzes and can check answers and explanation for the answers.

4. CONCLUSIONS

In recent years mobile devices have been widely used for accessing mobile networks and contents. Especially the smart phones have become a main device option for mobile learning, which has several characteristics that are not supported by desktop computers. smart phones can provide mobility and seamless contents access so that smart phones could be the best fit for mobile learning with frequent learning interactions. Virtual experiments learning contents needs frequent learners' interaction so that it has to be implemented based on smart phones that can extract learning interests and improve learning effects and flows for learners.

The primary objective of this research is to develop a virtual experiments learning contents for natural science learners for smart phones and exploit smart phones' sensors for learning interactions. The second objective is to develop the virtual experiments learning contents according to digital textbook development methodology (Kwang Sik Chung, et al.. (2010). Virtual experiments learning contents for natural science and engineering have advantages such as with learning interesting factors enhancing learning flows. Learning interactions factors enhancing learning effects and flows by virtual experience should be developed and serviced with virtual experiments learning contents with a smart phone. With these kinds of virtual learning contents and advantages, learners get knowledge and experiences about real experiments.

During the development of virtual experiments learning contents, we had many kinds of conflicts and misunderstanding between writers, content specialists (instructors), instructional design specialists, programmers and editors so that we need more concrete development methodology and scenario tracking tutorial learning model for virtual experiments learning contents.

We are planning to support communication and feedback function such as twitter, blog, RSS to our virtual experiments learning contents.

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정 광 식

1993년 : 고려대학교 대학원 (이학석사)
2005년 : 고려대학교 대학원 (이학박사-모바일 컴퓨팅)
2005년～현 재: 방송통신대학교 컴퓨터과학과 교수
관심분야 : 이러닝(e-learning), 유비쿼터스 컴퓨팅

권 수 열

1986년 : 고려대학교 대학원 (환경공학석사)
1992년 : 고려대학교 대학원 (환경공학박사-토목공학)
1992년～현 재: 방송통신대학교 환경보건학과 교수
관심분야 : 이러닝(e-learning), 지하수 정화 및 하수관리

웬하오 후앙

2002년 : 퍼듀대학교 대학원 (교육공학)
2006년 : 퍼듀대학교 대학원 (공학박사-교육 설계 및 공학모바일 컴퓨팅)
2005년～현 재: 일리노이 어바나-샴페인 대학교 교육대학교 교수
관심분야 : 이러닝(e-learning), 게임 러닝, 오픈 러닝