

Smart Science Laboratory for Improving Learning Interest

Jong Weon Lee, Kyung Jin Han

Dept. Digital Contents

Sejong University

Seoul, Korea

jwlee@sejong.ac.kr, kjinn.han@gmail.com

Eun Kyoung Choi¹, Kyung Soon Baek², Yoon Jang³

Dept. Cartoon Animation^{1,2},

Dept. of Computer Engineering³

Sejong University

Seoul, Korea

ekchoi@sejong.ac.kr¹, yubin6566@naver.com²,

jangy@sejong.ac.kr³

Abstract—We propose a smart science laboratory in this paper. There is a lack of scientific experiment and investigation in science education for elementary, middle and high school students in Korea. Teachers solely focus on transmitting knowledge and there is a lack of laboratory apparatuses for rapidly developing science areas. Because of these shortcomings, students lose interest in science as they progress through the education system. The smart science laboratory consists of virtual and remote laboratories, a local data collection procedure and hybrid visualization to overcome this problem. We hope we can increase students' interest and satisfaction in science using the smart science laboratory that can support and supplement science education in schools today.

Keywords—virtual laboratory; remote laboratory; science education; simulation.

I. INTRODUCTION

Traditional instructions such as lectures and teacher demonstrating an experiment in front of a class do not encourage students to think and to solve given problems. Researches show that there are advantages when students conduct investigations themselves for the purpose of science inquiry compared to traditional instructions [1, 2]. Investigations provide students with opportunities to interact directly with the material world, collect data, and learn scientific theories [3]. Hands-on physical investigations typically fill this need. Korean government tried to build up-to-date physical laboratories for several years. Due to the fact that science and technology evolves so quickly, it is difficult to constantly build up-to-date laboratories that can keep up with the current state of science and technology for all elementary, middle and high school students.

Virtual laboratories have been developed to replace or supplement physical laboratories. The concept of virtual laboratories implies the replacement of real measurements with simulation [4]. Virtual laboratories have been compared with physical laboratories and demonstrated that they can achieve similar objectives to physical ones. The research in [5] demonstrated that virtual laboratories can replace physical ones for acquiring conceptual knowledge. Many research studies have also shown the advantages of virtual, interactive exploration of unobservable phenomena compared with physical ones. Students can experiment unobservable phenomena, such as chemical reactions and

electricity, using a virtual laboratory [6, 7]. Students can vary the properties of rays to examine the unobservable light behavior in OptiLab [8]. The National Aeronautics and Space Administration (NASA) Education provides professional materials and educational materials about astronomy, weather, geology and ocean through genuine multimedia content and simulations that a user can modify variables [9].

For some experiments it is still difficult to replace physical laboratories with virtual ones. It is necessary to manipulate real equipments in the experiments. Many researchers have developed remote laboratories to overcome the limitation of virtual laboratories. Students can access real equipments and collect real data through remote laboratories [10-12]. iLAB is remote laboratory. It started from the research at Massachusetts Institute of Technology (MIT) with the goal of controlling professional scientific equipments in graduate school [13].

Many useful virtual and remote laboratories have been developed and provided students with science inquiry learning. Many specialized research institutes such as NASA and MIT have developed educational content that provides laboratory and scientific investigation experiments utilizing computing technologies. Korean students can obtain useful information from that content but they could decrease the interest in the content and its intuitiveness. The data covered in these virtual and remote laboratories are not from Korea but from foreign countries. These virtual and remote laboratories target specific topics and meet the goal of the education system in which those laboratories are developed. It is necessary to develop the virtual laboratory that can be adapted to the Korean science education system.

The goal of a proposed research is to develop a smart science laboratory that can supplement physical laboratories that are vital facilities in Korean science education and also foster advanced science education and reinvigorate science education. The desired effect of this is to boost interest and increase satisfaction among students in science education. The developed smart science laboratory has three characteristics.

- 1) Combine virtual and remote laboratories
- 2) Provide students with a way to collect local data
- 3) Provide a hybrid visualization that combines simulations and videos

In Section 2, the proposed smart science laboratory is described. Section 3 describes content developed for the smart science laboratory for the experiments and its results. Finally the conclusion is provided in Section 4.

II. PROPOSED METHOD

The proposed smart science laboratory combines virtual and remote laboratories to capitalize on the merits of each approach. When the scientific inquiry requires to modify model characteristics, such as time scale, or to observe not easily observable phenomena, such as the birth of typhoon, a virtual laboratory is applied. A remote laboratory is used if a real procedure or experiment result is helpful to students.

A. Virtual Science Laboratory

The proposed virtual science laboratory consists of three procedures: a local data collecting procedure, a visualization procedure on web and app environment, and an interaction procedure suitable for elementary, middle and high school students.

Mainly, public data are used in the proposed virtual laboratory. Public data of natural phenomena, such as changes in the contour of autumnal leaves in Korea, were used to create the corresponding simulation. We also added ways to collect data related to the simulation, such as photos of autumn leaves in local areas with location information, using students' mobile devices. The system compares public data and students' local data. If two types of data are matched, the system uses the result to verify the simulation results. If students' data are not a match with the public data, then the system suggests possible causes for the differences. The smart mobile device is also used to collect data, such as information on food additives, that are not available to the public yet. The system uses image processing techniques that allow students to easily collect data. For now, students can only capture images of food packaging with their smart mobile devices that makes it unnecessary to manually type the name of the additives into a mobile device or a website.

The visualization procedure utilizes the hybrid visualization approach that shows users the simulation result of the collected data and pre-created videos selectively depending on the goal of the learning. When users need to experiment with various conditions, simulations with given variables are created and shown to users. When the reality of the experiment is more important than the direct manipulation of the experiment, we show pre-created videos to users. The interaction was developed to meet the features of elementary, middle and high school students. For elementary school students, a simpler user interaction method was provided.

B. Remote Science Laboratory

Students can attend the scientific experiments and examine the results remotely using the smart remote science laboratory when they cannot be on site. To achieve this goal, we developed the system so that users can change samples and alter variables in the scientific experiment using the LabVIEW [14] program. The remote experiment done by a user is recorded and stored in a database. The system also

provides ways to request the scientific experiments when it is difficult or dangerous for novice users to involve the experiments directly. Students can view live or recorded videos of the experiments being conducted by an expert. We provide this passive approach to increase the diversity of the scientific experiments. Students can view any experiment done by other students through recorded videos. Students can plan their new experiments after viewing the recorded experiments.

III. EXPERIMENT

We asked 100 teachers from elementary, middle and high school using a questionnaire on what type of content would be suitable for the proposed smart science laboratory. Teachers considered the following three experiments useful for their students.

- 1) Experiments that cannot be observed visually
 - 2) Experiments in the area of physics, earth science and other related areas
 - 3) Experiments with real data and relevant to people's lives
- Based on these survey results we created two types of content, which involve typhoons and food additives, for the virtual laboratory. A spectroscope and high-speed camera were selected as the equipment for the remote science laboratory.

The typhoon simulation consisted of the birth of a typhoon, the direction of typhoons and typhoon forecasting. The process of how a typhoon is created was simulated and shown to students. Students can simulate different typhoons by modifying water temperatures and the originating locations of a typhoon. Students can also simulate the direction of a typhoon by adjusting temperatures, the originating position and positions of North Pacific High and Jet Stream around Korea (Figure 1). The typhoon simulations created by one student were recorded and shared with other students. Students are also able to predict the direction of well-known typhoons with the supplied information. The system could provide users with the partial position of typhoons and users can predict the position of the typhoon on the following day and compare the estimation with the actual position of the typhoon.



Figure 1 Simulating the route of a typhoon

The food additive simulation consisted of searching food additives, simulating effects of additives and a food additive diary. Students can search additives for the specific food products by entering the name and barcode of the food product on the website. The system will search for additives included in the food from the database and display the additives to users. When the additives of a target food are not found in the database, the system will ask users if they wish to add the additive to the database. The numbers of additives collected by each student and each school are recorded and shown to all students. The school that adds the most additives to the database receives a special prize. This may increase engagement with students in the process of collecting additives of new food product. These data will be useful to other users because food additive database has not been opened to public yet. If the student has a smart mobile device, he/she can capture images of the name and the barcode of the food using the camera on a mobile device. The image processing procedure will detect the name of the food from the captured images.

In food additive simulation, students can select a food additive and its amount then the food additive simulation part presents the simulation result to students. Students can simulate with various settings of the experiments to understand the changes caused by them. Figure 2 shows how food with/without food preservatives changed over time. Students can modify time variable and watch the simulation results of food with/without preservatives. The comparison videos are also provided to students to provide more realistic experimental results for the selected food additives. This hybrid visualization could improve students' understanding of food additives. My food additive diary records amounts and types of food additives users ate on each day. To use my food additive diary, students only need to capture images of the cover of food packaging instead of typing food additives using a keyboard. We applied image processing techniques so food additives can be automatically collected from the image captured by students.



Without Sodium Nitrite With Sodium Nitrite
Figure 2 Simulating the effect of food additive

The LabView program was used to change the samples of the spectroscope experiments and to modify the spectral region and degree of precision of the experiments through the app and website in the spectroscope remote science

laboratory. The results of the experiments were stored in the database and users can monitor the experiment procedure through live videos. It is a time-consuming procedure to find the optimal lab setting for capturing data with a high-speed camera. This also made it difficult to view the experiment in live view and to modify variables in the experiment. For the high-speed camera remote science laboratory, we developed an online procedure to requesting an experiment. When it is possible to capture the experiment with the high-speed camera, the procedure is recorded and edited so students can view the procedure and results online. The recorded procedures and results are stored and shared with other students.

The resulting content was exhibited in 2014 World IT Show in Korea from Oct. 20th to Oct. 23rd. Users provide positive feedbacks about the developed content. Figure 3 shows an elementary student with his mother experimented with the food additive content. He captured the image of the cookie packing using the camera attached to a smart mobile device and viewed the food additives included in the cookie.



Figure 3 An elementary student using food additive content in the show

IV. CONCLUSION

The goal of the proposed research is to develop a smart science laboratory that helps students gain experience in a lab environment to undertake scientific investigation. So far, the basic platform and sample content has been developed. The sample content was tested by ordinary people at the 2014 World IT Show in Korea and received favorable feedback. However, we have not yet tested the platform and content on students. We will select six schools to test the platform and content after developing more content. The resulting user test will be used to modify the platform and its content so students in many schools can use the smart science laboratory. Through the smart science laboratory, we hope to foster interest in science among students so that more students will be willing to enter the field of science.

ACKNOWLEDGMENT

This work was supported by the ICT R&D Program of MSIP[10114-14-1016, Building and demonstrating the 'Smart Science-Lab' to cultivate talent] and the Creative Vitamin Project.

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