Remote Laboratory System for Technology-Enhanced Science Learning: The Design and Pilot Implementation in Undergraduate Courses

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Abstract: In this study, a new remote laboratory (RL) system is developed through some innovative ideas and methods for practicing technology-enhanced learning of science in schools. The Internet-based RL system will enable students to control the server-side laboratory equipment and to carry out real-time scientific investigation activities at distance places. As a pilot study, a set of newly developed remote-controlled experiments were first tried out by a total of 64 undergraduate students who studied some science education and teacher training courses. The evaluation used mixed research method which included questionnaire survey and interviews as specifically developed by us to collect data on students' perceptions, views and implementation issues related to the use of the RL system. The survey findings showed that the participants agreed with the appropriateness of various educational merits of the RL system but negative comments and suggestions for improvement were also received. Through iteration of Design-Based Research (DBR), we have refined our RL system.

Keywords: remote laboratory, technology-enhanced learning, science education

1. Introduction

With the rapid advancement of technology and the prevalent use of Internet in education, science practical work in form of web-based laboratory or remote laboratory (RL) has recently been adopted in cloud computing. As a simple definition of the RL system, "the basic idea is for a user to connect via the Internet with a computer from place A to a real experiment carried out in place B" (Grober, Vetter, Eckert, & Jodl, 2007, p. 127). Recent education reforms have identified the importance of technology-enhanced science learning, which can be achieved in science education through RL system (Kong, Yeung, & Wu, 2009; Lowe, Newcombe, & Stumpers, 2013). Using this RL system, students can view and control apparatus/equipment in science experiments, and downloads real-time data in classroom, computer laboratory or even at their homes. Therefore, the RL can be considered as a kind of new development in technology-enhanced learning (TEL) in which appropriate technology and pedagogies are innovatively applied in science education.

The first part of this study is to design and develop of an innovative RL system through technology-enhanced inquiry for Hong Kong science education. Of course, we are aware that it is hard to evaluate this innovative system just based on the design or development itself. As a result, a pilot evaluation in two undergraduate classes was conducted as the second part of the study.

2. Research Methodology

2.1 The RL System Design

In developing and designing the RL packages, this study adopts the Design-Based Research (DBR) framework (Design-Based Research Collective, 2003; Reeves, 2006; Wang, & Hannafin, 2005) and it involves four important iteration phases of design, testing, analysis, and refinement.

For design, the development of the RL system includes identifying the needs of the RL system for science practical work and searching feasible experiments, calibration of sensors, software development, and designing a complete remote-controlled experimental setup for an inquiry science experiment. Hence, several feasible experiments (Table 1) that can be incorporated into the RL system were identified with reference to the local school science curricula. The system includes the Laboratory Virtual Instrument Engineering Workbench (LabVIEW) software which is a graphical programming language that uses icon-based rather than lines of text form to generate programs. It equips with the data acquisition hardware and remote control application through the web publishing tool.

Table 1: The design and content of remote-controlled experiments.

Experiment	**Changing Parameter**
E1: Sound as vibration	Wave type, sound frequency & volume.
E2: Electrical circuit	Number of bulbs in series & parallel.
E3: Phototropism experiment	Three position of light source & plants horizontal position.
E4: Gravitropism experiment	Plants vertical position at 30^{o} or continuously.

2.2 Evaluation: Testing and analysis

For evaluation, 64 valid undergraduate students in two different courses namely Course 1 (major in a science and web technology programme) and Course 2 (major in a teacher training programme) voluntarily participated in this mixed method research. During their laboratory session, a set of newly developed RL technology-enhanced inquiry activities was conducted by the participants. Based on their learning experiences, self-developed survey questionnaire with four Likert scale and open-ended questions as well as interview were used to collect participants' views, perception and difficulties of using the RL system.

3. Findings, Analysis and Discussion

3.1 RL system

For the RL system, four remote-controlled experiments were successfully developed. Figure 1a presents the design of the RL system for performing remote experiments and Figure 1b shows the webpage for the E4 plant experiment of Gravitropism to be conducted by students. The RL guide and movies for those experiments could be found online at http://rcl.ied.edu.hk:8000/sample/index.htm and the webpage also demonstrates how this remote technology is being employed.

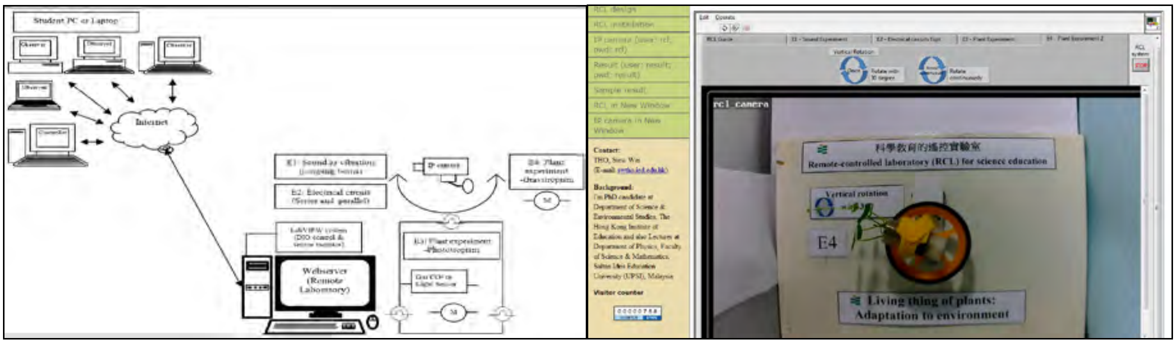

Figure 1. Remote laboratory system: (a) the structure of RL system for performing science experiments; (b) webpage display of the RL system for gravitropism experiment.

3.2 Survey

For this first implementation, we focused our analysis on the undergraduate students' views and suggestions to the RL system refinement before its formal implementation and evaluation in secondary schools. It is because their valuable views and suggestions are very important for us as they learned science education and teacher training courses. For this reason, no conceptual test was used in this DBR study. Table 2 reports the evaluation data as obtained from the student survey. Overall, the survey findings from all participants showed that they agreed with the educational merits underlying the RL system in the present study. However, Course 2 participants constantly rated higher in the survey items compared to Course 1 participants. Based on open-ended questions and interview data, the comments and suggestions for improvement of the RL system were received.

Table 2: Participants' response on survey items (N=64).

Category	Course 1: mean (SD) (N=30)	Course 2: mean (SD) (N=34)	Overall: mean (SD) (N=64)
Insight of Science & ICT	2.91 (.55)	2.98 (.64)	2.95 (.60)
Operating the RL system	2.90 (.50)	3.06 (.42)	2.98 (.46)
Enriching the learning	2.82 (.89)	3.03 (.59)	2.93 (.75)
Developing application	2.78 (.66)	2.99 (.52)	2.89 (.59)
Stimulating motivation	2.80 (.78)	3.14 (.54)	2.98 (.68)
Improving teaching skills	2.87 (.65)	3.06 (.45)	2.97 (.56)
Promoting group work	2.73 (.73)	2.97 (.57)	2.86 (.66)
Enhancing teaching self-efficacy	2.81 (.67)	2.99 (.45)	2.90 (.56)

3.3 Refinement

Based on analysis, we refined the RL system by using high resolution of IP camera, modifying existing remote experiments and adding new feasible remote experiments (plants respiration, battery bank, and solar energy experiments) as well as providing clearer RL operating guideline.

4. Conclusion

This pilot study has achieved several important outcomes. Initially, the students' perceptions, comments and suggestions of their learning experience with RL system were obtained. Then, the refinement RL system was successfully developed with some innovative application in a few science experiments that can be used inside or outside the school environment to enhance the science learning and complementary to the regular classroom teaching processes.

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