Developing HOTS with VISSER: Bridging the Need for Science Instrumentation in Philippine Schools

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ABSTRACT

There is a great need to improve science laboratory in the Philippines. Thus, the Versatile Instrumentation System for Science Educational and Research (VISSER) project was conceived. VISSER proposes to advance a system which can develop the higher order thinking skills or HOTS of students through laboratory activities that are essential to the development of science. VISSER likewise intends to deliver efficient, accessible and versatile solutions to perennial problems such as the lack of science equipment in laboratories through the use of a microcontroller platform, reliable sensors and educational modules. This research addresses the need to improve science laboratory activities in a classroom environment through the development of learning materials using Versatile Instrument System for Science and Technology (VISSER). Moreover, the research also proposes ways for VISSER to develop higher order thinking skills in the cognitive domain in the context of a science experiment.

Three traditional experiments were modified and tested with the use of VISSER - a microcontrolled-based platform. The study discusses how VISSER enhances higher order thinking skills in the experiments that are modified. It was concluded that higher order thinking skills (HOTS) can be developed through the use of a cost-effective yet technologically sophisticated instrumented science interface coupled with highly descriptive laboratory modules in the Philippines, as well as with other developing countries with the help of VISSER.

KEYWORDS: *HOTS, Science laboratory, Science Education. VISSER*

INTRODUCTION

The indispensable role of a laboratory as a medium of instruction for science education is well established. Studies by Schwab[1], Hurd[2] and Lunetta & Tamir[3] have shown the importance of hands-on labs for students to learn through investigation and inquiry. Stohr-Hunt[4] has shown that frequent hands-on activities improves students' performance on a standardized science test. Cognitive skills are developed by acquiring new information gained through experience as it relates to "schema" (prior knowledge). This learning paradigm occurs in labs in which teachers become facilitators rather than the sole authority for knowledge. Science laboratories are examples of learning environments wherein students acquire, apply and create knowledge.

Sadly, the Philippines allocates barely 2.3 % of its GDP on education. This is about 1/3 of the recommended budget for education by the United Nations[5]. The Department of Education (DepEd) data in 2012 showed that only 13 percent or 5,821 schools out of 45,977 public elementary and high schools have science laboratories[6], and some estimate that nationwide, there are 1,325 students that share one laboratory setup[7]. This statistic is alarming, and without a dramatic infusion of resources or some other transformative program, Philippine students are denied valuable learning experiences to be competitive on the world stage.

In order to bridge the gap between the need and lack of science laboratories in the Philippines, a program called VISSER (Versatile Instrumentation System for Science Education and Research) was established last May 2012 under the Balik Scientist program. It is a two-year project funded by the Department of Science and Technology (DOST) and is currently housed at the National Institute of Physics of the University of the Philippines Diliman.

VISSER is a collaborative program that also involves UP Diliman, UP Los Banos, University of San Carlos and the University of Maryland, College Park, and mainly focuses on the goal of “putting modern science laboratories at every school and college”. The deliverables include at least 60 handheld devices that incorporate inexpensive but sophisticated ready-to-commercialize experimental modules.

This paper provides a broad overview of the program and illustrates the use of the VISSER system and how it can be adapted in standard experiments. It discusses the pedagogic role of VISSER in enhancing HOTS (Higher Order Thinking Skills), and delivers a commentary on future implementations.

METHODOLOGY

Program Overview

The overarching goal of the VISSER program is to alleviate the shortage of laboratory instruments and modules in the Philippines, by using the intellectual capital available in the country. It involves three key steps. The first is to spur the creation of innovative ideas for laboratory modules from teachers, students, researchers and other stakeholders. It is implemented by staging one to two week long workshops around the country for teachers and students; and training them in the rudiments of VISSER. The trainees engage brainstorming activities with the clear goal of identifying topics that are included in the current science curriculum for which experiments using VISSER can be effectively introduced. They then design the experimental procedures and write preliminary manuals that conform to established standards. Apart from the workshops, an alternative path in achieving the same goals is the incorporation of VISSER in an introductory engineering design class. It was implemented at UP-EEE, which yieded significant results.

The second step is to optimize the prototypes and refine the design specifications by considering realistic constraints. Full-time project staff and researchers from the ranks of the university faculty evaluate the initial designs and make modifications in close collaboration with the science educators in the country. Together, this team suggests changes in the nascent modules that consider issues of cost, pedagogical efficacy, acceptance by the teacher, and safety.

The last and final step involves the preparation of the compiled manuals and thorough review by experts in the field of experiment. This also includes beta testing and designing for large-scale production. The manuals are finalized and considered to be ready for widespread dissemination.

The VISSER Data Acquisition System

The VISSER handheld as shown in Figure 1A is a microcontroller-based platform that could be connected to various sensors such as temperature, humidity, conductivity, light, voltage, ultrasonic distance, color, pH sensors, etc. It could read analog and digital values for the above mentioned quantities. This handheld is programmable which allows the user to dictate how to manipulate input and output data.

In order to illustrate the efficacy of the VISSER handheld, high school experiments that deal with simple harmonic motion of pendulums, the Tyndall effect and Beer’s law were implemented. The experiments on simple harmonic motion utilize an ultrasonic distance sensor for measuring the displacement and period of the pendulum. The other experiments use three photo-detectors to simultaneously measure the intensity of the scattered light in the case of the Tyndall effect, or the intensity of the transmitted and absorbed light in the case of Beer’s Law, as the concentration (number of drops) of the colloidal solution is increased.

RESULTS AND DISCUSSION

Sample Experiments

In the first experiment, the displacement and period of the pendulum were measured using the ultrasonic distance sensor. The ultrasonic sensor creates a short sound burst at 50kHz and detects its echo. The distance is calculated by measuring the time .

Traditional experiment for pendulums only gets the relationship of the period of the pendulum to the angle of displacement and the length of the pendulum, while by simply relying on the reaction rate of the reader which is subject to errors. The same is true for traditional experiments for springs. However, with VISSER handheld, there's no need to rely on the reaction rate of the experimenter. The handheld could output time and displacement for the pendulums' motion. Also, if connected to a software that could plot a graph like Python, real time plots can also be seen. Moreover, displacement of pendulums that were swung at various angles could also be computed automatically, which traditional experiments cannot provide.

For both the Tyndall and Beer's Law experiments, a test tube rack with nine holes was utilized. Six holes as shown in Figure 1B were used for the LED light that serve as the monochromatic. The other three slots as shown in Figure 1A were assigned to the photoresistors (LDR) placed perpendicular to the light path where the beam of light from the three LEDs on the sides would be most visible for Tyndall experiment and directly to the other three LEDs for the Beer's law experiment. For this sensor, the VISSER handheld makes analog-to-digital conversion (ADC) at a sampling rate of 10 kHz. Since the intensities tend to fluctuate, five (5) samples were taken and were averaged for a more accurate reading.

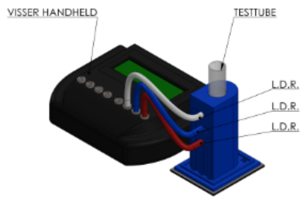


Figure 1A

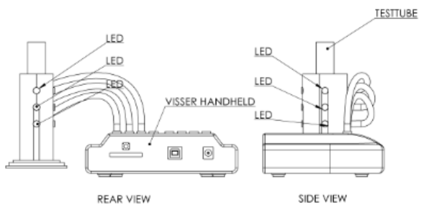
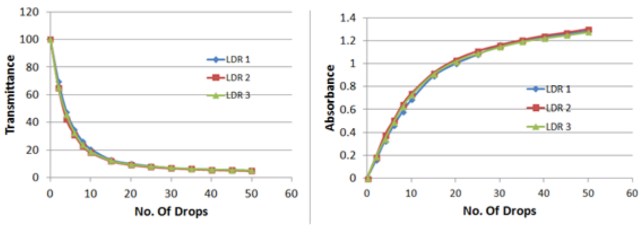


Figure 1B

Figure 1A shows the VISSER handheld connected to a Tyndall and Beer's experiment set-up. Figure 1B shows the rear and side view of the set up

The Tyndall effect experiment only demonstrates how light viewed transverse to its propagation direction become visible as it reflects off colloidal particles in an otherwise transparent solution. In this experiment, the light sources that were switched on were the perpendicular to the LDRs. The test tube rack was then connected to a VISSER module to record the light intensity readings for the three LDRs, as uniform addition of drops to initial solution were made.

The last experiment which involved the verification of Beer's law used the same procedure and setup with Tyndall effect experiment, with the exception of the LED placed directly in front of the three LDRs were switched on. Figure 2 shows sample data that verified Beer's for one of the three trials made. From Figure2b, absorbance is a linear function of concentration of solution for small concentrations.



(a) (b)

Figure 2. (a) Transmittance and (b) Absorbance versus concentration of a creamer solution

However, it is striking that for high concentrations, the law is not obeyed as shown in the plot. Figure2a exemplifies that the transmittance is not linearly proportional with the concentration of the solution, which clearly demonstrates deviation from ideal conditions.

Table 1 summarizes the key advantages of the Visser system. A particularly useful feature is the ability to use a given sensor for multiple experiments: the sensor for the Tyndall effect and Beer's law for the same principle of detection of light intensity. The only major difference is the position of the LEDs for each setup. Consequently, the sensor is especially designed to be easily used by changing its mode of measurement with the use of a simple switch.

Table 1. Summary of Experiments: Difference from Traditional Experiments, VISSER's usage and its Advantages

	Simple Harmonic Motion of Pendulum	Tyndall Effect	Beer's Law
Main difference with traditional experiments	Has automatic time and displacement reading	Able to measure intensity scattered light	Able to measure intensity of transmitted and absorbed light
Where VISSER is used	Measurement of displacement and period; extends to even measurement of force	Measurement of intensity and time	Measurement of intensity and time
Advantages	More accurate in time measuring time; has battery	Since intensities are fluctuating, a more accurate method of measurement/reading of intensities can be dictated i.e . getting the average value of the first five readings.	Since intensities are fluctuating, a more accurate method of measurement/reading of intensities can be dictated i.e . getting the average value of the first five readings.

Outlook

Actual laboratory activities and experiments, similar to what was described, will enable students to gain hands-on experience of scientific laws and principles. Students can relate their daily life occurrence to observations in the laboratory, which can further develop their understanding to scientific principles. VISSER can improve learning by effectively reducing time needed in collecting and processing of data through accurate sensors and data processors. Time saved can be used for answering guide questions with the supervision of teachers to further enrich their learning experience. Error is also reduced since manual measurements rely on subjective judgement of the experimenter.

When completed, each VISSER setup will include illustrative, up to date, and easy to understand modules that are appropriate to the learning needs of a specific grade-level. Each module has well defined objectives that can guide students in developing HOTS. These modules will be supplemented by well-written, highly descriptive manuals that will facilitate individual and group learning. Modules will be designed to focus on analysis of information from gathered data rather than developing skills on how to gather accurate data with conventional laboratory materials and equipment. These modules will encourage learning through conceptual understanding and student creativity rather than rote memorization, thus making these modules nearly effortless to use in learning and teaching. Experimentation, inquisitive thoughts and ideas will be encouraged.

In the Bloom's Taxonomy of Learning Domain, creating is the highest form of cognitive learning, whereas remembering is the lowest. VISSER lets students to create different set-ups and investigate various phenomena through its wide range experiments and applications. Having a single platform helps students connect different activities in different field of science, which can allow them to initiate diverse researches and studies. With the use of VISSER, other cognitive skills like applying, analyzing, evaluating and creating methods can be done in laboratory experiments and activities.

Finally, VISSER trains students to use scientific inquiry in solving conventional problems in their society and environment. At the same time, VISSER helps students to value scientific culture and ethics, and apply these in their everyday experiences. As early as high school, research skills and culture can be developed, which is vital in developing countries like the Philippines.

CONCLUSIONS

This paper highlights the use of a science intrumentation interface, called VISSER handheld, which when accompanied with highly descriptive learning modules, can help develop higher order thinking skills for its users. VISSER allows more time in the analysis and manipulation of experimental data through efficient data acquisition and reduced processing time. Accurate and precise measurements of physical quantities can be made simultaneously, and thereby allow sophisticated analysis by correlating different phenomena. This versatility can open to other fields of exploration for the end user beyond the objectives set by standard experiments.

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