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Scientific modeling with mobile devices in high school physics labs

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A B S T R A C T

Scientific modeling is thought to help students understand the world and scientific phenomenon. Science laboratory in school should provide well-designed activities to promote students' model building skills. Thus, this study aims to propose microcomputer based labs with several data acquisition tools and a modeling tool, which can assist students to collect and visualize data in faster and fancier ways, and generate mathematical models to fit the data, thus exercising their skills of scientific modeling. Thirty-two high school students participated in the science laboratory courses within two semesters for four labs. Results showed that students' overall success rates of model building were approaching 50%; the duration of participants' modeling time decreased with the increase of the experimental labs; the benefits of doing physics labs with smartphones were confirmed by the success rates, personal preferences, and students' feedback. Regarding students' spontaneous model building behavior in the first lab, almost 90% of the participants fitted data with linear equation; most participants adjusted coefficients to fit the data, instead of changing the highest degree of equation; and different strategies were used by successful participants and the others. These results indicated that the combination of modern data acquisition tools and fitting data with a modeling tool would provide an alternative and meaningful approach to doing physics labs at high school.

1. Introduction

Traditional physics labs in high school have two major problems. First, following step-by-step lab instructions, students focus almost entirely on fitting experimental data to known theories. Few instructors ask students to produce scientific models to fit the data. Second, most of the data logging methods are slow, resulting in low sampling rate and precision. In

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other words, science teachers focus too little on the training of scientific inquiry while too much on memorizing textbook knowledge. As a result, students are generally weak in inquiring in, explaining, formulating scientific issues and in gathering evidence to support scientific hypotheses. This calls for changes in science education. Past research results clearly indicate that learning by doing experiments enhanced learners' skills of science laboratory work (Hart, Mulhall, Berry, Loughran, & Gunstone, 2000; Lumpe & Oliver, 1991).

In laboratory practice, scientific modeling is a critical activity and powerful strategy for meaningful learning (Schwarz et al., 2009; Wu, Wu, Kuo, & Hsu, 2015). Mediating between theories and the real world, model building is to abstract and transform representation of a system (Davis et al., 2008), allowing model builders to create theories, test hypothesis, analyze data, and make predictions. However, scientific modeling is rarely incorporated into high school science laboratory. Traditionally, students are told the theory with given equations in a science lab. So their job is simply to collect data to confirm the given equations.

In 2012, Chen et al. proposed an approach of Microcomputer based laboratories (MBL) to solve challenging problems in traditional laboratory work, including low sampling rate and low precision of data acquisition tools, limited time of science classes, and the lack of teaching resources. This approach uses small and mobile tools of data acquisition with embedded microprocessors, which reduce the time in data collection and graph plotting (Kelly & Crawford, 1996; Srisawasdi, 2012; Tortosa, 2012). In this way, students can focus their attention in explaining the relationship among the data variables (Russell, Lucas, & McRobbie, 2004). This approach sets an excellent, realistic example of technology-assisted learning.

However, the laboratory tools of MBL can be quite expensive (Tortosa, 2012), leading to its limited use in school teaching (Chen et al., 2012). Given that students in MBL can propose their research hypothesis and conduct multiple trials to examine the cause and effect relationships, they do not build an explicit mathematical model that relates a dependent variable to one or more independent variables. Hence, this study proposes to combine some new, inexpensive data acquisition tools with a software that enables students to experience explicit model building in science laboratory work. With these technologies, students are asked to do experiments and collect data without any given equations. One of the most common and accessible tools is smartphones, which are getting smarter and cheaper every year. In order to evaluate the learning results with smartphones, this study also used Lego Mindstorms NXT and digital video camera for the sake of comparison. For most students, these common electronic toys are taken as a robotic kit or as an entertaining device like PlayStation but seldom thought as tools for scientific investigation like a microscope. In addition, this study has adopted a modeling tool called InduLab for data analysis, visualization, and the discovery of mathematical relationship among data variables (Wong, Chao, Chen, Lien, & Wu, 2015). Using the collected data plotted in InduLab, students are asked to express a dependent variable as a function of an independent variable. In short, this study investigates two aspects of science laboratory work: the feasibility of using InduLab as a model building tool as well as the spontaneous model building behaviors of students.

2. Literature review

2.1. MBL and related studies

Laboratory training is a critical component of science education. Several meta-analysis studies pointed out that laboratory work can improve learners' science process skills and content knowledge (Shymansky, 1989; Stohr-Hunt, 1996). Regarding the motivation aspect, without any corresponding laboratory work, lecturing on scientific concepts and theory in a traditional classroom can be monotonic and boring (Tortosa, 2012). Moreover, laboratory work offer opportunities for students to work in group and to communicate their ideas verbally (Hofstein & Mamlok-Naaman, 2007). Unfortunately, with limited time and resources, laboratory teachers often over-rely on the laboratory manuals. Thus the experiments supposed to be exciting and innovative often turn into cookbook-style, order-following procedural steps with little excitement (Chen et al., 2012). To address some of these issues, MBL succeeds in reducing the time in data collection and visualization and helps students with graph plotting and problem solving, which brings laboratory work closer to the experiences of scientists in the real world (Krajcik, Mamlok, & Hug, 2001). In addition, the actual inquiry-based experiences that MBL provides can promote learners' conceptual understanding (Gunhaart & Srisawasdi, 2012). This approach allows students to interact directly with physical phenomena or with data gathering from the phenomena (Pyatt & Sims, 2011), which further promotes effective scientific learning (Hofstein & Lunetta, 2004). Therefore, MBL could be used as a cognitive tool in enhancing the understanding of scientific concepts.

MBL uses new technologies such as smartphones, personal digital assistants, Bluetooth or geographical information system in experiments. As pointed out by many studies, MBL has several advantages. First, students can experience a realistic process of scientific inquiry (Mokros & Tinker, 1987). Second, by saving much time in data collection and data plotting (Kelly & Crawford, 1996; Srisawasdi, 2012; Tortosa, 2012), students can devote more time and efforts to analyzing and explaining experimental results (Lavonen, Juuti, & Meisalo, 2003; Russell et al., 2004; Tortosa, 2012). Third, the acquired experimental data can be presented in various representations (Mokros & Tinker, 1987; Zbiek, Heid, Blume, & Dick, 2007). Fourth, selected variables can be plotted and studied almost instantaneously (Brungardt & Zollman, 1995; Pierri, Karatrantou, & Panagiotakopoulos, 2008; Russell et al., 2004; Tortosa, 2012), which provides prompt feedback for students to adjust their hypothesis and to establish links between a physical phenomenon and the associated data plots (Aksela, 2012; Linn & Songer, 1991) which further improves in-depth understanding of scientific concepts (Dori & Sasson, 2008) and higher order thinking skills (Barnea, Dori, & Hofstein, 2010; Friedler, Nachmias, & Linn, 1990; Lavonen et al., 2003).