Rediscovering scientific laws in high school physics labs with mobile devices

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Abstract: Traditional physics labs in high school ask students to follow step-by-step procedure to collect data in order to confirm given physical laws. This study proposes to let students take up the role of scientist in physics labs. Modern physics labs can make use of powerful mobile technologies of smartphones and Lego Mindstorms NXT. These devices can be used to act as moving objects as well as data acquisition devices. Moreover, students are asked to find the functional relation between physical variables, e.g., pendulum length and pendulum period, by detecting patterns in experimental data. An empirical study was done in a real high school setting and some interesting preliminary results were found.

Keywords: Scientific discovery, physics labs, mobile devices, pattern finding, hypothesis generation

Introduction

Traditional physics lab is a step-by-step procedure leading to predictable results with no surprises. Some traditional physics labs lack precision. For example, traditional free-fall experiment marks the position of a falling object with a dot on a strip of paper. The precision is quite low. Some lab needs to make assumption. For example, in a pendulum experiment, a student takes the total time of 10 cycles and derived the average period by dividing the total time by 10, thus assuming the periods are equal. But they do not know how constant the period is. Moreover, they do not see the curve of harmonic motion with damping. In short, in traditional labs, students are asked to confirm given scientific laws with experimental data.

Our study takes an approach similar to the ThinkerTools Inquiry Curriculum (White and Federiksen, 2000), which follows the scientific method in the following steps: (1) question---students are asked to think the functional relationship between the period P of a pendulum and the length L of the pendulum; (2) hypothesize---students produces a new term by combining old terms such as P/L; (3) investigate---students carry out physics experiments using different lengths of pendulum and find out the average period for each length; (4) analyze---students study the data of P and L and try to find out their relationship; (5) model---students express P as a function of L like a scientific law; (6)

evaluate---students can do another experiment using a novel length and check the predicted period using the hypothetical model against the measured period. The novelty of our study is the use of a mobile device (smartphone and NXT) as an object in the experiment and a data acquisition tool (e.g., Peters, 2010; Wogt & Kuhn, 2012).

This article proposes to turn physics labs around in a way such that students can take up the role of a scientist (Figure 1). This can be achieved by using modern technology in acquiring high-precision data and finding patterns in these data to rediscover scientific laws (bottom-left of Fig. 1). Obtaining high-precision data is possible with low-cost equipment such as smartphones and Lego Mindstorms NXT (bottom-right of Fig. 1). After numerical data are acquired in experiments, students can be asked to find out an algebraic relationship between variables (representing physics features) with a computer-assisted strategy (top-right of Fig. 1). The environment is designed based on previous studies of InduLab (central component of Fig. 1, Wu et al., 2006) This is the stage of pattern finding and hypothesis generation. For the students doing these labs, their skills of scientific discovery can be enhanced (all corner components of Fig. 1).

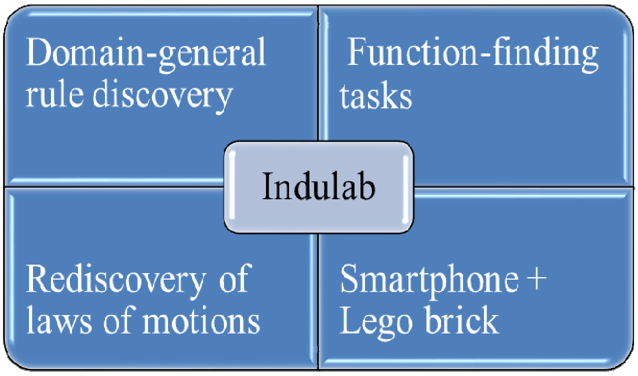

Figure 1: Components of a modern physics laboratory for teaching

Research Method

A class of 36 seventh grade students in a high school in Central Taiwan was chosen to do the experiment of physical pendulum for four weeks, with two fifty-minute sessions per week. They were divided into six groups randomly. In the first week, the researcher lectured on the objective and detailed steps of how to run this experiment. In the second week, three of the six groups did the experiment with Android phones while the other three groups used NXTs to acquire angle data with different lengths of pendulum. For each length of the pendulum, they measured the period of the pendulum for at most ten periods and averaged them. Then they recorded the lengths of the pendulum and the corresponding periods in a table. In the third week, the first three groups did the same experiment with NXT while the other groups used Android phones. In the fourth week, they did pattern finding and hypothesis generation for the Android experiment and for the NXT experiment.

Table 1 shows the sequence of variables proposed by one student. The student might have detected the pattern of decreasing T/L for increasing T. If so, T*T/L was a reasonable variable to try next. For the pattern finding and hypothesis generation part, 5 of the 35 students using smartphone data had once generated the target variable of T^2/L or L/T^2; 5 of the 34 students using NXT data had once generated the target variable.

Table 1. Sequence of variables proposed by one student

L(m)	T(s)	T/L	(T^2)/L	(100T^2)/L	(100T^2-4L)/L
0.27	1.03	3.81	3.92	392.92	388.92
0.31	1.10	3.54	3.90	390.32	386.32
0.37	1.20	3.24	3.89	389.18	385.18
0.45	1.30	2.88	3.75	375.55	371.50

Conclusion

Traditional physics labs in high school ask students to follow step-by-step procedure to collect quantitative data that fits a given physical law. Sometimes the precision of some measurement instrument is not of high quality and bold assumptions have to be made. We propose to transform the physics labs so that students can acquire data with high precision and find patterns in the data in order to rediscover physical laws. Data acquisition with high precision is achieved with modern mobile devices of Android phones and Lego Mindstorms NXT. Pattern finding and law rediscovery are achieved by a computer-assisted strategy of pursuit to produce new algebraic variable from existing ones. A few experiments were designed by the researchers and run by high school students in physics labs. One experiment was to find the relationship between the length of a physical pendulum (of NXT or smartphone) and the period of the pendulum.

Results indicated that the acquired data were of high quality and the period of a physical pendulum remained almost constant when the pendulum swings. For the part of pattern finding and law rediscovery, about 14% of students proposed the targeted law among many others. Most students needed more training in doing this type of pattern finding, which is an important skill in scientific discovery. Comments from some students said that they were excited to use modern mobile technology in physics labs.

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