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Transforming the Teaching Laboratory into an Inquiry Laboratory for the Future Innovators

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Abstract

We proposed and realized an inquiry laboratory module to cope with instructors' and students' interdisciplinary needs for science inquiry. The center of the new module is one of the well-known open source microcontrollers and the feelers can be various sensors, switches or motors. Teachers and students can work together in designing and constructing the systems needed for their innovative inquiry projects. The newly developed module is not only a platform for inquiry; it also equips students with the fundamental competencies for the modern technologies and future innovations.

Key words: STEM education, practice, inquiry

Introduction

The term science comes from the Latin word scientia, meaning "knowledge", and had evolved into the knowledge of nature acquired systematically for explanations, predictions and applications. The competencies of observation and experimentation for science inquiry have being emphasized in all eras of science education reform. For example, about half-century ago, the PSSC (Physical Science Study Committee) Physics course included not just only a textbook, but also specially designed laboratory experiments that were simple, easily assembled and inexpensive. Teaching laboratory had become a standard infrastructure in school [1]. Over the years, due to the industrialized mass production, the instruments for the teaching laboratory had become more standardized but less inquisitive. Although the commercial laboratory instruments can generate standard experimental data more efficiently, they had become less versatile and require less hands-on operations.

In response to the worldwide trend of emphasizing practice and inquiry, we proposed and realized a maker's inquiry module to cope with instructors' and students' versatile and interdisciplinary needs for science inquiry. An example of reaction time inquiry is presented and discussed.

STEM Education and Science Inquiry

About half century later after the promotion of PSSC Physics, the economic impact initiated a new education reform. For example, the United States House of Representatives requested the National Academies to form a COMMITTEE ON PROSPERING IN THE GLOBAL ECONOMY OF THE 21ST CENTURY in 2005 [2], and the US Next Generation Science Standards (NGSS) [3] emphasized on reinforcing the STEM (Science Technology Engineering Mathematics) education [4]. In order to reinforce the intercorrelation among the science curriculum, technology and engineering, the current science education reform in the compulsory education focuses on the engineering practice and science inquiry. For example, the first dimension to be advanced in the Framework for K–12 Science Education of the US NGSS also emphasized "Scientific and Engineering Practices" as the first dimension of its frame work [3]; and in our country's newly announced 12-year compulsory education curriculum, there is a new course named "Natural Science Inquiry and Practice" [5]. Because the social evolution involves confluences of varies of disciplines, interdisciplinary programs such as STS (Science, Technology and Society) had been viewing science and technology as socially embedded enterprises [6]; and interdiscipline had been one of the fundamental characters.

Teaching laboratories are considered essential for science education, and are required for science standards in many countries. Resent research analyzed the impact of taking an associated laboratory course on the performance of the introductory physics courses and indicated that average benefit was not enough to show the effectiveness of the laboratory course supporting mastery of physics content [7]. New approaches of laboratory courses focus more on the inquisitive or investigative aspects were being proposed. Although more elaborate, they achieve the desired inquiry goal far more effectively [8, 9].

Instrumentation for Inquiry Laboratory

It is necessary to have effective tools to do a good job. Thanks to the maker education, which is an integration of playfulness, experimentation, iteration, collaboration and innovation, the limitations of black-box type traditional apparatuses can be liberated. Instructors and students can make (or attempt to make) an instrument that accomplishes something they previously thought might not be possible or to modify an existing instrument in a way that the original manufactures had never imagined. The involvement in the creation of an instrument from concept to reality also teaches valuable lessons about resourcefulness and persistence, and helps students act as learners to own their learning, and provides them with the opportunity to demonstrate their proficiency of a series of learning objectives without the traditional written test assessment. Inquisitive experiment stresses the importance of the iteration of student's decision making, outcome, and improvement. To create successful critical thinkers, we need to furnish the laboratory with flexible gadgets needed to analyze problems and to practice the design-implement-improve-design… iteration.

Inquiry Example: Reaction Time

Increasing in reaction time can lead to safety risks at work. In situations such as the braking response, the reaction of the operator is not simply a one step process, but rather a sequence of complex reactions. The braking response involves mental processing time, movement time, and device response time. Mental processing time consists of four subsequent components: sensation, perception/recognition, situational awareness, and response selection [10]. Movement and device response times will remain fairly constant when using the same device in similar situations. The operator's mental processing time, however, is highly subject to change in the presence of distractions that add to his or her cognitive load. The higher a subject's cognitive load, the longer his or her mental processing time is expected to be [10].

Distractions are a part of everyday life, but they can be deadly while operating a machine. For example, according to the American Automobile Association, the use of a cell phone while driving increases the risk of crashing four times. Other distractions, such as listening to music and conversing with others at work, can be just as dangerous [11].

Although, due to the widespread usage, cell phone is a popular field of inquiry, it is also important to study, the effects that other distractions can have on workers. In fact, all three of these situations (using a cell phone, listening to music, and conversing with others) distract a driver both visually and cognitively [12]. This suggests that when distracted, one's physiological state is altered. The influences of distractions on the reaction time are important inquiry subjects.

In order to facilitate the interdisciplinary needs of science inquiry, we have developed a Science Inquiry Module based on the Arduino microcontroller , accompanied with a LCD display and a breadboard for both instructors and students to design and construct innovative instrumentations.

To explore the reaction time, students will construct two switching circuitries, one to simulate the red light control, the other to simulate the Brake response as shown in the Fig.1. As soon as the experimental subject sees the red light, he or she will press or step on the brake switch and the Arduino board will detects the two events and times to count and display the reaction time.

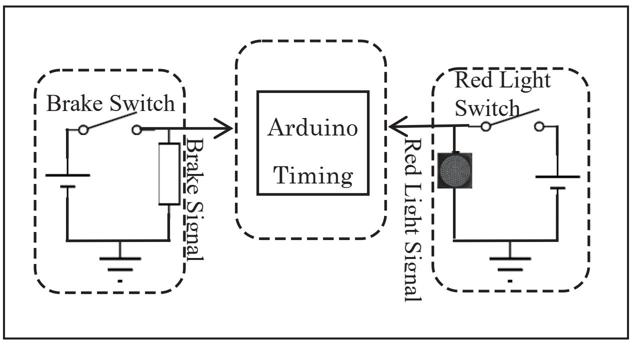

Fig. 1 Block diagram of driver's brake reaction time measuring system.

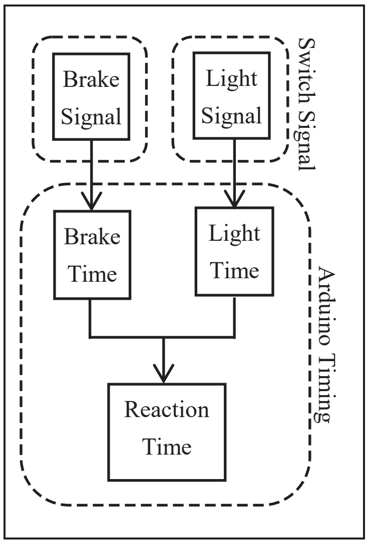

Fig. 2 Programing flow chart for the of driver's brake reaction time measurement.

The Arduino programming algorithm is demonstrated in the flow chart of Fig.2. The red light may be switched on manually or automatically at a random time by the Arduino board trough the software control using the command: **random(min, max)**. The red light may also be replaced by the simulation of other sudden traffic incidences.

For the novices, the cognitive load will be reduced if a whole-task can be approached through some sequence of part-task [13]. Although the red light and the brake circuitries in the block diagram of Fig.1 functioned differently, they are the same as the basic switch circuit in Fig.3. As the switch is open, the output signal is low, while the switch is closed, the output signal is high.

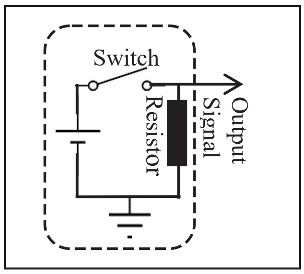

Fig. 3 The part-task of switching circuitry.

Similarly, the Brake time and the Light time block diagrams in the programming flow chart of Fig.2 are the same event monitoring and timing algorithm as show in detail in the Fig.4. In the program list of Table 1, the first application of the part-task is single-underlined and the second application is double-underlined. The beginning section declares the variables for the red light, brake and the reaction time. In the Setup section, the active the serial port and sets the data rate to be 9600 bits per second. In the Loop section, the first two if segments detect the red light signal and record the red light time if it has not been recorded. The third if segment repeats the signal detecting and time recording for the brake signal. Finally, the reaction time is calculated and printed to the PC monitor via the serial port.

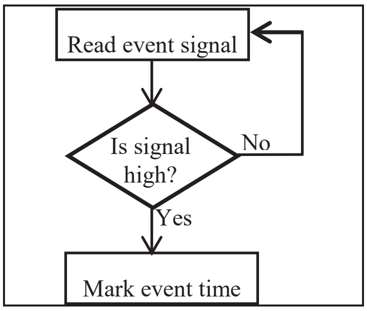

Fig4. The part-task of the event detecting and timing algorithm.

TABLE I
Program for reaction time inquiry

```
// Declare
int RedLightV;  //Define an integer for red light signal
Int RedLightTime=0;  //Define an integer for red light time
int BrakeV;  //Define an integer for brake signal
Int BrakeTime=0;  //Define an integer for brake time
Int ReactionTime;  //Define an integer for reaction time

// Setup
void setup()
{
  Serial.begin(9600);  //Activate serial monitor
}

// loop
void loop()
{
RedLightV =analogRead(0);  //Read red light signal from A0
 if (RedLightV > 500)  //If red light signal is high
  {
   if (RedLightTime ==0)  //If no red light time recoded
     {
     RedLightTime = millis();//Read  red light time
     }
   BrakeV = analogRead(1);  //Read brake signal from A1
   if ( BrakeV > 500)  //IF brake signal is high
     {
   BrakeTime = millis();  //Read brake time
    ReactionTime= BrakeTime – RedLightTime; //Calculate reaction time
   Serial.print("ReactionTime=");  //Print "ReactionTime="
   Serial.println(ReactionTime);  // Print  ReactionTime value
    delay(100000);
    RedLightTime =0;
     }
   }
 }
```

Conclusion

Although the instrumentation flexibility seems to be the foundations for realization the industrial innovation, it is also the support of science inquiry. In the abstracts of the original report of the 2017 Nobel Prize in physics [14], the major concept is gravitational-wave which appears five times. The next important concept which appears four times is the signal processing which demonstrates its importance in this pioneering fundamental research. Our works of transforming the teaching laboratory into an inquiry laboratory through the flexible instrumentation not only fulfill the inquisitive needs in in the practices of modern science education, but also lay the foundation of the interdisciplinary competencies for the future work force.

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