Experimental Designs for Inquiry with Problem-Based Strategy

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Taking into account that current teaching methods fail to lead students to feel the connections between science and society, and that some drawbacks exist in experimental courses, we have designed a series of experiments with Integrated Circuit (IC) cards which lead the reader to follow a problem-based strategy. The experiments are developed to help students get a better experience through inquiry. Several questions are provided for each experiment as a guide to start the investigation. These questions are without standard answers, so students are suggested to explore by themselves. With the experimental results, we could also ask students to think over the restrictions of how to utilize the IC card in daily life.

I. INTRODUCTION

Science-Technology-Society (STS) instruction has been carried out for several decades, having been proposed as a way to improve science education. An international trend has been growing among researchers in reforming the practice of science education. Yager and Tamir (1993) concluded that STS instruction has positive influences on students' conceptual understanding, process skill, attitude and creativity in science.

However, students' negative responses when asked how they feel about their experiences with science indicate that there is still a large problem in students' attitudes toward the relation between science and society. Most of the time, students cannot take what they have learned from science class and apply it to society, even though the two are actually closely linked. Science education in schools sometimes fails to fully motivate students about the importance of what they are studying.

Currently, laboratory experiences are considered to be special processes to help students develop ideas about the nature of a scientific community and the nature of science. The National Research Council (1996) emphasized that the laboratory is especially important in the current era, in which inquiry has re-emerged and is advocated for science teaching and learning (p. 23).

However, studies have shown that students often perceive that the principal purpose for a laboratory investigation is either to follow the instructions or to get the right answer. They may feel that measuring and manipulating equipment are goals, but fail to recognize much more important conceptual or even procedural goals (see for example Champagne, Gunstone, & Klopfer, 1985; Eylon & Linn, 1988, Crawford, 2000). Tobin and Gallagher (1987) found that science teachers rarely, if ever, exhibit behavior that encourages students to think about the nature of scientific inquiry and the meaning and purposes for their particular investigation during laboratory activities.

Many teachers do not perceive that helping students understand how scientific knowledge is developed and used in a scientific community is an especially important goal of laboratory activities for their students. Consistent with the findings of Lunetta and Tamir (1979) and others, students are seldom given opportunities to use higher-level cognitive skills or to discuss substantive scientific knowledge associated with the investigation, and many of the tasks presented to them continue to follow a "cookbook" approach (Roth, 1994).To many students, a "lab" means manipulating equipment, but not manipulating ideas.

Given that current educational instructions fail to inspire students about the importance of science to society, and especially since laboratory instructions present prepared conclusions and experiments with only one solution, this paper seeks to expose students to inquiry-based experiments with widely used, daily life materials. A series of interesting and enlightening experimental designs have been developed to instruct students in cultivating their imagination and creativity to design and implement new experiments, following question-based strategy with non-standard answers. Our aim is to help students have a sense of the relation between science and society, as well as to instruct students in carrying out experiments through inquiry.

II. MATERIALS

In an effort to improve STS instruction, as well as to make students understand how science is important to our society, we have developed experiments using Integrated Circuit (IC) cards (see Fig.1 (a)) and card readers (see Fig.1 (b)), which are familiar to everyone (many students have bank cards, library cards, access cards and so on). Since IC cards are completely sealed, it is impossible to know exactly what is contained in the card from the outside. Therefore, IC cards could be a possible material to use in experiments, helping students to explore what features the card has when it connects to the reader.

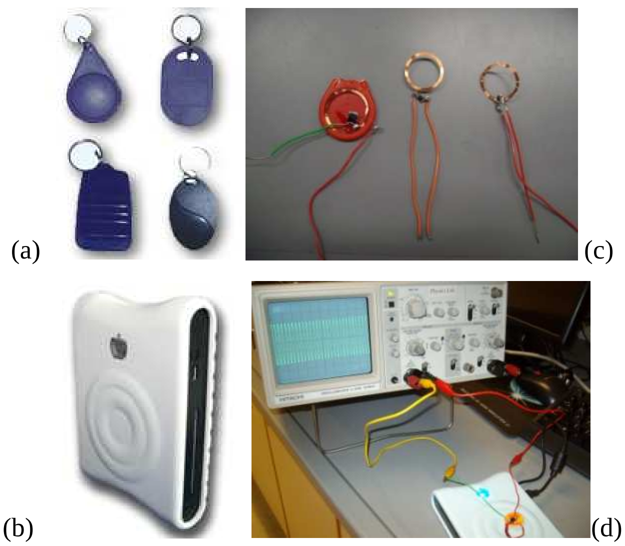

Figure 1.: Experimental materials: (a) represents four examples of Intergraded Circuit (IC) cards. (b) is an S8 IC card reader. (c) shows several disassembled IC cards with wires connected. (d) is an oscilloscope, which shows the signal from the IC card inducted by the reader

There are two methods of connecting an IC card to a reader: contact-based, where the card needs to be physically inserted to transmit data, and contactless-based, where the card connects to the reader through electromagnetic waves. The IC cards (Fig. 1(a)) used in our investigation use contactless chips.

Given the “experimental” nature of the materials, students may not know what to explore, as their understanding is usually limited to the product itself. It is not easy for them to integrate the product with their scientific knowledge. Therefore, several questions are proposed as follows to help students think about the materials and catalyze exploration:

(1) What is the operating frequency of an IC card inducted by the reader?

(2) Why does the reader use a plastic shell, and not metal?

(3) What is the inductive range when the IC card connects to the reader?

In order to study the above factors, the IC card and reader need to be connected to an oscilloscope (see Fig. 1(c, d)), and students must work in groups and utilize an inquiry taking question-based strategy.

III. RESULTS AND ANALYSIS

Each group of students would be presented with a question-based strategy with non-standard answers, and dominant students in each group would no doubt take the lead in exploring this new learning strategy. However, teachers may offer some additional assistance when needed, especially for guiding students on how to get through the whole procedure. Figure 2 shows the entire experimental procedure of each inquiry activity. First, the standard materials (IC cards and reader) are chosen and given to the students. Then, several possible problems are posed as above, from which students can pick one or more to be their main research question(s). When students have selected a targeted issue on which to concentrate, it is suggested that they discuss and brainstorm as many ideas as possible about how to carry out further investigation. After students finish their group discussion, more detailed questions are proposed to students as reference, helping them to execute self-inquiry activities within each group. Once results are obtained, students will discuss them with each other, sharing their opinions about how the results respond to the question. Afterward, students will create and argue a case concerning restrictions on IC card use in the final step.

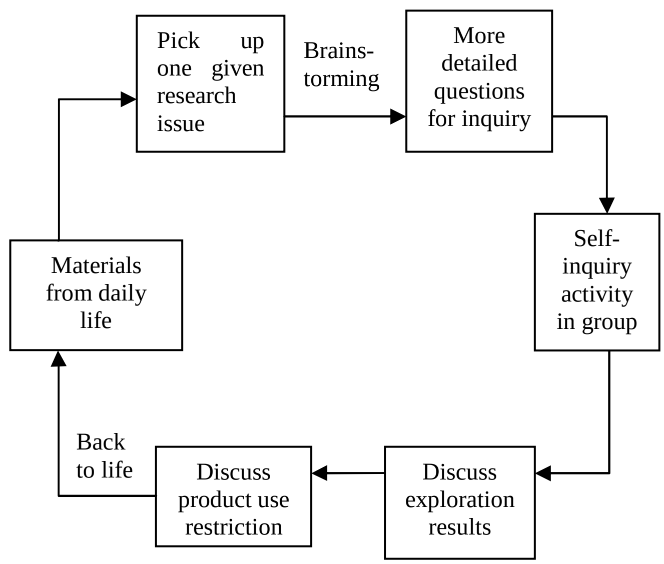

Figure 2: The experimental procedure of each inquiry activity.

The following three experimental designs are posed as examples to show how to explore the previous three research issues, as well as to reveal what detailed questions we present to students for each research issue. These questions are designed to encourage students to start their own investigation, following a problem-based strategy. We then provide the inquiry processes with experimental results. In addition, some discussions on the use of IC cards are also presented.

Case 1: What is the operating frequency of an IC card inducted by the reader?

This is the most basic issue when the IC card and reader are given to students. Detailed questions could be asked as follows:

(1) How could you obtain the operating frequency of an IC card inducted by the reader?

(2) What is that operating frequency?

(3) What property does the electromagnetic wave of that frequency have? Is it a long wave or a short wave?

Students could read the operating frequency of the IC card inducted by the reader from the oscilloscope interface. Normally, the operating frequency of IC cards is limited to 13.56 MHz. It is very important for students to truly understand the nature of the connection between IC cards and scientific knowledge. IC cards, which we use frequently in our life outside of school, and which seem totally external and independent of the classroom, are actually very dependent on the same scientific knowledge we learn in class. Therefore, teachers should present their students with a probed question: Have you ever thought about the scientific process behind the frequency of an IC card? How is this frequency linked to our existing knowledge of electromagnetic waves? Discussions will take place within a group, leading students to feel a connection between science and products in daily life.

Case 2: Why does the reader use a plastic shell, and not one made of metal?

This research issue stems from the fact that all the IC card readers we have located have plastic shells. We want students to ponder this phenomenon and perform some experiments to prove that a plastic card reader shell is a better choice than a metal one.

Students are asked to discuss how to carry out an experiment to come up with a solution. After the discussion, more questions are supplemented to students to get a better understanding about the investigation:

(1) Why doesn't the reader use a metal shell? Does metal influence the induction between the IC card and reader? What metal would you like to choose for testing?

(2) What premises do you need to be satisfied when testing with different metals? How do you go about satisfying these premises?

(3) Does the square of the metal affect the results?

Here we pose an experimental design as a case for investigating Question 2. This example could be used for teachers to expand more cases for study, as well as for students to compare with their own exploration:

In order to make sure that all experiments are carried out identically, a fixed distance between the IC card and reader should be maintained; therefore, the IC card should be fixed in a stable position near the reader. In Figure 3 (a), the result from the oscilloscope shows that the peak-to-peak value (Vpp) of the signal from the IC card inducted by the reader is 1500 mV, without putting any materials between them. We have also obtained the Vpp of each signal in different situations. The oscilloscope displays three results of 160mV, 240mV and1500mV separately when an iron check, aluminum sheet, and plastic plate respectively are inserted in between the IC card and reader (see Figure 3 (b, c, d)).

(a) (c) (b) (d)

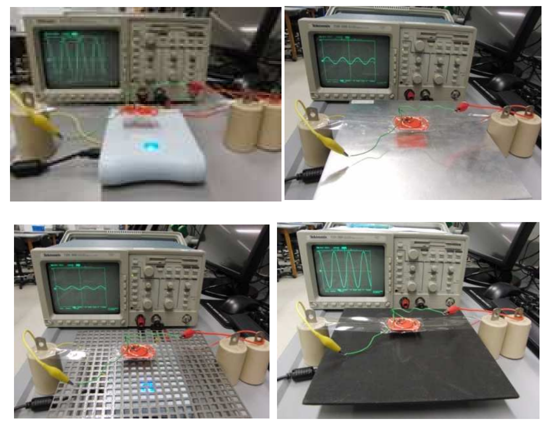

Figure 3: (a): No plate. (b): An iron check. (c): An aluminum sheet. (d): A plastic plate. The peak-to-peak value (Vpp) of each signal with different materials inserted between the IC card and the reader: (a) 1500 mV; (b) 160mV; (c) 240mV; (d) 1500mV

From the results, students would get the idea that diverse materials influence the experiment significantly. In particular, metal check and metal sheet weaken the signal considerably. However, when a plastic plate is inserted between the IC card and reader, there is no diminution from the initial setup with no material between them. Discussions about this phenomenon would occur within each individual group. Furthermore, another question could be posed to students to spark additional discussion: when used in daily life, can the IC card be bound together with keys or metal key rings for an extended period of time? This question instigates students into contemplating the science they have learned in terms of society, connecting the two concepts.

Case 3: What is the inductive range when the IC card connects to the reader?

When an IC card connects to a reader, an inductive range may exist. Take distance as an example: there is a limitation on the possible distance between card and reader, outside of which the reader is unable to connect with the IC card. We would like to let students explore the limitation of this distance through inquiry.

We also have several questions listed below for students to ponder during their investigation and after their discussions.

(1) What is the farthest distance a reader could remain connected to the IC card?

(2) How do the inductive signals change as the distance changes?

(3) How can you describe the varied inductive signals corresponding to the changing distances?

These questions give hints as to what factors the students can study, and consequently encourage students to carry out their own experiments independently. We have also designed an experiment as an example. We placed the IC card directly on the surface of the reader and recorded the Vpp of the inductive signal from the oscilloscope. We then moved the IC card away from the reader by 1 cm at a time, and we recorded the result at each step until the signal became too weak for the reader to pick up. The data are shown in Table 1. A diagram (see Figure 4) is provided to students so that they can better understand the relationship between the increasing distance between the reader and IC card, and the varied peak-to-peak value of inductive signals.

Table 1: The changing distances and the varied peak-to-peak value of inductive signals

Distance (cm)	0	1	2	3	4	5	6
Vpp (V)	6.0	4.2	2.8	1.0	0.8	0.6	0.4

Distance (cont.)	7	8	9	10	11	12
Vpp (cont.)	0.4	0.4	0.4	0.4	0.4	Unstable

$$Vpp = 5.88e^{-0.442h} + 0.239e^{-0.0025h}$$

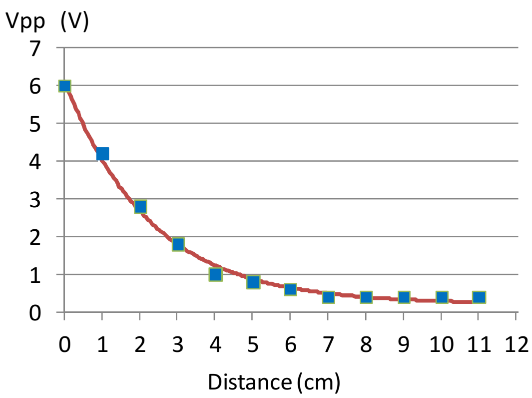

Figure 4: The varied peak-to-peak value of inductive signals against the changing distances

From the diagram, students can easily see that the magnitude of the inductive signal (Vpp) decreases as the distance between the IC card and reader grows. At first, there is a rapid drop in Vpp as the distance increases up to 4 cm; as the distance increases even more, the drop in signal levels off.

If the students can thrive well with this new inquiry process, they are encouraged to think deeper as to why the IC card and reader work the way they do, and what the data and diagram stand for.

IV. DISCUSSION

As mentioned in prior research, current forms of science education fail to get students to understand the close connection between science and society (Champagne, Gunstone, & Klopfer, 1985; Eylon & Linn, 1988, Crawford, 2000). Additionally, even in existing courses that highlight inquiry-based features, instructions are always given to students, meaning that almost all students will end up accomplishing the task by following the same method and getting identical experimental results.

Taking all of these troubles into account, we designed a series of interesting and enlightening experiments to instruct students in cultivating their imagination and creativity. The result is a group of students independently designing and implementing new experiments – experiments that follow a question-based strategy and have non-standard answers. IC cards, which are familiar to every student, are chosen as the key experimental material, so as to help students understand how closely science connects to everyday life. Three research issues are presented to students: for each issue, we provide several detailed questions to guide them through how to start their own exploration. Three experimental designs (one for each question) are provided to students, so that they may compare them with their own experimental designs and achieve a better understanding of the experiment as a whole.

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