Induced Collaborative Engagement for a "Solution-to-Question" Model using Remote Experimental Laboratories as a Tool

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***Abstract*—Despite the discovery that the collaborative model for remote experimentation laboratories is quite effective for pedagogy, feedback questionnaires still record a high percentage of dissatisfaction from students performing experiments in remote labs. Research however has shown that learning is made easier when fun or play is included in the process. This paper tries to answer two questions: (i) how can engagement be induced amidst a group of students collaborating together to perform an experiment on a remote lab; and (ii) how can this induced engagement create fun and hence improve the learning process? To achieve this aim, the "Solution-to-Question" Model was conceived, created from the approach that is adopted in computer games. This model was used by the Remote-labs research group at the Obafemi Awolowo University in the design and implementation of a Remote laboratory platform. This paper focuses on two experiments conducted on a LabVIEW platform, and involves students experimenting on parallel and series resistances. The results of the study showed that the "Solution-to-Question" model increased the collaboration, interest level and engagement level of students in the laboratory. Engagement and interest enhance the learning of the student.**

***Index Terms*— Education model, Remote laboratory, Student Engagement**

I. Introduction

LABORATORIES are essential to education. Laboratories afford students the opportunity to experience the concepts they have been taught in class. Traditional laboratories require direct contact between the students and the laboratory setup in a physical location called a laboratory. This system however poses some limitations well captured by a number of questions put forward by National Instruments [1]. For example, students cannot perform experiments in their rooms in the middle of the night while studying a theory and it is generally too tedious and difficult to bring experiment setups to class to illustrate concepts to students practically. Remote laboratories emerged as an answer to these limitations. They make it possible to do lab work at any time of any day, from the comfort of one's bedroom or during a live lecture in class. They also make it possible to share laboratories across students and researchers at great distances from each other – thus, remote labs inherently have the capacity to foster collaboration between students and researchers of different demographics, across great distances.

A sketch of a typical remote lab model is shown in Fig. 1. In this paper, we define a remote laboratory as a laboratory whose experiments are conducted over a network. Hence the "remote equipment" in Fig. 1 may be physical equipment or virtual equipment (a virtual model of physical equipment).

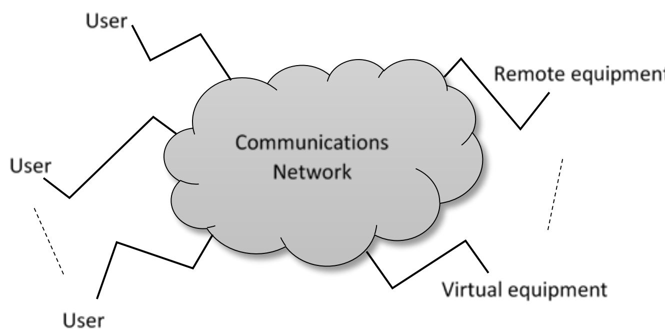

Fig. 1. Typical Remote Lab Structure [2]

A. Rapid Loss of Interest

Several advances in laboratory education have been credited to remote labs [3]. Remote labs have been found to be successful in teaching and research in several different areas such as digital process control [4, 5, 6], aerospace applications [5], PID control [7, 8], digital electronics [9], robotics [10, 11] predictive control, embedded communication systems [12] and real-time video and voice applications. Despite the successes of remote labs, they face a number of challenges. In our experience, one of the most prominent challenges to remote labs is the rapid loss of interest by the students when performing experiments in the remote labs. This problem leads to a decline in the rate of learning by students.

Interest has been defined as "something we care about, is important to us or that we have (mostly) positive feelings towards" [13]. Interest can be divided into two: individual interest and situational interest [14, 15]. When an assignment is

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given to a student to perform an experiment in a remote lab, the interest may be individual i.e the student cares about learning, or situational i.e. the student cares about just completing the assignment. The level of interest of the student depends on the design architecture of the remote lab. Loss of interest in experiments reduces the utility that students find for the labs and hence reduces the gains from the remote labs. Interest, it has been shown, is a necessary ingredient to learning [16]. Since quick loss of interest in performing experiments on remote labs poses as a major problem, a solution is required.

B. Our Approach

In attempting to solve this problem of loss of interest, the "Solution-to-Question" model was used. Research carried out at the Remote-Labs unit at the authors' university led to the design and implementation of a platform which used this model (Solution-to-Question) as its design architecture. The goal was to increase and sustain the interest level of the students in the remote lab. It was hoped that the Solution-to-Question model would help spur "engagement" in the remote lab just as computer games do.

II. Theoretical Development

Some fundamental concepts used in this research work are first presented.

A. "Question-to-Solution" and the "Solution-to-Question" Models

The conventional "Question-to-Solution" model is the usual approach to traditional and remote labs design, which requires a procedure in arriving at a given solution. Students who use this type of labs constantly have one major question in mind, which is, "what is the next step or procedure?" By a repeated process of following the procedures or steps provided by the lab manual, a solution can be obtained. In the drafting of lab manuals using this model, more effort is put into creating procedures for individual experiments.

The "Solution-to-Question" model is an ongoing research in the authors' university for the right approach to the design of remote labs. This model uses the approach similar to that of computer games. In the modeling of computer games, there are two main blocks: the goal block and the tools block. The goal block contains the aim of the game which the player tries to achieve. The tools block contains the instruments / equipment provided to achieve the goal. Most computer games have their story board directed after this model. Fig. 2 shows an example of this model for a game called "Angry Birds". The goal is to hit the green pigs (goal block) by using the red birds (tools block), and the player is rewarded with points for this [17]. From this design the player is not provided with a definite procedure to hitting the green pigs. This leaves the player with multiple options of hitting the green pigs. Fig. 3 shows the parallel between the architecture of remote labs adopted and the game model. A final output voltage is given and a student is required to find a series-parallel resistor configuration that will result in that voltage.

With this model the goal is the solution (i.e. the experiment

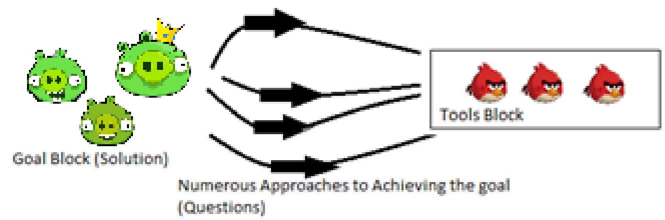


Fig. 2. Model for Angry Birds

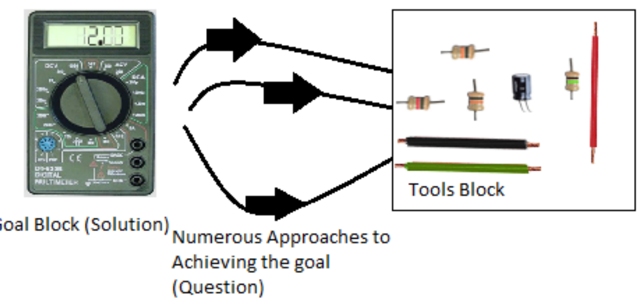


Fig. 3. Solution-to Question Model

set up connected such that it correctly gives the output voltage specified and the appropriate readings taken). The numerous approaches to achieving the goal are the questions, which are made possible by using the tools (lab instructions and components provided).

To explain our model further, a student may be given components of the circuit of Fig. 4 and asked to set the circuit up in the lab and measure the voltages across certain resistors or the potential difference between points a and b i.e. V_{ab}. This approach is the "Question-to-Solution" approach.

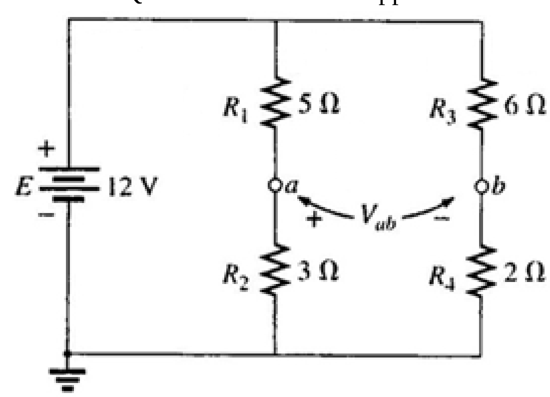


Fig. 4. A resistive network

In the "Solution-to-Question" model, on the other hand, the student would not be given the value of the source voltage or the resistors' values. Instead, the student may be given just the values of voltages across R3 and R4 and the potential difference between points a and b (V_{ab}). He will then be asked to use circuit theory to find possible values for R1, R2 and the supply voltage E that would satisfy the given data. In solving this, for example, the student can generate questions such as:

1. What value of E is reasonable?
2. What ratio of R1 to R2 will give me the specified voltages?
3. If I set $E = 12\,V, R_2 = 2\,\Omega$ and $R_3 = 5\,\Omega$, then what value will R1 and R4 have to be in order to give me the specified V_{ab}?

The Question-to-Solution model typically lies in the second level of Bloom's taxonomy of educational objectives in the cognitive domain i.e. "Understanding" [18, 19]. The Solution-to-Question model, however, lies in the third level i.e. "Applying".

Table 1 presents the major differences between the Question-to-Solution model and the Solution-to-Question model.

TABLE I
DIFFERENCES BETWEEN THE "QUESTION-TO-SOLUTION" AND THE "SOLUTION-TO-QUESTION" MODEL

S/N	Question-to-Solution Model	Solution-to-Question Model
1.	The model starts with a procedure. For example, procedure or steps to set-up a voltage division circuit.	The model starts with a goal or rather a solution. For example, getting a 5 V output from a 9 V input.
2.	The model ends with a final solution. For example, an output voltage from a voltage division circuit.	The model ends with one of multiple possible procedures or steps which are adopted in obtaining the solution. These procedures are created by self-generated questions asked by students. For example, questions may be generated which will involve the theory of voltage division.
3.	The questions to be answered by the students are in the lab manual	The questions generated by students are answered by the students.

B. Collaborative Learning and Engagement

Collaborative learning is the process whereby two or more people learn together. It is sometimes also defined in terms of joint problem solving [20]. The power of collaboration is displayed in the fact that collaboration, when done well, does not just additively combine the strengths of the individuals collaborating. Their strengths are combined exponentially. With the advent of the social era, collaboration has been made easier through the use of social network platforms such as Skype, WhatsApp, Facebook, etc. With this new trend, the adoption of these platforms in learning will improve the collaboration of students. In this research work, the collaboration platform adopted was Skype chat and an interactive real-time sketch pad. These two tools were used to create a means of collaboration between students performing experiments on the remote lab.

Uncontrolled Engagement or addiction is basically viewed as a bad thing. It has been defined as a "*chronic, relapsing disease that is characterized by compulsion*" [21]. The addict compulsively seeks the object of his engagement even when it is harmful to him health-wise or otherwise. According to Brian and Wiemer-Hastings [22] email, chat and the web in general are innately addictive and everyone is susceptible. Young [23] added that interactive real-time services are the most engaging. The two prominent interactive services are internet relay chat (IRC) and multi-user domains (MUDs). With these in mind, this research study aimed at inducing engagement in the process of performing experiments on remote labs. With engagement, concentration is induced and hence learning and innovation are promoted.

III. DESCRIPTION OF EXPERIMENTATION

A. Choice of Remote Lab Case Study

The remote lab used as a case study for this research is a "Resistance Lab". A lab based on resistor networks was chosen because the analysis of resistor networks is fundamental to electric circuit theory. Several practical circuits comprise a network of resistors and other electric components which can be represented by their impedances and then analyzed as "resistors" in circuit. For example, the analysis of a network of resistors, inductors and capacitors can be easily analyzed using techniques used for purely resistive networks.

The analysis of resistor networks is often done based on two simple rules: the rule governing the connection of resistors in series and that governing the connection of resistors in parallel. These are the platforms used in the design cases for our experiments as explained following. Case 1 experiments are those which make use of the Question-to-Solution model (i.e. the "traditional" remote lab). Case 2 experiments are those which make use of the Solution-to-Question model.

1) The Traditional Remote Lab for Series-Parallel Circuits (Case 1)

This lab was designed using the traditional model i.e. the "Question-to-Solution" model. The students were provided with a circuit as shown in Fig. 5. The component specifications for this experiment were specified in the lab manual. The task for the experiment was to input the components' specification values as gotten from the lab manual, and to record the outputs from the individual indicators. The procedure was included in the lab manual. The online experimental procedure given to a student is as follows:

1. Connect the circuit as shown in Fig. 6.
2. Use an input of 9 Volts
3. Set resistor R_1 to 10 ohms
4. Set resistor R_2 to 10 ohms
5. Set resistor R_3 to 10 ohms
6. Set resistor R_4 to 10 ohms
7. Flip the mechanical switch on to take measurements.
8. Record the readings for V_1, V_2, V_3 and V_4. and determine $V_3 + V_4$
9. Fill the form at http://goo.gl/forms/YBbJ67PE5I

2) The "Solution-to-Question" Model for Series-Parallel Circuit (Case 2)

The second lab developed was developed using the "Solution-to-Question" model. The students were not provided with a circuit, but rather with tools: resistors of specific values, a multimeter, wires, a bread board and a power supply unit. The virtual interface for this remote lab is shown in Fig. 6. Students could pick components from a box and place them on the virtual breadboard. The platform for the Solution-to-Question model lab was designed using LabVIEW. It contains a chat platform which uses the Skype third party Application Programming Interface (API) provided for LabVIEW. The

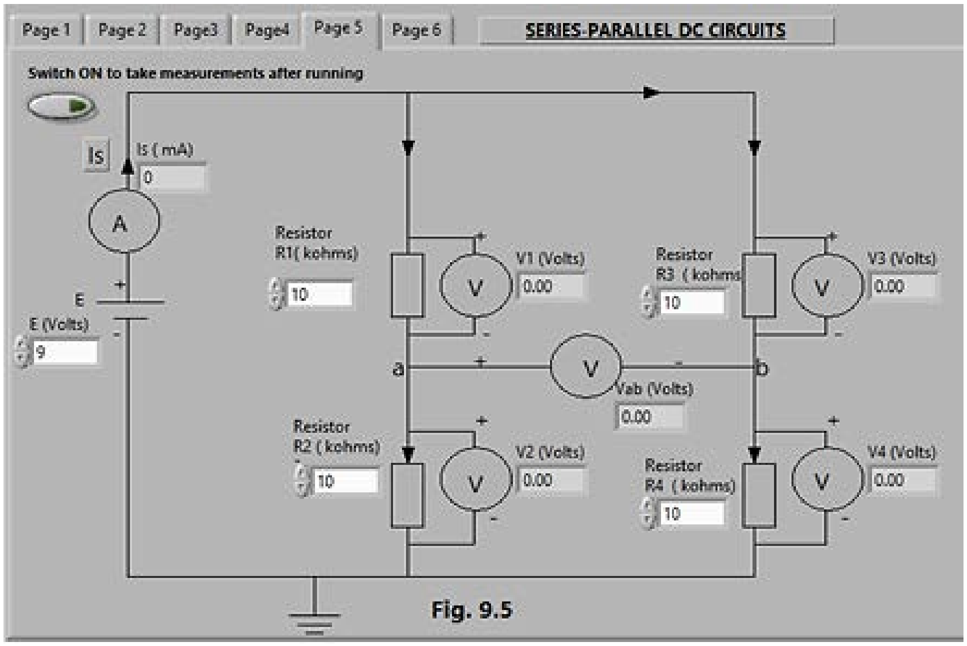
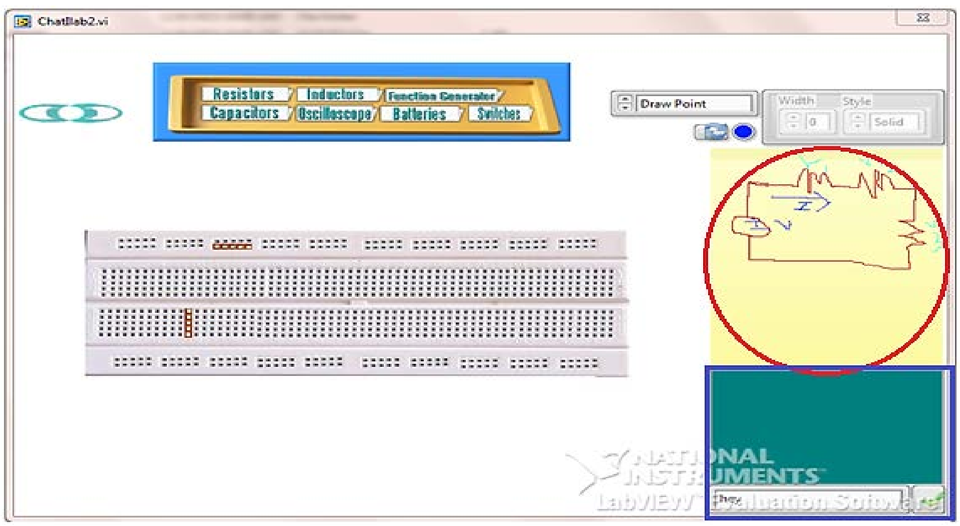
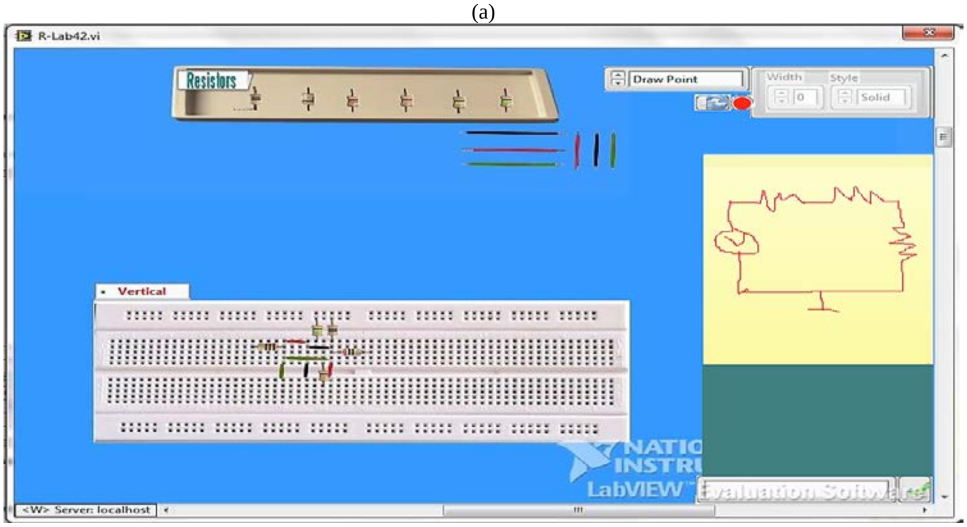


Fig. 5. LabVIEW screen shot for traditional series-parallel experiment



(a)



(b)

Fig. 6. (a) Resistor remote lab interface showing tools, chat interface and sketch pad. (b) Resistor remote lab interface with the resistor tools selected.

students can share and discuss real time updates of experimental set-ups done on the virtual breadboard (Fig. 6). The platform adopted the Solution-to-Question model as its design approach. The red circle in Fig. 6(a) shows a real time sketch pad which enables students to share draft circuit sketches online. The blue rectangular box shows a real time chat box. Fig 6(b) shows the resistor remote lab interface with the resistor tool selected.

The task for this experiment was that the student should construct a voltage division circuit using the tools provided and hence obtain an output voltage specified by the lab manual. The input voltage to the circuit was also included in the lab manual. No resistor values or circuit configurations were provided to the student in the manual as were provided in the traditional case. The experimental procedure given to students in this case is presented below:

1. By the use of the tools provided i.e. resistors, multimeter, wires, a breadboard and a power supply, set-up a circuit that outputs 5 V when an input voltage of 9 V is applied.
2. The circuit should be a combination of series-parallel resistances and a voltage source only.
3. Fill the form at http://goo.gl/forms/YBbJ67PE5I.

3) The Traditional Remote Lab for Thevenin’s Theorem Circuit (Case 1)

The experimental procedure for this experiment is presented below (the experiment setup is shown in Fig. 7):

1. Connect the circuit as shown in Fig. 7.
2. Calculate the Thevenin’s voltage and resistance to the left of the load resistor
3. Set up the Thevenin’s circuit using the values earlier calculated
4. Measure the voltages and currents across the Thevenin’s and load resistors.
5. Record all readings.
6. Finally fill the form at http://goo.gl/forms/YBbJ67PE5I

4) The Traditional Remote Lab for Thevenin’s Theorem Circuit (Case 1)

The experimental procedure for this experiment is presented below (the experiment setup is shown in Fig. 8):

1. You are given the Thevenin’s circuit of Fig. 8. $E_{TH} = 4.8\,V, R_{TH} = 2.32\ k\Omega,$ and $R_L = 470\Omega$
2. Using Thevenin’s theory develop a T-type 3-resistor circuit to replace R_{TH} and evaluate an input voltage E such that your final circuit and the given Thevenin’s circuit are equivalent
3. From the resistors given, connect up a new circuit with the calculated resistors and voltage E obtained in 2
4. Measure and record the voltages and currents across the load resistor and other resistors.
5. Fill the form at http://goo.gl/forms/YBbJ67PE5I

In this example, students could arrive at different combinations of resistors and voltages. The important thing was that the current and voltage across the load resistor R_L, in the final circuit they ended up with, was the same as the one on the Thevenin’s equivalent circuit.

Fig. 9 shows some of the virtual tools (a function generator, an oscilloscope and a multimeter) provided in the Case 2 Remote-Lab platform.

IV. Performing the Experiments

As mentioned earlier, each experiment was set up using LabVIEW. Students were divided into groups in order to compare the two approaches to remote lab design above. Sixty students were used for the tests. The students were randomly grouped into two sets of thirty each and then each set of thirty was randomly grouped into groups of threes. Hence, the sixty students were grouped into two sets of ten groups each with three students in each group. The students were placed under the same conditions but in different remote locations. The start time for the study on the individual groups was the same. For the two case studies, two manuals were provided: one manual for the platform designed with the traditional approach

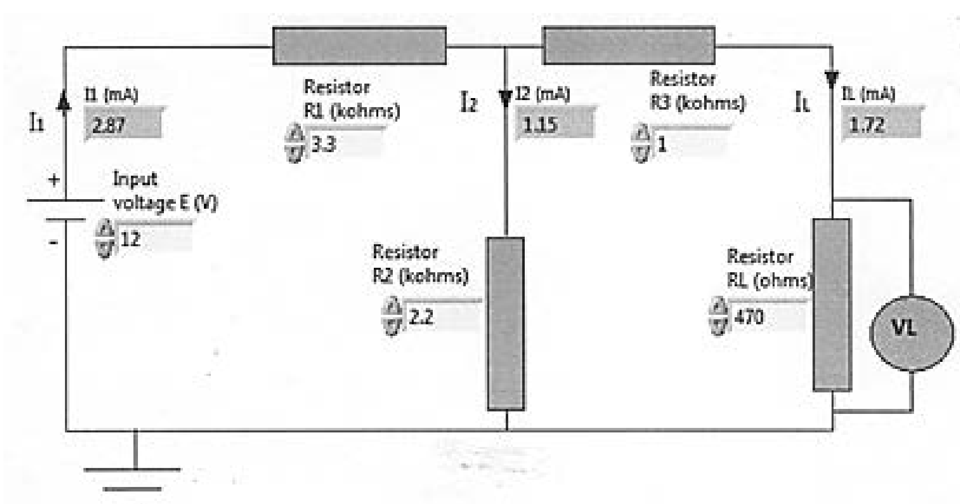


Fig. 7. Circuit for which the Thevenin’s equivalent is required.

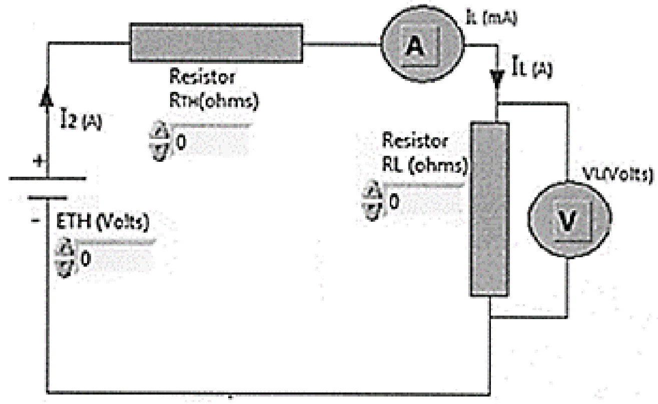
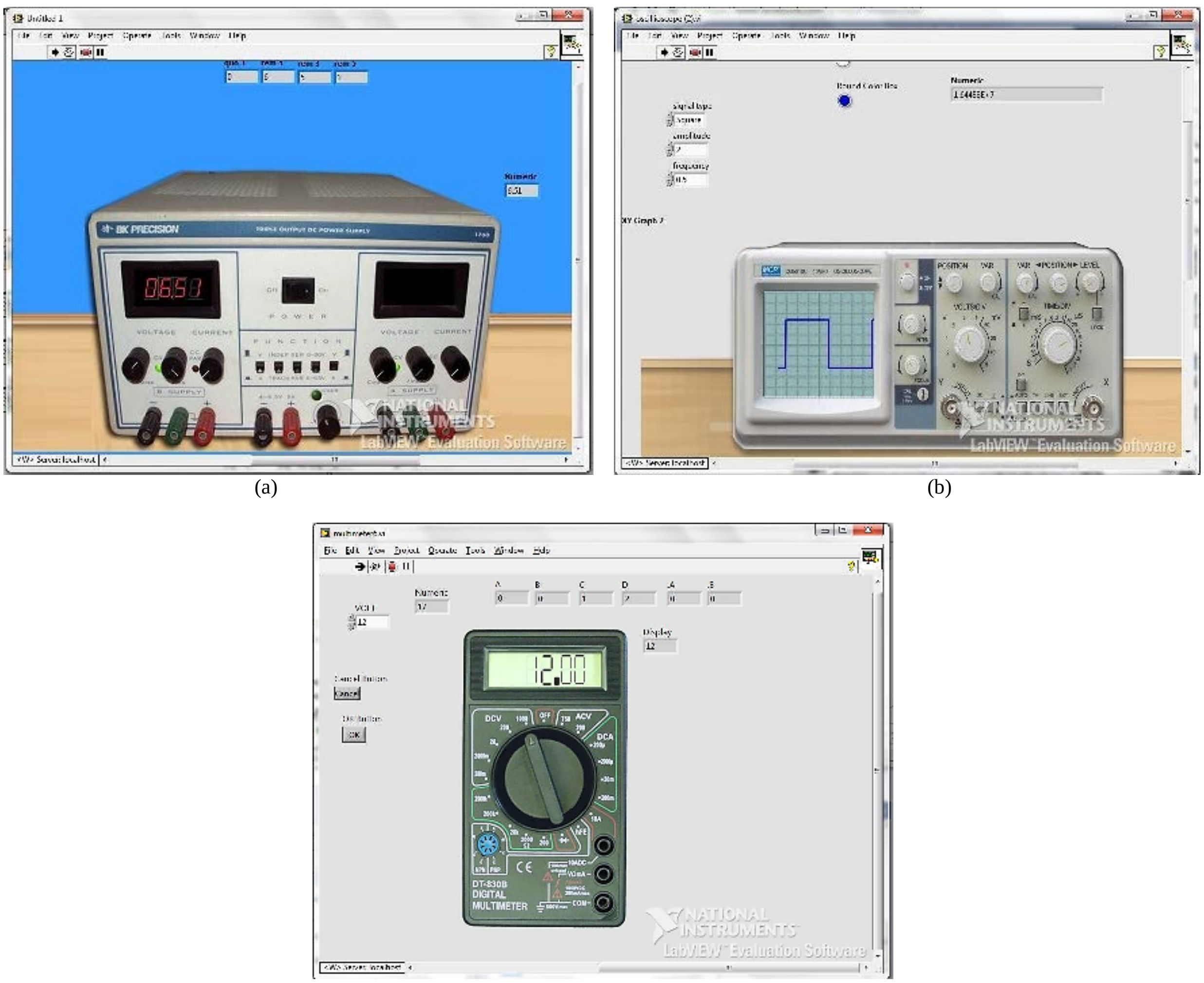


Fig. 8. A Thevenin's equivalent circuit.



(a) (b)

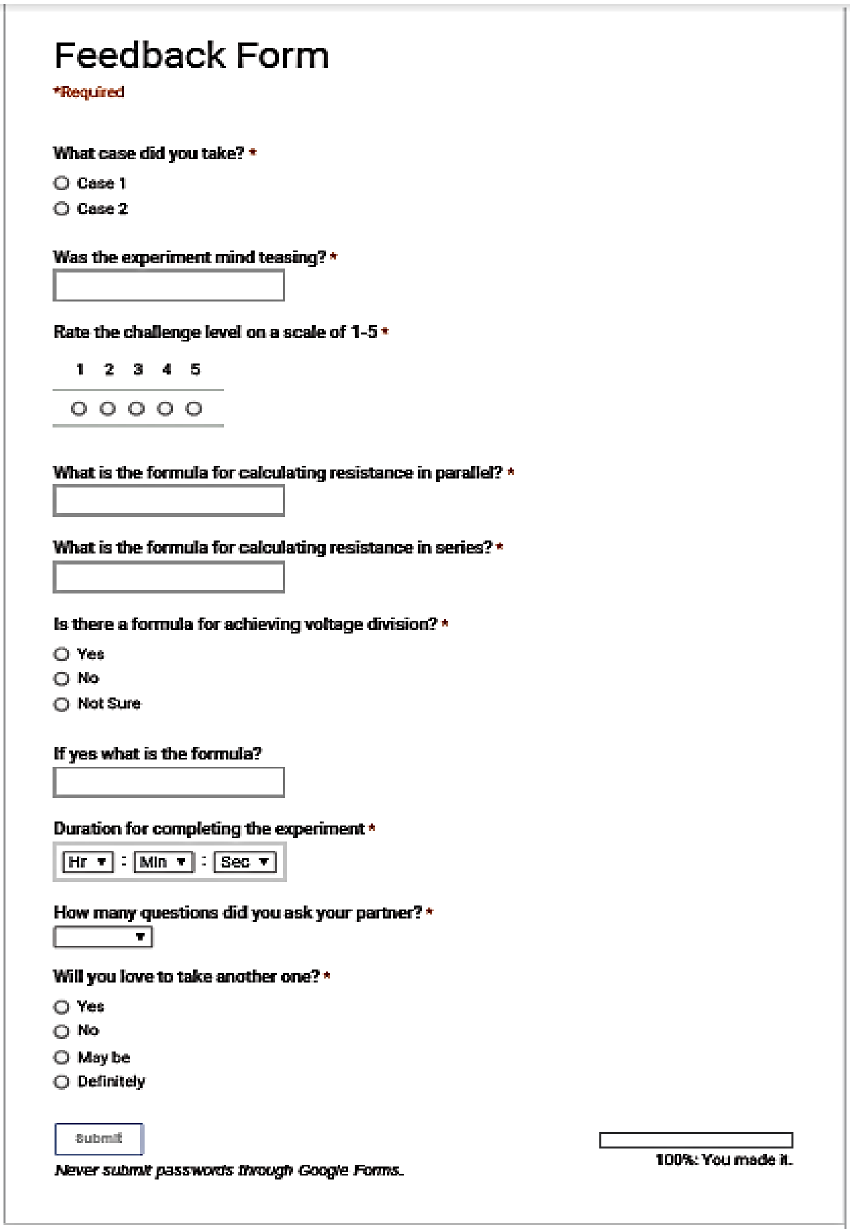
(c)

Fig. 9. Some of the Case 2 Thevenin remote lab tools (a) Power Supply Unit (b) Oscilloscope (c) Digital Multimeter

(Question-to-Solution model) and is called case 1 and the other for the platform designed with the Solution-to-Question model which is called case 2. At the completion of the experiments by the individual groups, a feedback form was filled. The form filled by the students is shown in Fig. 10.

V. Discussions

The results gathered by analysis of the students' responses on the feedback forms are presented in Fig. 11 [24]. Fig. 11(a) and 11(b) show that, relatively, all students had a basic knowledge base of both series and parallel resistance. Fig. 11(c) indicates that students who took case 2 found the



Feedback Form

*Required

What case did you take? *

- Case 1
- Case 2

Was the experiment mind teasing? *

Rate the challenge level on a scale of 1-5 *

1 2 3 4 5

What is the formula for calculating resistance in parallel? *

What is the formula for calculating resistance in series? *

Is there a formula for achieving voltage division? *

- Yes
- No
- Not Sure

If yes what is the formula?

Duration for completing the experiment *

Hr : Min : Sec

How many questions did you ask your partner? *

Will you love to take another one? *

- Yes
- No
- May be
- Definitely

Submit

100%: You made it.

Never submit passwords through Google Forms.

Fig. 10. Feedback Form

experiment more mind teasing. The challenge level from Fig. 11(d) shows that students found case 1 less challenging than case 2. Figs 11(f) and 11(g) show that the groups who took the second experiment (case 2) collaborated more but also spent more time in completing the experiment. Testing the 60 students for their understanding of series-parallel circuits and of Thevenin equivalent circuits after performing the experiments yielded comparable results for both cases.

VI. Findings

From the results of this study, it can be seen from Fig. 11(g) that engagement can be induced by using the Solution-to-Question model. Fig. 11(f) also shows that no case 2 (Solution-to-Question model) student performed the experiments single-handedly. They all collaborated. In fact, only 17 % of them interacted only once. 50 % of them reported having to interact several times to solve the problem. In contrast, 63 % of the case 1 (Question-to-Solution model) students interacted only once and only 17 % of them interacted many times. 3 % of them performed the experiment with no interaction. Hence, the case 2 model induced collaboration between the students.

Fig. 11 (g) presents the time it took the students to complete the experiments. On the average, it took the case 1 students 19 minutes and 8 seconds to finish the experiments. On the other hand, it took the case 2 students 22 minutes and 10 seconds, on the average, to finish the experiments.

Fig. 12 presents the student responses when they were asked if they would like to perform such an experiment again. While 3 % of the case 2 (Solution-to-Question model) students said they would not like to perform the experiments again 30 % of the case 1 (Question-to-Solution model) students reported “No”. Interestingly, 43 % of case students reported that they would definitely want to perform the experiments again. Thus, in a nutshell, students who took the case 2 experiments found them more challenging, spent more time performing the experiments and reported that they would love to have more experiments. In contrast, the case 1 students spent less time and found the experiments less engaging and more of them reported that they did not want to perform further experiments. The results of this study therefore show that case 2 students collaborated more, spent more time performing the experiments and retained a high level of motivation, concentration and interest throughout the experiment period [24]. While it is difficult to assert that the cognition level of the students was increased by use of the Solution-to-Question model, considering the increase in interest and engagement level it is reasonable to expect the Solution-to-Question model to give a higher pedagogical value than the Question-to-Solution model.

VII. Conclusions

The outcome of this study shows that the adoption of the “Solution-to-Question” model in the design of remote labs will result in an increase in the interest level, mild increase in engagement to the platform and an increase in collaboration. The major factor that may affect the positive results of using the “Solution-to-Question” model is if undue large amounts of experimental procedures are included in the drafting of its lab manual. The student would not be given the challenge and opportunity to reason out the backward steps required to get back to the “question” from the “solution”.

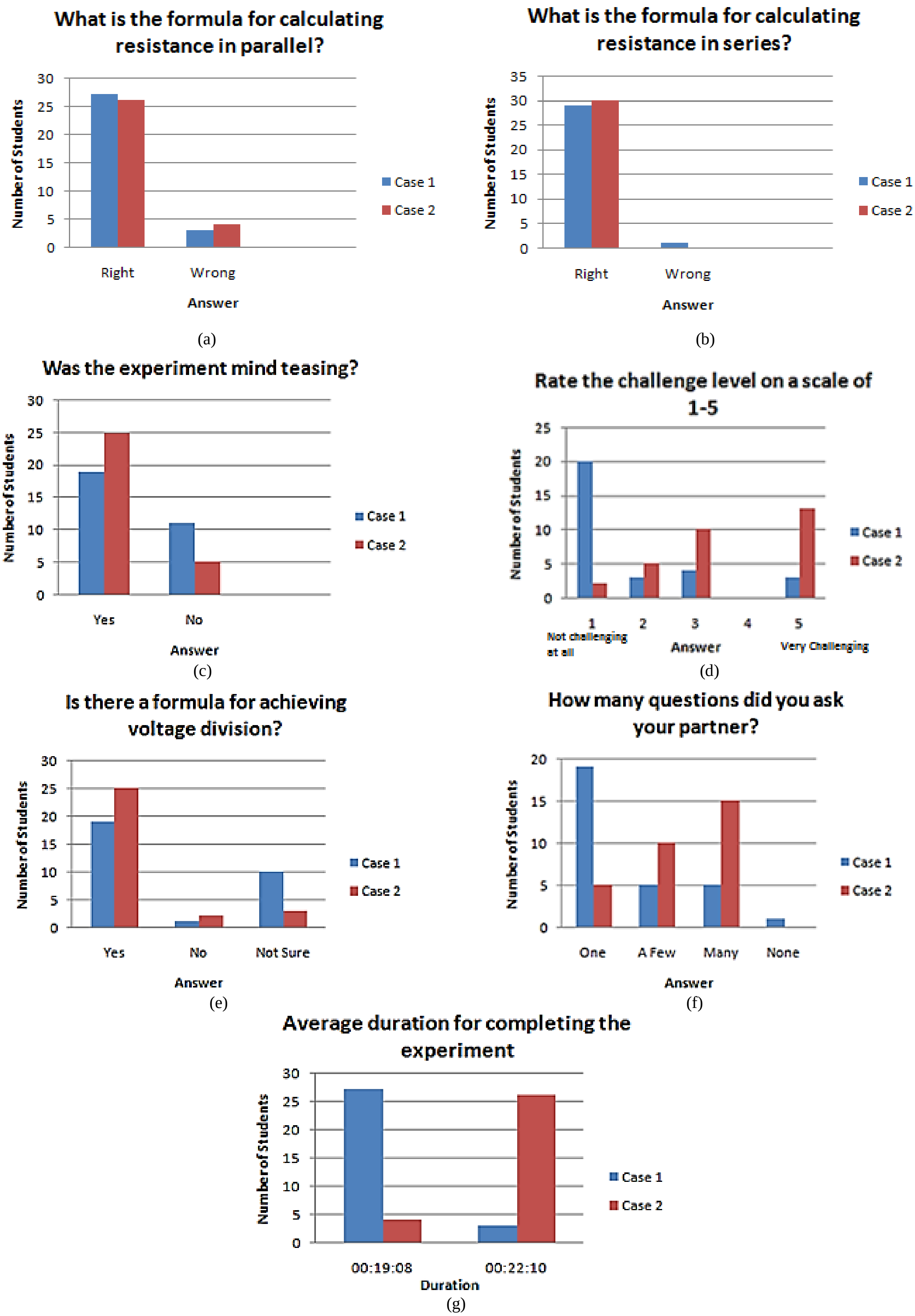
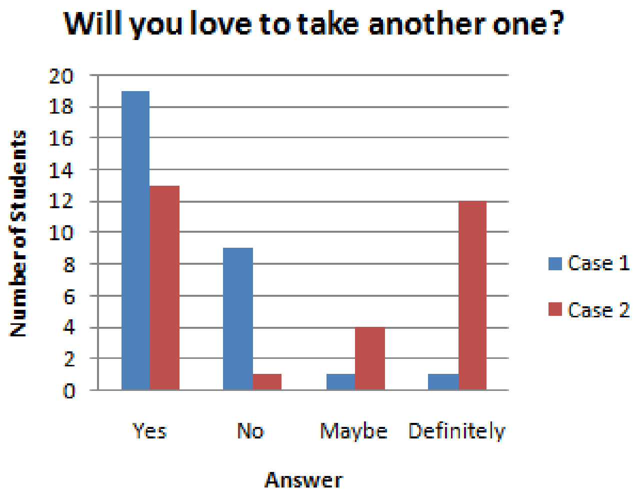


Fig. 11. Students' responses for case 1 and case 2



(g)

Fig. 12. Statistics showing induced engagement level

In summary the "Solution-to-Question" model induces engagement and interest at a sufficient level, thereby providing a better approach or paradigm for the design of remote experimental laboratories. As circuit complexity increases, it may be necessary to give a bit more known data to the students. This helps to prevent the student being stuck when working backwards using the "Solution-to-Question" model. Finally, remote laboratory developers should bear in mind that engagement and interest enhance learning.

While the study presented here was done on remote laboratories, the results suggest that the Solution-to-Question model would work as well for traditional laboratories. We therefore also recommend that traditional laboratories also be designed using the Solution-to-Question model.

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