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INTRODUCING RESEARCH SKILLS THROUGH THE USE OF THE SCIENTIFIC METHOD IN ENGINEERING LABS

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Abstract

The ability to perform research and scientific inquiries is often among the educational objectives of engineering programmes. While it is logical to think that the research skills can be developed in the labs, especially when engineering students perform quite a number of experiments while doing their studies, upon closer examination, it is apparent that most laboratory protocols in the introductory classes are demonstration based where students work on a protocol designed by the instructor to prove a concept learned in lecture. Often a laboratory manual starts with theory, description of apparatus, procedures, and then discussion questions. This flow focuses the students' effort on proving the concept and it is not aligned with the scientific method that advocate starting with observation, forming a hypothesis, logically deriving predictions, performing experiments and finally drawing conclusions. This paper reports on the use of both case-based learning and the scientific method at a laboratory setting in a first year mechanical engineering course. In this case a scenario is provided whereby students need to form a research question and use the scientific method to attain viable technical conclusions. Students found this approach very useful and engaging. They were very motivated and worked well with their teammates to achieve the team objectives.

Keywords: Scientific method, Research skills, Case- based learning.

1. Introduction

In order to conceive effective and sustainable solutions to challenges at hands, engineers require sound understanding of the underlying scientific principles. This sound understanding can be achieved through the use of the scientific method as a framework. The engineering labs where undergraduate students spend considerable amount of time performing experiments related to material properties and energy among others, seem to be the right place to nurture the scientific enquiry and research skills. However, in reality this is far from true. Most laboratory protocols in the introductory classes are demonstration based.

Students work on a protocol designed by the instructor that proves a concept learned in lecture. Additionally, most of these laboratories have a detailed protocol, not allowing the student to design or experimentally learn concepts on their own [1]. Hodson [2] argued that the educational styles used for laboratory work has seriously misrepresented and distorted the nature of scientific inquiry

Often a laboratory manual starts with theory, description of apparatus, procedures, and then discussion questions. This flow focuses the students' effort on proving the concept and it is not aligned with the scientific method that advocate starting with observation, forming a hypothesis, logically deriving predictions, performing experiments and finally drawing conclusions [3].

This paper reports on the use of both case-based learning and the scientific method at a material properties laboratory setting in a first year mechanical engineering course to replace the conventional manner in which the lab experiment was conducted. In this case a scenario is provided whereby students need to form a research question and use the scientific method to attain viable technical conclusions.

2. Lab Experiment

The lab experiment selected for this study is the Brinell Hardness Test. Traditionally; the students are required to work in teams of 4-5 to use a testing machine to measure the Brinell hardness of different metallic specimens. During the lab session, the students are briefed about the experimental apparatus and procedures and supervised throughout the lab session. Figure 1 shows the existence lab sheet for the experiment.

Clearly, this approach aims at producing the expected results every time the experiment is performed. In the process, it is felt that a valuable opportunity to inculcate the scientific method of thinking is lost. The following section describes the alternative method to be used to run this experiment.

3. Alternative Presentation

In this study, the conventional approach is replaced by introducing the students to a scenario that simulates a real case that they may face when employed. They are then asked to use the scientific method to arrive at a solution. In case of the Brinell hardness test, the proposed scenario is outlined in Fig. 2.

4. Methodology

At the beginning of the lab session, the scientific method is presented to the team. The Scenario sheet is then given to them and a 5 minute reading and discussion period is encouraged. This is followed by a stage where the instructor highlights the importance of using the scientific method to tackle the case stresses the main stages of observation, forming a hypothesis, logically deriving predictions, performing experiments and finally drawing conclusions. As the hardness testing device is already available in the lab, the instructor shall make sure to direct the experimental design to converge on the available equipment. This can be done by hinting that testing and experimentation can be done using available equipment without the need to reinvent the wheel.

Typically the process will go as follows

1. Observation: Copper is not a suitable material for table tops as it is easily scratched.
2. Hypothesis: This feature of copper (being easily scratched) is related to the molecular structure, other metals may behave differently and if another metal is used, for example aluminum, different (better) results can be expected.
3. Testing (Experimenting): If a hard enough sphere, of diameter D, is pressed against different materials (using the same load, F) it will go deeper in the softer material (making a wider indentation area, A) compared to the harder material. The higher the ratio F/A the harder the material.

Conclusion: Hypothesis is correct.

This is shown schematically in Fig. 3 below.

BRINELL HARDNESS TESTING

APPARATUS:

1. 4 pcs of specimen (Aluminium, brass, copper and mild steel)
2. Microscope/Vernier Caliper
3. Gunt Universal Testing Machine WP 300

PROCEDURES:

1. Insert the test specimen aluminum into the universal testing machine. The procedure of inserting the test specimen into the testing machine is shown in the instruction manual provided.
2. Lower the test ball onto the sample by rotating the hand wheel.
3. Smoothly applied the test force of 9.8 kN. Do not apply the force too quickly.
4. Hold the test force for around 10 – 15 seconds and then release.
5. Remove the sample and measure the diameter of the impression using a measuring magnifier. Record down the diameter. If necessary, take few measurements from different angles, hence obtain the average impression.
6. Repeat this experiment by substituting the test specimen with other materials.

Brinell Hardness						
Sample No.	Material	Impression diameter in mm			Brinell Hardness HB	
		d1	d2	d (average)	measured	From literature
1						
2						
3						
4						

7. Calculate the Brinell Hardness number using the formula shown below:

$$HB = \frac{0.102xF}{A_B} = \frac{0.102xF}{0.5\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where D = diameter of ball = 10mm
d = diameter of the impression
F = Force applied

DUSCUSSION:

1. From the experiment results that have been obtained, which material has shown the highest hardness?
2. What is the accuracy of the experiment compare to the data found in the literature?
3. What will be the results obtained if the applied force (F) is too large for a certain size of ball or vice-versa?

Fig. 1. Data Sheet for the Brinell Hardness Test Experiment.

ENGINEERING SCENARIO

BACKGROUND:
You are a part of the Engineering Department of Great Services Sdn Bhd. The company produces variety of furniture products for domestic and industrial use. A new product (table) that was recently launched by the company seems to be generating a lot of customers' complains. The complaints are mainly related to the top of the table where a copper centre was placed for ornamental purposes. The customers complained that the copper centre "easily scratched" and often had some deep marking on it if something hard is dropped on it.

TASK:
During the weekly Management Meeting, both Marketing and Customer Service Departments requested that your Department investigates the customer claims, finds what the challenge was and quickly come up with a solution. This is of utmost importance as one of the important customers, Taylor's University College, who is in the final stages of placing an order for 1000 tables for its cafeteria is reportedly in talks with a competing furniture manufacturer as it was unhappy with sample tables provided.

OUTCOME:
Working with your supervisor and colleagues

1. Propose a method to rate materials based on their resistance to scratching and plastic deformation.
2. Design a simple experiment to perform the test
3. Propose an alternative material to replace the copper top. This material should be readily available at your Company's stores, preferably brass, aluminum or mild steel.
4. Test the suitability of your proposed alternative material.
5. Discuss any other tests that you could perform to achieve similar outcome and any improvements you would suggest for your own method.
6. Discuss other factors, besides the resistance to scratching that should be considered when selecting materials for a table top.

Fig. 2. Scenario Sheet for the Brinell Hardness Test Experiment.

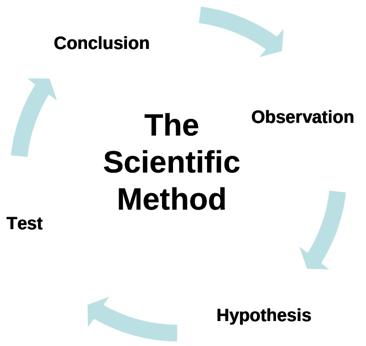

Fig. 3. Schematic Representation of the Scientific Method.

• Instructors Role

The role of the instructor is to encourage interaction between the students and the identified case. As such the role of the instructor would be to guide the students in defining the case and perhaps in some cases to provide the background to the case. It is recommended that the instructor guides the students in such a way so as to ensure that the following questions are posed to them.

- What is the case?
- Why do we need a solution?
- When do we need it by?
- Where is going to be implemented?
- Who would be affected by the outcome of the solution?

• How would we go about obtaining the solution?

It is recommended that the instructor makes an effort to pose the above “5W 1H” model to the students to structure the discussions and analytical fact finding mission. However care should be taken as not to cross over from the relevant role as played by the instructor. The lecturer could also insinuate to point out important sections during discussions and perhaps to recommend further questions. In very simple terms, students would need to develop skills of Case identification, Solution identification, Solution implementation and Case review – the CSSC methodology highlighted in Fig. 4. Each step clearly ensures that the students are learning as they progress along. This process “CSSC” aims as coaxing students to think for working and practical solutions to a case.

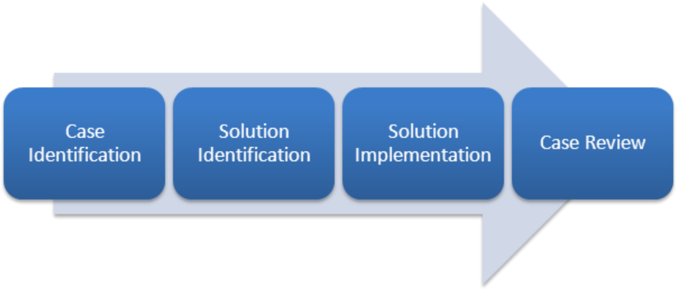

Fig. 4. CSSC Methodology.

5. Results and Discussion

A total of 60 first year engineering students performed this experiment throughout their first semester. All the students joined the course after completing a suitable (science-based) pre-university or a foundation course. The other laboratory experiments the student performed during the same semester were done using the traditional method. In the laboratory, students worked in teams of 6 and the lab session starts with a quick assessment of the student comprehension of the scientific method. This is achieved by asking them to answer four simple questions

1. Have you heard of the scientific method?
   ☐ Yes ☐ No
2. What are the basic steps for the scientific method? Please mention them in sequence.
3. On a scale of 1 (novice) to 5 (expert), assess your level of mastery of the scientific method.
4. How many times you used the scientific method last year to solve a case?

While all the students have heard of the scientific method, only 40% of them were able to correctly and completely answer question 2. More than 70% of the students gave themselves a ranking of 3 or less when answering question 3. While the average value for the answer of question no 4 was 0.4

After completing the experiment questions 2 and 4 were asked again. There was improvement in almost all the cases. To assess the long term effects of using the scientific method and case-based learning in the lab and to compare their effectiveness to that of the traditional lab methods another questionnaire was administered at the end of the 14 week semester. The following questions were asked.

1. What are the basic steps for the scientific method? Please mention them in sequence.
2. On a scale of 1 (novice) to 5 (expert), assess your level of mastery of the scientific method.
3. On a scale of 1 (not useful) to 5 (very useful), assess usefulness of using the scientific method during the Brinell hardness experiment.
4. On a scale of 1 (not recommended) to 5 (highly recommended), state whether you recommend the scientific method and the case based learning (using the case scenario) to be used in other lab sessions as well.

Generally speaking, there was a good retention rate of the description of the scientific method based on the answers for question 1. Answers for question 2 were very consistent with the post experiment answers. The answers given to questions 3 and 4 suggest that majority of the student found the use of the scientific method and case-based learning useful and they recommended the extension of the technique to other lab experiments.

6. Conclusions

Case-Based Learning was introduced into materials lab of the first year of a mechanical engineering undergraduate course. This was aimed at introducing the students to the scientific method of thinking. A scenario was created whereby students needed to evaluate the hardness of different materials and the flow of the lab events was guided by the instructor to converge on the available experiment. The students who performed the lab experiments reported that they both enjoyed the lab session and developed an appreciation to the usefulness of the scientific method. It is envisaged that the extension of the use of the Case-Based Learning and the scientific method to deliver the lab experiments will enforce and enrich the students learning experience, hence requiring them to solve and tackle cases head-on, finding a viable and implementable solution for it, thus encouraging the “learning by doing” pedagogy. The environment created provided for a highly charged learning environment where the students themselves are able to identify what needs to be learnt by providing a solution to the case and in essence the tool in providing the students’ knowledge and skills is the case.

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