ENHANCING CREATIVITY IN SCIENCE THROUGH INVESTIGATIVE TASKS

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INTRODUCTION

Investigative tasks engage students in a more creative and meaningful pursuance in learning the processes of science. They provide opportunities for pupils to use conceptual knowledge and skills in experiential learning situations. This paper generally reviews the nature of investigative work and reports on recent research studies investigating open versus closed investigative tasks in school science. The first study was conducted in the United Kingdom, and the second, a comparative study, in New Zealand and Singapore. The implications of the findings from these studies will then be discussed and suggestions made as to how local teachers can enhance the possible acquirement of process skills through investigative work.

INVESTIGATIVE WORK

In science, the tasks constituting investigative work differ a great deal, ranging from closed and highly structured experiments, termed practicals, to open and somewhat exploratory oriented investigations. Apart from complementing theoretical class instruction in science, the essential aims of investigative work are to teach the processes of science. These processes include skills such as planning, asking suitable questions, making measurements and observations, recording, predicting through the use of evidence, interpreting, analysing, providing explanations, drawing conclusions, and inferring relationships. These skills can be encompassed within the following 4 major categories (Dhillon, 1996a).

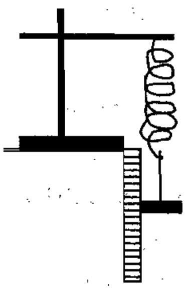
1. *Formulation* includes identification of the problem, refinement of it for study through the writing of an appropriate hypothesis for study, prediction of the outcome of the hypothesis informed through related conceptual knowledge, and planning of the study.
2. *Implementation* entails the actual performance of the investigation and collection of data. This includes such skills as observing, making measurements and recording.
3. *Evidence* involves analysing and interpreting the data to infer relationships and drawing conclusions.
4. *Explanation* entails providing the link between theory and the findings or evidence. It should help to clarify the findings in the wider scientific knowledge by building on what is known and that, which is found.

A ***closed investigation*** involves a specific path (re: figure 1) for conducting an investigation. The steps of the investigation are specified and there is little, if any, leeway for the students to deviate or to use their initiative. It is a teacher-directed and structured investigation providing guidance to the students at all stages. The decision on the question or problem to investigate is decided by the teacher. A closed investigation directs the student to easily definable variables requiring a set route to be followed and leading to a single correct outcome.

Figure 1: A closed task on mechanics.

Springs and Hooke's Law

1. *Arrange the apparatus as shown in the diagram. Make sure you have put the ruler upside down and at the right height.*
2. *The ruler should be fastened so that its '0' mark is at the bottom of the spring when there is no weight on the spring. Then it will measure the extension.*
3. *Put weights on gently, starting with the hanger alone and then adding 1, 2, 3, 4, 5, 6 and 7 extra weights.*
4. *For every extra weight, write down the position on the ruler. This is the extension of the spring. Put your results in a table.*
5. *Draw a graph using axes as shown below.*



Weight	Extension

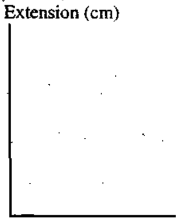


Figure 1

An ***open investigation*** involves many possible solutions with many routes (re: figure 2). It is a pupil-led investigation with questions being asked by students, who are allowed to decide on an aspect of the question they want to investigate and to proceed as they wish. The amount of structure and direction is minimal. As the degree of openness of a question increases, so too do the number of decisions that students are required to make. It provides the possibility of a variety of routes and a specific outcome is not sought.

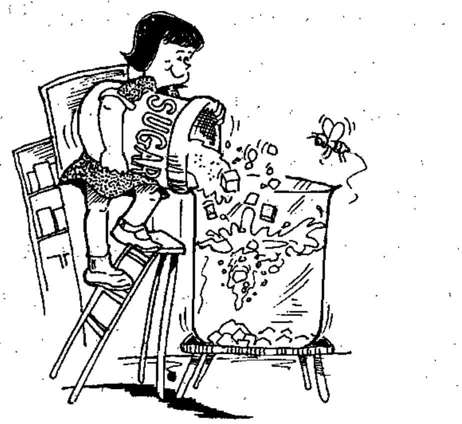


Figure 2

Figure 2: An open task investigating the factors affecting the dissolving of sugar in water.

Scenario:

Sharon has a part time job after school in a super market. She restocks the shelves and packs at the checkout. Yesterday she had to restock the sugar shelves. She was amazed at all the different types of sugar that was available. On the shelves she found white sugar, sugar cubes, soft brown sugar, coffee sugar, icing sugar, and castor sugar. At school Sharon's science class had been talking about dissolving. They had to do an investigation about it for homework. Sharon decided she would find out about dissolving sugar.

An open investigation is contrasted with a closed investigation by the degree of variation that it is possible to generate within the problem. The wording of the question used to generate the investigation is responsible for the degree of freedom given to the students with respect to how they handle the problem (Lock, 1990).

REVIEW OF RESEARCH

The studies to be reported on were conducted by Foulds, Gott & Feasey (1992) and the comparative study in New Zealand and Singapore by Dhillon (1996b).

The creativity component of the closed and open investigative work was measured through students exhibiting the skills of asking a suitable question, planning, handling variables, recording and reporting, and making conclusions from evidence. Both studies focused on the acquisition of these skills through investigative work. In addition the UK study also looked at measurement skills while the New Zealand and Singapore study looked at the ability to predict an outcome. For each of the skills addressed by both studies the findings are reported together. The findings from the UK study are reported in normal text while those from NZ and Singapore are mentioned in italics.

In the UK study 2208 secondary students aged between 15 and 17 were involved. The schools performed different investigations ranging from closed to open tasks. Student reports, observations, questionnaire and interviews were used to assess attainment of the skills mentioned above.

In the comparative New Zealand and Singapore study, 110 New Zealand and 90 Singapore high school students aged 16 and 17 were surveyed, in order to identify the skills acquired through closed and open investigative work. For the purpose of this study, the directed practicals performed in Singapore were termed *closed investigations,* while the exploratory investigations performed in New Zealand schools were termed *open investigations.* A post-test questionnaire was used to determine the following skills acquired by students through the type of investigations performed.

- **Asking a suitable question**

The majority of students were able to identify the key variables in an investigation. In an open investigation requiring a larger number of possible variables, the performance of the students was adversely affected.

Every student was able to suggest at least one question for investigation. Students performing open investigations were able to suggest more questions. The aim of the experiment is usually provided in a closed investigation. In open investigations students are required to identify and suggest questions.

- **Planning**

This had little influence on the ability to identify the correct variables. Planning seemed to be an unstructured activity, as many students did not realise what was required. Many of the essential steps in planning make demands on knowledge and understanding, such as the reasons for a particular range of measurement chosen. Many students saw planning and carrying out investigations as two tasks. The ability to plan was not dependent on the closed or open nature of the investigation.

Insufficient detail was provided by most students regarding the method used (43.2% of the Singapore group and 44% of the NZ provided a method with some detail). This was attributed to the lack of attention students paid to fine details.

- **Controlling variables**

The complexity of the investigation affected the ability of students in controlling variables. As the investigation became more complex, with more variables requiring control, student performance in this task dropped.

The Singapore group performed better than the NZ group in identifying variables for investigation. In the closed investigations students were usually given the variable being investigated and in the question the data was provided. In open investigations students were not given the variables to investigate but identified the variables they wished to study. 88% of the NZ group and 96.7% of the Singapore group were able to suggest at least 2 control variables. The concern here is that the students should have suggested at least 4 control variables.

- **Recording and reporting**

Of the 66% of students who recorded data using tables, 36% omitted information such as headings or units. Data involving two independent variables were presented in separate tables by 33%. A majority of those who presented composite tables found the complexities of headings and other information difficult to organise. 40% of all students in both the closed and open investigations who graphically displayed their data generally performed the task well.

Both groups presented the data in tabular form. The Singapore group was less prone to using graphs with only 20% doing so. They did not distinguish between recording and presenting. In closed investigations students are usually requested to draw graphs and in the questionnaire this was not explicitly stated. In comparison, 64% of the NZ group represented information in graphical terms.

- **Conclusion and evidence**

The analysis and evaluation of data were severely neglected by most students irrespective of the type of investigation performed. The conclusions and inferences made little use of the data gathered. A majority totally failed to realise the significance of the data. They produced conclusions not in keeping with it. In certain cases the conclusions were even at odds with the data.

24% of the NZ group and 28.9% of the Singapore group provided a viable but incomplete explanation for the suggested conclusion. Students in both groups were able to obtain information and provide explanations from graphically represented information. They were unable to use graphical information and relate practical considerations and constraints to arrive at an answer. Most merely used the graphical information omitting the practical constraints.

- **Measurement**

It is important to obtain quantitative data upon which to base subsequent interpretation. The majority of students quantified the key variables with 66%, 73% and 87% of year 7, year 8 and year 9 doing so respectively. A significant number of pupils in all years still judged changes in qualitative terms. A majority failed to consider the reliability, validity and accuracy of their measurements.

- **Prediction**

All groups, including those surveyed in the UK, performed well in predicting outcomes. This could be because they did not have to predict the correct outcome. This shows that both closed and open investigations might aid the students in acquiring this skill.

CONCLUSION

The findings in this paper have implications for teachers and students who respectively use and perform closed or open investigative work in science education. The findings from both studies show that closed as well as open investigative work has its benefits as well as weak points.

The implication of this is that students should be exposed to both types of investigative work. Assigning the proper task can enhance the benefits of each type of investigative work. Greater attention and guidance needs to be provided in attempting to rectify the weaknesses identified. Open investigative work clearly provides the means by which independence of thought and action may be developed since the amount of direction and structure provided to the students can be minimal.

IMPLICATIONS

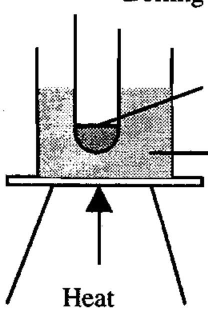
1. ***Assign tasks to address gaps in pupil's conceptual and procedural knowledge***
    - ***Closed tasks:*** students are good at some parts of investigations and weak at others. The weaknesses may be identified as gaps in conceptual and procedural knowledge. The teacher needs to assign appropriate tasks to address the gaps. The closed investigations can be used to provide pupils with specific learning contexts. (Re: figure 1 on mechanics and figure 3 on heat)

Figure 3: A closed task in a specific learning context.

Specific latent heat of fusion of a solid

1. *Set up the apparatus as shown in the diagram.*
2. *Heat the given solid in a boiling tube over a water-bath until it has completely melted.*
3. *Remove the water-bath. Allow the molten solid to cool down, noting its temperature until it is constant.*

4. *Use the table below to tabulate your results.*
5. *Plot a graph of temperature versus time.*
6. *Find the gradient (g) of the graph where solidification starts and the time (t) for which the temperature is a constant.*
7. *Use L = Stg to calculate the latent heat L, where S is the specific heat capacity of the solid.*



Time/min	Temp/C

Figure 3

- ***Open tasks***: pupils need opportunities to put their investigative skills to use in creative situations. It should be noted that investigations requiring a high level of conceptual knowledge should only be attempted after students have gained familiarity and are comfortable with the concepts (re: figure 4). This will ensure that time is spent on grappling with process skills instead of trying to make sense of the concepts involved.

Figure 4: Open investigations requiring increasing conceptual demands.

1. *Find out how the distance travelled by a toy car depends on the amount the elastic is wound up.*
2. *Find out how the distance travelled by a model car depends on its weight, and the force used to move it.*
3. *Determine if the speed of the car depends on the energy stored in the band.*
4. *Find out how the efficiency of the motor depends on*
   (a) the load being lighter, and
   (b) the speed at which it is operated.

(Adapted from Foulds et al., 1992)

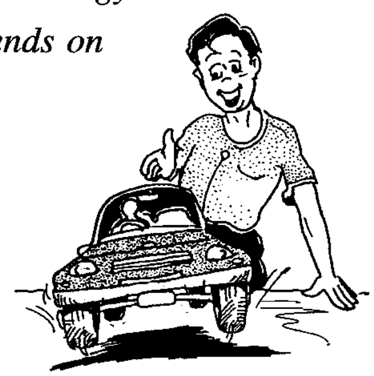


Figure 4

2. ***Provide planning sheets and structure for students***
   In closed investigative work (re: figures 1 and 3) students are usually provided with details in a structured form. These act as a model for planning. In open investigative work merely providing students with the task statements is usually not sufficient unless they are experienced in performing such tasks (re: figure 4). Students initially embarking on open investigative tasks could be given planning sheets to provide focus (re: figure 5). As they gain experience in investigative work then the direction can be reduced to enable more initiative and input from the students. Similarly, as students gain experience and acquire skills, the investigations to which they are exposed could be gradually changed from closed to open by incrementally reducing the amount of structure and detail.

Figure 5: An example of an open investigation planning sheet.

Things to think of when planning and performing your investigation

The Problem	What is the problem or task that you have chosen or have been set?
Background Knowledge	What previous knowledge do you have which might be useful?
Predictions	What do you think might happen in your investigation?
Linking Prediction With Theory	From what you already know why do you think your prediction will happen?

FOR DATA COLLECTION

Things I Will Change	**Things I Will Keep The Same**
What I Will Measure	**What I Will Measure It With**

METHOD

Write step by step instructions for what you are going to do

Have your plan checked by your teacher

Carry out the investigation and write a report including an aim, predictions, results, and discussion of findings and conclusion.

3. ***Intervene to provide guidance***

Planned intervention is essential at all points throughout the investigation, especially during the initial planning stages. Student attention needs to be focused on the various aspects of import. They should be provided with practise in the skills of : *raising a question, hypothesising, deciding which variables to change, control and measure, recording and presenting appropriately, interpreting and analysing, evaluating the evidence, and explaining the inference or conclusion.*

Teacher intervention should be performed at each stage to ensure that the student is performing the investigation at the appropriate level. The teacher could intervene by asking questions and suggesting ideas to students to provoke critical evaluation on procedures and outcomes during investigations. For example:

- to give information;
- pull together and advance pupils ideas;
- focus the students on the task;
- help relate conceptual knowledge to the task;
- help develop procedural understanding through correction, demonstration and discussion.

4. ***Modify investigations from a closed to open format***

When students show they are capable, then open investigations will provide greater practice of the skills involved in the processes of science. Traditional experiments can easily be modified to provide open, unstructured and undirected tasks *by reducing the amount of instructions provided.* Alternatively the students could be given general scenarios which delete specific information to make the scenario open-ended. For example, the closed experiment supplied in figure 1 could be modified, taking the instructions away and merely providing a general statement such as: *investigate the factors affecting the extension of the spring.*

Reducing the amount of information and structure provided in the closed task could also be done. For example, the teacher might choose to start with the detail provided in figure 1 and for future investigations gradually remove the graph axes, the table, the weight values and the number of readings that should be taken and so on.

SOURCES

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A closed task investigating lenses.