CONTEXTUAL THINKING IN SCIENCE EDUCATION

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Abstract: While general thinking skills may have a role to play in the general education of students, there is little doubt that thinking in the context of a discipline is a powerful tool for learning the main concepts of a subject. In this paper, the author will discuss the attempts of a group of pre-service science teachers in using convergent and divergent thinking based on appropriate tasks. Such attempts to integrate their thinking process within the context of their knowledge expertise and specialisation have important implications for science teacher education. The author will also discuss a number of appropriate pedagogical considerations and opportunities that are available for classroom science teachers to facilitate and enhance teaching-learning.

Introduction

In many discussions and dialogues on educational reforms and reviews, educators have called for contextual learning. Learning by doing, experiential learning, real-world education and active learning are other terms that could be associated with such learning. Such concerns have to do with the need for students to understand academic concepts within the context of the real life domains of students (Reed, 1996). Such learning will need to ensure connection between school and life (Pearce et. al., 1992; Bolt & Swartz, 1997; Brown, 1998), incorporate career-related and employability aspects of academic content (Woodhull, 1997).

Broader definitions of contextual learning include learning where new information are presented to students in familiar contexts (Hull & Souders, 1996) and in contexts relevant for the students (Dabbagh, 1996).

While there is no doubt that students’ interest may be improved with real life context, one has to ensure that learning must also be accompanied with contextual thinking, that is, thinking within the context of the discipline.

Contextual Thinking in Science Education

As with many general educational principles and practices, general thinking skills have an important role to play in the general education of students. Yet, there is little doubt that thinking in the context of a discipline is a powerful tool for teaching-learning the main concepts of a subject. Science educators have always acknowledged that the nature of science is one that calls for inquiry and demands that those who deal with the subject approach it in a thinking manner. I would like to suggest that this thinking philosophy is the heart and soul of science, not a by-product of science. It is also acknowledged that this philosophy may not always be reflected in the actual practice of science teaching.

In science, contextual thinking will involve a variety of thinking skills – science process skills, Piagetian thinking modes (such as combinatorial thinking, probability thinking, proportionality thinking), deductive and inductive thinking, and analytical thinking. Such thinking needs to be anchored within the context of substantive science so that the integrated whole would:
• encourage more high order processing activities;
• offer significant in-depth knowledge, allowing students to explore the various perspectives, to make connections and interconnections and to perceive the concept’s complexities;
• enhance meaningful conceptual learning; and
• enable students to use their existing cognitive structures to construct new understandings.

Examples of Tasks for Contextual Thinking

In previous papers (Yap, 1996, 1997 & 1998), a number of examples that encourage thinking within the context of teaching-learning of science were given. Such examples were used in different approaches and practices of teaching-learning science – classroom demonstrations, laboratory activities and experiments, and problem solving.

In the laboratory experiment which requires the circuit connection below, the variable resistor \( R \) is to be formed by connecting one or more of the 3 identical resistors provided. These may be connected either in series or in parallel to obtain different values for the resistance of \( R \).

![Figure 1](image)

The contextual thinking that becomes part of the active involvement and participation of ‘doing’ such an experiment would be inculcated through the following questions:

- How many possible combinations of \( R \) are there?
- What is the minimum possible value of \( R \)?
- Represent each combination with an appropriate diagram.

Combinatorial thinking is necessary in such a task. However, in order for meaningful teaching-learning to occur, it has to be applied within the context of the conceptual knowledge of series and parallel connections and the respective effective resistance.

An example of a laboratory activity that involves deductive inquiry and active hands-on participation (making models) is given as follows.

Ahmad lives in a double-storey house. He has installed a switch downstairs and also a switch upstairs to control the same bulb which is located in the middle of the stairs.

Sketch a diagram to show how the bulb and the switches are connected to the power supply.

Make a model, based on your sketch, to see whether it will really work.
This particular example also has the context of everyday life or experience. However, for successful completion of the task, spatial thinking has to be firmly anchored on knowledge of different types of switches.

For an example of laboratory demonstration, consider the ‘Loose Lid’ demonstration (or sometimes referred to as the ‘air pressure problem’) from the early work of Richard Suchman (1966) under his Inquiry Development Program.

A drinking glass or jar is filled to the brim with water (make sure that there are no air bubbles trapped in the container). A piece of cardboard is placed over it as a lid. A demonstrator holds the lid against the container and turns the container upside down. He takes away the hand holding the lid, but the lid remains in place and the water remains in the upside-down container.

**Figure 2**

A number of possible questions were raised to inculcate thinking but learning could only be meaningful within the conceptual knowledge base of force and pressure. Thinking within the context of problem solving is illustrated by an adaptation of a problem taken from The Physics Teacher (Fan, 1992).

Consider the two masses, $m_1$ and $m_2$, in the figure below. At time $t=0$, $m_1$ is at rest and $m_2$ is moving with velocity $v_0$. Is it possible to apply the same constant force (suppose the direction is right) for the same time to both masses to bring them to equal velocity at a given moment?

**Figure 3**

$$t=0$$

Not only is the problem relevant to the syllabus, but also appropriate thinking demanded from students. There are at least two possible approaches to tackle the problem, namely, using (1)
mathematical equations and (2) velocity-time graphs. Even if the use of mathematical equations may be beyond most students at the secondary level, it can be approached using velocity-time graph(s). Students naturally have to be able to interpret such graph(s) and relate to the physics concepts involved in solve the problem. In addition, there are three comparisons of m1 and m2 to take into consideration before providing an appropriate response. Hence this problem requires one to use combinatorial thinking within the knowledge context expected of students.

In this paper, I would like to focus more on a specific task taken from the Science Curriculum Improvement Study on models in science (Berger & Karplus, 1968). The task, which I shall call ‘Six-Bulbs Mystery Board’, is given as follows:

You are provided batteries, wires and a mystery board involving the connection of six identical bulbs. When connected to the batteries, bulb 5 is the brightest, bulb 4 next and bulbs 1, 2, 3 and 6 are equally dim, almost not lit at all. Your task is to identify (with the aid of a diagram) how these six bulbs are connected!

In particular, I would like to discuss how this task can be adapted for contextual thinking and to provide insights on pre-service and in-service teachers’ contextual thinking based on the adapted task.

Adapting for Contextual Thinking

The task as given above is one that calls for deductive inquiry, focussing on convergent thinking. Instead of focussing on just the correct connection, one could adapt the task to include divergent and spatial thinking. One could encourage the use of combinatorial skill and knowledge of series and parallel connection to work on possibilities before continuing to deduce the correct connection of the mystery board. For each connection identified, they could also use their knowledge of voltage, current and resistance in series and parallel connections to check whether it conforms to the conditions of the task.

Suggest as many possible connections as you can that will ensure that bulb 5 is the brightest, bulb 4 next and bulbs 1, 2, 3 and 6 are equally dim, almost not lit at all. For each possible connection, include an explanation (using mathematical reasoning and/or your knowledge of relevant physics principles/ideas) as to why it is indeed possible.

Thus, the nature of contextual thinking demanded of this adapted task involves:

- Divergent thinking but more specifically combinatorial thinking,
- Spatial thinking,
- Convergent thinking.

The knowledge base or context for meaningful thinking to take place comprises the following:

- Knowledge of series and parallel connection.
- Brightness of a bulb is a function of electrical power.
- Electrical power can be expressed by any of the following electrical relationships:
  \[ P=I^2R, P=VI \] or \[ P=V^2/R \]
- For identical bulbs, the resistance of the bulbs is identical.
- Two or more identical bulbs will be equally bright if it can be established that the current passing through each of the bulbs is the same.
Two or more identical bulbs will be equally bright if it can be established that the voltage across each of the bulbs is the same.

**Insights and Discussion on Pre-service and In-service Teachers’ Contextual Thinking**

Over the last few years, this adapted task, among others, had been introduced in pre-service and in-service teacher education to illustrate how science curriculum, instruction and assessment should adapt for the new millennium. Insights on contextual thinking were derived from the diagrams of the various possible combinations that conform to the description of the brightness of the various bulbs.

When left to attend the task on their own, either individually or as a group, one of the first observations was that not all the possible combinations were usually given. Whatever the number of combinations obtained and whether ‘correct’ or not, they would be quite satisfied initially.

Some groups would try to work with bulbs 1, 2, 3 and 6 connected in series, while others would try to work with bulbs 1, 2, 3 and 6 connected in parallel.

![Figure 4](image1.png)

![Figure 5](image2.png)

For those who ‘struggled’ with the series connection, their initial perception and conception was that the 4 bulbs were equally bright only because of equal current passing through each of the bulbs. As for those who ‘struggled’ with the parallel connection, their initial perception and conception was that the 4 bulbs were equally bright only because of equal voltage across each of the bulbs. Conceptually they were not wrong, but the task demanded that all relevant knowledge and possibilities should be included.

From the diagrams drawn of the possible combinations, there appeared spatial thinking problems. One example was that of Figure 6 below.
They had the conception that bulb 5 was brighter than bulb 4. This conception was based on the belief that the current passing through bulb 5 is greater than the current through bulb 4. They would reason that the current through bulb 5 will be divided into two components, one through bulb 4 and one through bulbs 1, 2, 3 and 6. This thinking would be based on a ‘partial understanding’ of Kirchoff’s Law. This example provides clear evidence that contextual thinking is so important and a great stimulus for more meaningful learning of some of the concepts that we thought we had learned so well.

For some learners, an addition of the power source to Figure 6 may help them to consider the possibility that current through bulb 5 may be the same as that through bulb 4. However, based on just visualisation of the diagram it may not evident still. Some mathematical calculation and manipulation may help.

In such cases, learners may be directed to compare for themselves the voltage across bulb 4 and bulb 5 instead of focussing on the current.

For learners who insist on focussing on the current and also to enhance spatial thinking, they may be advised to redraw the diagram as in Figure 8.
Another diagram of a possible connection that was given is that in Figure 9. The conception was that bulb 4 will be brighter than bulbs 1, 2, 3 and 6. Here they viewed bulb 4 as one group compared to another group comprising bulbs 1, 2, 3 and 6. This second group could be reduced to one effective bulb with resistance that is a quarter of the resistance of bulb 4. They would agree that the voltage across the two groups of bulbs would be the same and hence the current and brightness different. Again there is difficulty for some to visualise that the voltage across each of the bulbs 1, 2, 3, 6 and 4 is the same.

Adaptations for Different Needs

It has never been easy to change the science curriculum, instruction and assessment in order to reflect and inculcate meaningful thinking. It is also recognised that our education system needs to cater for students at different grade levels and also for different ability groups within the same grade level. The task introduced above may be perceived as too difficult or demanding for some students. An adaptation that has been suggested is to begin with 3 or 4 bulbs instead of 6 bulbs.
If the use of power from the mains is a safety concern, it is also possible to replace a similar board with a lower voltage supply.

On the other hand, for the more advanced level and/or students, one could encourage the use of content knowledge to check whether two or more connections may result in similar brightness. Where mathematical knowledge and skills are part of the educational objectives, learners could be requested to work out the power of individual bulbs. For example, would there be a difference in terms of brightness for bulbs in Figure 10 and Figure 11.

**Figure 10**

![Figure 10 Diagram]

**Figure 11**

![Figure 11 Diagram]

**Concluding Remarks**

Meaningful learning is a complex and multifaceted process that goes beyond a drill-oriented approach. Meaningful understanding will only be ensured when students are constantly being confronted and challenged with situations and contexts that require them to think. Existing science curriculum, instruction and assessment are not adequate to help our students for such meaningful learning. The challenge for science teachers is to be able to adapt and innovate in ways that will promote more contextual thinking.
References


