Power Thinking and Thinking Power

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Abstract

This paper will address the thinking of pre-service teachers on the physics concept of electrical power and their ability, and hence power, to think through a task on electrical power. In the thinking task assigned to them, they were asked to observe the brightness of two similar pairs of bulbs (25W and 40W) that were connected differently. Each connection was either in series or in parallel. In each case they were asked to observe whether the 25W bulb or the 40W bulb was brighter. They were then asked to determine which pair was connected in series and which in parallel. From their explanations and drawings, it was possible to determine their thinking on power, their ability to draw on everyday experience and knowledge and also their ability to draw on physics knowledge. As an essential component of science teacher education, they were also encouraged to think of appropriate pedagogical opportunities for enhancing teaching-learning.

Introduction

The relevance and importance of the thinking process in science education and science teacher education cannot be overemphasised. There is a need for science educators and teachers to incorporate routinely and habitually thinking features in their instruction, curricula planning and assessment. In earlier papers by the author (Yap, K. C., 1996 & 1997), this had been given due emphasis.

This paper will address the thinking of pre-service teachers on the physics concept of electrical power and their ability, and hence power, to think through a task on electrical power.

Studies on Electricity and Electrical Power

A number of studies have been carried out on students' conceptual diffifculties in electricity (examples are Fredette N. & Lochhead, J., 1980; Cohen, R., Eylon B. & Ganiel U., 1983; Steinberg, M. S., 1983; Duit R., Jung, W., & von Rhoneck, C., 1985; Steinberg, M. S., 1987; Shipstone D. M. et al., 1988; McDermott, L. C., & Shaffer, P. S., 1992). These studies deal mainly with the basic concepts of current, voltage, potential difference and electrical energy. In a more recent study by Berg and Grosheide (1997) the concept of electrical power was included. All these studies involved students and curricula at the grades 7 and 8 levels.

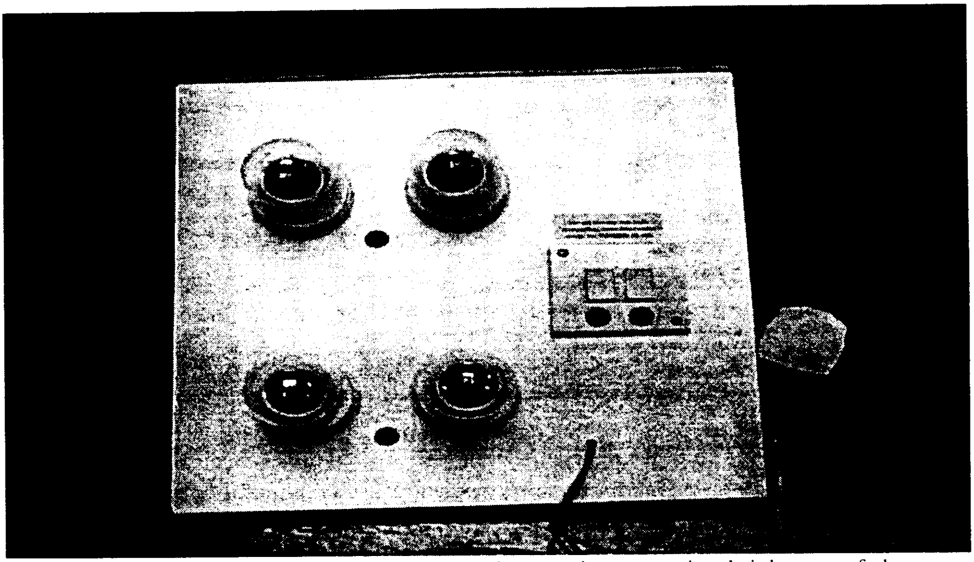
The present paper deals with concepts that go beyond those that were discussed above. Other than the brief report of the series-parallel demonstration described by Steiger and Hwang (1995), the author is not aware of any other study on electrical power of electrical bulbs in series and parallel connections. Even then the main motivation for this study was to infuse thinking into our pre-service science teacher education programmes. It was felt that the alternative conceptions and conceptual difficulties would also surface when the thinking process was investigated.

The Thinking Task

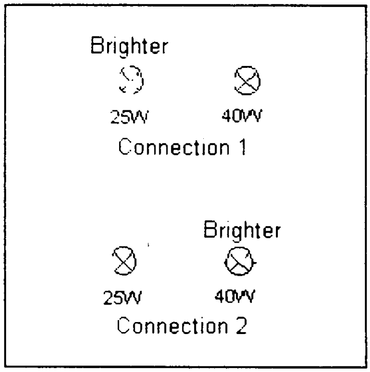
Mohanan (1997), in supporting critical understanding and thinking, had argued *"that the science classroom should have a workshop component where students discover facts, construct theoretical explanations of facts, look for alternative explanations, present evidence and argumentation in support of factual and theoretical claims, and evaluate claims and arguments. In other words, the teaching of science will have to be centred round a number of tasks aimed simultaneously at the development of scientific knowledge and scientific thinking, rather than mere transmission of facts, theories, and evidence."*

While we may agree with Lemke (1992) that learning science cannot *"be limited to classrooms and school science laboratories at all"*, we would still like to ensure that the tasks and examples we introduce in science classrooms and laboratories relate to daily life and also stimulate conceptual thinking. We would still seek to integrate features that assist, trigger, facilitate conceptual analysis and construction. At the same time, such tasks should not exclude appropriate mathematical savvy. Where appropriate, they could be used to show the importance of meaningful understanding and use of mathematical relationships.

One such task that was employed in the present study is an adaptation of the series-parallel demonstration described by Steiger and Hwang (1995). Based on an understanding that pre-service teachers and students find fascination, challenge and motivation in learning through indirect means, a mystery board comprising a series and a parallel connection of a similar pair of bulbs was constructed. A photograph of this mystery board is shown below.



The task for the pre-service teachers was to observe the respective brightness of the two bulbs with different power ratings (for example, 25W and 40W) in each of the two connections. When the switch for connection 1 was turned on, the 25W-bulb would be brighter than the 40W-bulb. When the switch for connection 2 was turned on, the 40W-bulb would be brighter.



Based on these observations, they were then asked to determine which was a series connection and which a parallel connection. They were encouraged to raise relevant questions. Needless to say they were requested to indicate their thinking process. The various appropriate electrical relationships ($V=IR$, $P=I^2R$, $P=VI$ and $P=V^2/R$) were given and help to determine any reasonable measurements was also made available.

Knowledge Context

In setting this task, it was assumed that most pre-service teachers would possess the typical school textbook knowledge of Ohm's law and power equations. In this task, one would realize very quickly that knowledge of the respective resistance of the bulbs may have a critical influence. This knowledge is not communicated explicitly in typical school textbook and classroom teaching.

From a pedagogical viewpoint, one would desire that the problem solving process would lead to a confirmation of the respective resistance of the two bulbs.

Hypothesised Approaches in Solving Task

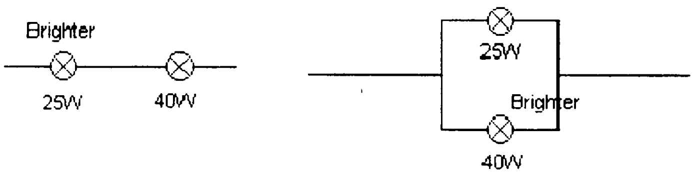
In setting this task, the author had earlier hypothesised that the pre-service teachers would probably use one of the following approaches.

Prior Knowledge and Experience Approach

One hypothesised approach to the problem solving process was to begin with the prior knowledge and experience of using a higher wattage bulb for a brighter room and linking this to the knowledge of parallel connection for household electrical lighting. It was rationalised that they may have such daily-life experience and would relate to knowledge of household connection at the primary school level. From here one would expect them to 'predict' that connection 2 would be a parallel one. Through the identification of the equation $P=V^2/R$ (since the voltage identical across the 25W-bulb and the 40W-bulb) and the use of inverse proportional thinking, they would then conclude that the resistance of the 40W-bulb is lower than the 25W-bulb.

They would then explain why the 25W-bulb would be brighter for the connection. At this point it would be appropriate for a confirmation to be conducted. One could actually measure the respective resistance of the two bulbs using an ohm-meter.

First Principles Approach
What if the earlier prior knowledge and experience as discussed above do not exist? In such a situation, it was hypothesized that they would start from first principles. They would then draw two possible scenarios as indicated below and proceed from these two scenarios.



Scenario A

Scenario B

If scenario A is correct, then the resistance of the 25W-bulb is greater than the resistance of the 40W-bulb ($R_{25} > R_{40}$). However if scenario B is correct, then the resistance of the 25W-bulb is less than the resistance of the 40W-bulb ($R_{25} < R_{40}$). At this point it would be apparent that one need to establish the respective resistance of the two bulbs.

Power Ratings Approach
The third hypothesized approach made was that they had an understanding of the power ratings on electrical bulbs. However, knowing that typical school textbooks and teaching do not introduce and relate to daily life experiences and phenomena, it was felt that this approach would be unlikely. It was also for this reason too that this attempt to look at the power thinking and thinking power was made.

Participants and Data Involved in Study

This 'thinking' task had been given to a small group of eight pre-service teachers as one of the regular activities that involve active hands-on and minds-on participation during regular curriculum time. It was designed to model a possible thinking environment within a regular class. They were allowed to work and discuss in pairs. Nevertheless, observations based on interaction with previous groups would also be included at appropriate sections.

Insights and Discussion on Pre-service Teachers' Thinking

Thinking Power

In order to provide a representative description of the 'thinking ability' involved in solving the task, a summary of the scripts by the four pairs of pre-service teachers is presented below.

Pair A:
Started with a drawing of a series connection of the 25W-bulb and 40W-bulb;
Showed knowledge that the electrical current through both bulbs are the same;
Assumed that the resistance of 40W-bulb greater than resistance of 25W-bulb; (did not indicate why)
Used equations V=IR and P=IV to deduce that voltage across and power of 40W-bulb greater than voltage across and power of 25W-bulb;
Finally deduced that connection 2 would be a series connection.
Continued with a drawing of a parallel connection of the 25W-bulb and 40W-bulb, same assumption of resistance of 40W-bulb greater than resistance of 25W-bulb and 'correct' use of equations to deduce that connection 1 would be a parallel connection.

Pair B:
Basically the same group A's response except they started off by assuming resistance of 25W-bulb greater than the resistance of 40W-bulb.

Pairs C and D:
Started with "prediction" that connection 1 a series connection and connection 2 a parallel connection; (did not indicate why)
With a drawing of a series connection of the 25W-bulb and 40W-bulb, showed knowledge that the electrical current through both bulbs the same;
Used equation $P=I^2R$ *to show direct proportionality relationship of power (P) and resistance (R);*
Assumed power rating of bulb to be same as power (example, power of 40W-bulb equal 40W) to show that resistance of 40W-bulb greater than resistance of 25W-bulb;
Continued with a drawing of a parallel connection of the 25W-bulb and 40W-bulb, showed knowledge that the voltage across both bulbs same and used equation $P=V^2/R$ *and inverse relationship of power and resistance to show that resistance of 40W-bulb less than resistance of 25W-bulb.*

Pair A started with the wrong assumption of the resistance of the two bulbs and arrived at the 'wrong answer'. They did not check to see what the outcome would be if they had assumed that the resistance of the 25W-bulb was greater than the 40W-bulb. However one must note that they had the appropriate textbook knowledge and could apply the appropriate equations.

While Pair B may have started with the correct relationship of the resistance values of the two bulbs, it certainly did not indicate their 'thinking power'. If they had started as Pair A did, they would probably be 'satisfied' with their attempts also.

Pairs C and D also had the typical textbook knowledge but had assumed the power ratings to be applicable for both series and parallel connections and came up with different conclusions about the relationship of the resistance values of the 25W-bulb and the 40W-bulb in each case.

Pairs A and B had assumed that knowledge of resistance was important. They made assumptions of the resistance without making any attempts during the session to raise question(s) on this nor asked whether they could confirm their assumptions. It would be quite typical for them to have no prior knowledge and experience of the resistance of the two bulbs. It appeared quite appropriate to categorise this as a 'resistance-assumption' approach. It does not matter whether they started with the assumption that the resistance of the 25W-bulb was greater or that the resistance of the 40W-bulb was greater.

On the other hand, Pairs C and D appeared to adopt the 'power ratings approach'. However, due to their misunderstanding of the power ratings on the bulbs they found that there was no convergence in their conclusions of the relationship of the resistance values of the two bulbs.

While most of the pre-service teachers may possess the typical school textbook knowledge of Ohms law and power equations, an observation of interest was that there was no attempt to check their assumptions of the respective resistance of the two bulbs or confirm their conclusions of the relationship of the resistance values of the two bulbs.

Power Thinking

From the scripts provided by this group of pre-service teachers and interaction with other earlier groups, various conceptual difficulties facing our pre-service teachers were observed. Specifically, conceptual difficulties with respect to the electrical power of bulbs and lack of meaningful understanding of mathematical relationships were observed.

Conceptual difficulties with respect to the electrical power of bulbs
What does a higher wattage on an electrical bulb mean? Does it mean that a higher wattage bulb will always be brighter? Under what circumstances would this be true? These questions appeared to throw some pre-service teachers off balance.

A number of 'alternative' conceptions appeared to be evident among the pre-service teachers, namely:

- a higher wattage bulb should be brighter than a lower wattage bulb in all connections; this conception had in part been reinforced from their real-life experience with choosing and changing to higher wattage bulbs in order to have a brighter room,
- a bulb would get the energy it demanded regardless of the voltage across the bulb, and
- a higher wattage bulb must have a larger resistance

Meaningful understanding of mathematical relationships
Based on previous experience with other groups, this task appeared to have caused disequilibrium in the understanding and use of the three power equations. This was especially true when it involved the resistance. When the resistance was compared for the 25W-bulb and the 40W-bulb, they could argue that the power was larger for larger resistance using the equation $P=I^2R$ or they could argue that the power was smaller for larger resistance using the equation $P=V^2/R$. This uncertainty and confusion apparently indicated a poor understanding of mathematical relationships, a lack of simple mathematical savvy and failure to identify a simpler relationship depending on the connection under discussion.

However, all the four pairs here did not appear to have this problem.

Implications of Study

It would be appropriate for educators to take note of the following.

- There is a need for our pre-service teachers to be exposed to more activities that involve integrative thinking based on everyday experience. Such activities that stimulate meaningful thinking and learning should not be taken for granted.

- There is a need to make explicit links to prior experience and the curriculum at a lower level at appropriate opportunities.
- Pre-service teachers should also be provided opportunities and experiences that they could model during their future teaching assignments. Hopefully they would be encouraged to think of appropriate pedagogical opportunities for enhancing teaching-learning.

Conclusion

In our effort to build a future generation of thinking students, it would certainly be wise for us to invest in the schools and teachers of today. There is a need to expose our pre-service teachers with not only more but also a variety of opportunities and practices that will stimulate active and meaningful thinking.

References

Berg, Ed van den & Grosheide, Wim (1997). Learning and teaching about energy, power, current and voltage. *School Science Review*, *78*(284), 89-94.

Cohen, R., Eylon, B. & Ganiel, U. (1983). Potential difference and current in simple electric circuits: A study of students' concepts. *American Journal of Physics*, *51*, 407-412.

Duit R., Jung, W. & von Rhoneck, C. (Eds.). (1985). Aspects of Understanding Electricity – Proceedings of an International Workshop. IPN/Schmidt and Klaunig, Kiel, Germany.

Fredette, N. & Lochhead, J. (1980). Students' conceptions on simple circuits. *Physics Teacher*, *18*(11), 194-198.

Lemke, J.L. (1992). *The Missing Context in Science Education: Science*. Paper presented at a multi-disciplinary symposium "In Search of Inquiry" at AERA, Atlanta, GA. Arlington VA: ERIC Documents Service (ED 363 511), 1994.

McDermott, L.C. & Scaffer, P.S. (1992). Research as a guide for curriculum development: An example from introductory electricity. *American Journal of Physics*, *60*, 994-1013.

Mohanan, K.P. (1997). *How Does Education Paralyze Independent Thinking? Critical Understanding and Critical Thinking in Science Education*. Paper presented at the 7th International Conference on Thinking, Singapore.

Shipstone, D.M. et al. (1988). A study of students' understanding of electricity in five European countries. *International Journal of Science Education*, *10*, 303-316.

Steiberg, M.S. (1983). Reinventing electricity. In H. Helm and J. Novak (Eds.), *Proceedings of the International Seminar on Misconceptions in Science and Mathematics*. Cornell University, Ithaca, New York, 388-401.

Steinberg, M.S. (1987). Transient electrical processes as resources for causal reasoning. In J. Novak (Ed.), *Proceedings of the Second International Seminar on Misconceptions and Instructional Strategies in Science and Mathematics, III*. Cornell University, Ithaca, New York, 480-489.

Steiger, W.R. & Hwang, S.R. (1995). A Series-Parallel Demonstration. *The Physics Teacher*, *33*, 590.

Yap, K.C. (1996). Teaching to Think and Thinking to Teach: The Physics Trend. Invited presentation at the 4th International Workshop in Physics Education: "New Trends in Physics Teaching", Puebla, Mexico.

Yap, K.C. (1997). The minds-on approach: The thinking half in science teacher education. 7th International Conference on Thinking, Nanyang Technological University/ National Institute of Education, Singapore Abstr. p.151.