# PROBLEM-SOLVING IN PHYSICAL SCIENCE AS PERCEIVED BY GRADE 12 LEARNERS DURING WINTER SCHOOL SESSIONS

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## Abstract

Although problem-solving is central to any Physical Science course, most high school learners often find it very difficult. First time university entrants especially to departments of Mathematics, Science and/or Technology Education, of South African university reportedly have poor numeracy and problem-solving skills. These are coupled with indifferent attitudes to learning Physics, a discipline perceived as formula-driven and mathematical. This study, sought to establish perceptions of the Grade 12 learners who attended the winter school regarding problem-solving in physical science. The study adopted a non-experimental, exploratory and descriptive method. A sample comprising 187 captive but randomly selected learners responded to a researcher-designed questionnaire distributed to them during the final week of the Winter School session. Winter school is part of the university's community outreach programme to support learning from historically disadvantage schools. The learners came from fifty high schools and were enrolled for a Physical Science crash programme meant to capacitate them in the physical sciences. Data were statistically analysed using SPSS. Results indicated that key factors which directly influenced the learners problem-solving skills related to their beliefs, content knowledge, teacher's teaching strategies, motivation, laboratory use, and non-completion of the school syllabus in a year etc. Recommendations as well as suggestions for further research aimed at addressing the identified factors are advanced.

**Keywords**: Problem-Solving, Physical Science, Grade 12 Learners

## INTRODUCTION

The perceived difficulty of physical science as a subject primarily emanates from the problem solving nature of the subject. Success in learning the subject requires some experimental work experience, a high degree of problem solving skills coupled with high level of mathematics knowledge. To be a successful physicist, one must be an accomplished problem solver. This can be achieved by employing the language of mathematics to communicate both qualitative and quantitative principles of physics. Therefore mathematics is the essential key feature in the quest to understanding physics (Valiotis, 2008). As a result, almost all physical science branches have got some problem solving element.

## BACKGROUND

Problem solving as defined in the Business dictionary (2013) is "the process of working through details of a problem to reach a solution. Problem solving is also viewed as a cognitive processing aimed at achievement of a goal when the solution is not obvious to the problem solver (Meyer, 1992). It integrates concepts and skills to overcome unusual complete situations (Dogru, 2008). Problem solving may include mathematical or systematic operations and can be a gauge of an individual's critical thinking skills". It integrates concepts and skills to find a way around unusual complete situations by finding and creating new solutions and applying new rules to be learned (Dogru, 2008; Mayer & Wittrock, 1996).

The *Curriculum and Assessment Policy Statements (CAPS)* (Department of Education, 2011) for physical science was introduced in South African schools in 2012 at grade 10 as a replacement to *National Curriculum Statement (NCS) Grades 10-12* (2002). The aim was to improve on the shortcomings of NCS and to accommodate new innovations and trends in the ever-changing scientific realm. According to the Physical Science CAPS document, the revised National Curriculum Statement Grades R-12 main aims amongst others are to produce learners that are able to:

• identify and solve problems and make decisions using critical and creative thinking;

• organise and manage themselves and their activities responsibly and effectively;

• collect, analyse, organise and critically evaluate information;

Therefore CAPS strongly emphasise the central role played by knowledge of problem solving skills in the teaching and learning of physical sciences. Process skills, critical thinking, scientific reasoning and strategies are identified as important prerequisites for scientific inquiry and problem solving.

## RESEARCH OBJECTIVES

This study sought to:

- Identify the methods and strategies learners claim to use in physical sciences problem solving process and identify factors if any, which influence choice of these methods.
- Investigate the effect, if any, which CAPS approach to teaching and learning, might have on improving problem solving amongst grade 12 physical sciences learners.

## RESEARCH QUESTIONS

The following guiding questions were developed from the research objectives:

- Which methods and strategies do grade 12 physical sciences learners claim to use to solve physical sciences related problems?
- What factors (if any), influence choice of these methods?
- Does CAPS approach to teaching and learning have an effect on improving problem solving skills by grade 12 physical sciences learners?

## METHOD

This study adopted a quantitative research design. It was, thus informed or guided by the descriptive research paradigm sought to establish perceptions of the Grade 12 learners who attended the winter school about problem-solving in physical science.

### *Participants and setting*

Two groups of grade 12 physical science learners from North West, Gauteng, Free State and Eastern Cape Provinces who attended a two week Winter Vacation School at Central University of Technology, Bloemfontein campus participated in this study. The data was collected over two years. The first set of data was collected from Group 1, comprising 84 learners who were the last group to write the National Senior

Certificate R10-12 physical science paper in 2013. The second set of data was collected from Group 2 (123 learners) who were the first group to write the physical science paper under CAPS in 2014. A wide range of learners, mostly from public schools participated in this study.

### *Ethical Issues*

In this study, the researchers complied with ethical issues of consent, confidentiality, anonymity and privacy. The data gathered in this exercise was solely and strictly used for the purpose of this study (McMillan & Schumacher, 2010; Neuman, 2006). Permission to conduct this study was sought from the University through its Schools Advancement Academy.

### *Data collection*

Data were collected by means of a questionnaire. The data collection tool Problem Solving Strategies Survey **(**PSSS) was used to assess the learners' metacognitive problem solving strategies, i.e. attitudes and general behaviours during their problem the solving process in physics. This questionnaire is based on the procedure the learner is likely to follow when solving a physical science problem (French & Cummings, 2001; Holingworth & Mcloughlin, 2001). A 5-point Likert-type or frequency scale attitude questionnaire was constructed. The scale contained 8 items that provided information on each learner's likeliness to use a particular strategy. These strategies and their description were categorically designed according to the format created by (Ogilvie, 2009). The strategies were divided into two categories; restrictive strategies (marked R1-R4) and unrestricted strategies (marked U1-U4). The restrictive strategies are those problem solving approaches whose application is limited to well-structured end of chapter exercises. However, their effectiveness fades with more complex, ill structured and open-ended problems. On the other hand, unrestricted strategies characterise the expert problem-solving approach. Their application has no limitations and can be useful in the case of more ill structured and open ended problems.

The scale was provided to the learners with five (5) options and their ratings with respect to likeliness of strategy use (maximum score= 40 and minimum score=8): Definitely (5), Very likely (4), possibly (3), possibly not (2), Not at all likely (1). Learners rated how often they are likely to use these strategies irrespective of whether they know and identified them as problem solving strategies. This survey was undertaken to provide sufficient preliminary data on the learners' adherence to and deviation from the problem structure and approach as followed by the experts. The questionnaire was administered to the learners during the last week of the winter school.

### *Data analysis*

The data collected from PSSS were analysed using excel and graph pad software (Motulsky, 2015). Frequency, percentage, mean (M), standard deviation (SD), t-test were employed to compare the two groups. This was done to understand if there is any difference in problem solving attitudes between the two groups of learners. All statistical tests reported in this paper were conducted with a significance level of $\alpha = 0.05$.

## FINDINGS

The descriptive results of this survey are given in table below:

**Table 1:** PSSS descriptive results: learners (n = 84)

| | | Definitely | Very likely | Possibly | Probably not | Not at all likely |
|---|---|---|---|---|---|---|
| **R1:** Make a list or table | **#** | 45 | 20 | 17 | 2 | 0 |
| | **%** | 54 | 24 | 20 | 2 | 0 |
| **R2:** Recall a similar textbook problem and use it as a model | **#** | 36 | 44 | 4 | 0 | 0 |
| | **%** | 43 | 52 | 5 | 0 | 0 |
| **R3:** Look up for a specific formula or appropriate equation | **#** | 73 | 11 | 0 | 0 | 0 |
| | **%** | 87 | 13 | 0 | 0 | 0 |
| **R4:** Start with the | **#** | 0 | 5 | 43 | 19 | 17 |

| | | | | | | |
|---|---|---|---|---|---|---|
| solution (from the back of the book) and work backward | % | 0 | 6 | 51 | 23 | 20 |
| **U1:** Draw, redraw, or visualize a picture or graph | # | 24 | 26 | 29 | 3 | 2 |
| | % | 29 | 31 | 35 | 4 | 2 |
| **U2:** Think about relevant physics concepts are required to correctly solve the problem | # | 35 | 25 | 24 | 0 | 0 |
| | % | 42 | 30 | 29 | 0 | 0 |
| **U3:** Make assumptions about the situation | # | 8 | 55 | 12 | 9 | 0 |
| | % | 10 | 65 | 14 | 11 | 0 |
| **U4: Ask yourself** questions about what is going on in the problem and problem solution | # | 43 | 25 | 14 | 0 | 2 |
| | % | 51 | 30 | 17 | 0 | 2 |

**Figure 1:** PSSS descriptive results: learners (n = 84)

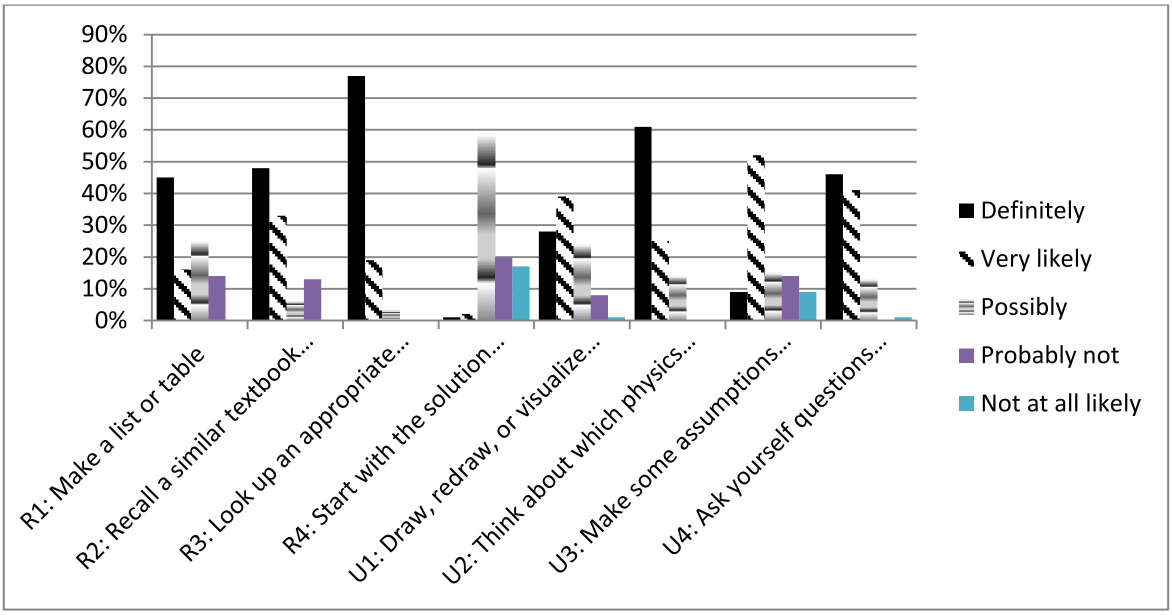


Table1 and figure 1 presents the mean scores and standard deviations of the two groups according to their likeliness of using the restrictive strategies. T-tests for independent samples were carried out for the four restrictive strategies to asses any significant difference in learners' attitudes between the two groups. From the PSSS results, significant statistical differences were found for R1 (t=4.04, p<0.0001, extremely significant)), R2 (t=2.58, p= 0.01 (<0.05)) and R3 (t=3.08, p=0.0023 (<0.05)). It was only in the R4 where the difference is considered to be not statistically significant (t=0.91, p = 0.37). It can be said that both groups have equal likeliness of not applying R4 strategy.

**Table 2:** Comparisons between group 1 and group 2 for PSSS on their likeliness to apply restrictive strategies

| Data Tool | Strategy | Group | n | M | SD | df | t | p |
|---|---|---|---|---|---|---|---|---|
| PSSS | R 1 | 2013 | 84 | 4.29 | 0.87 | 205 | 4.04 | < 0.0001 |
| | | 2014 | 123 | 3.67 | 1.21 | | | |
| | R 2 | 2013 | 84 | 4.38 | 0.58 | 205 | 2.58 | 0.01 |
| | | 2014 | 123 | 4.02 | 1.2 | | | |
| | R 3 | 2013 | 84 | 4.87 | 0.34 | 205 | 3.08 | 0.0023 |
| | | 2014 | 123 | 4.65 | 0.59 | | | |
| | R 4 | 2013 | 84 | 2.43 | 0.88 | 205 | 0.91 | 0.37 |
| | | 2014 | 123 | 2.54 | 0.81 | | | |

Mean scores and standard deviations of the 2013 and 2014 according to their likeliness of using the unrestricted strategies are presented in table 2. T-tests for independent samples were carried out for the four unrestricted strategies to asses any significant differences in learners' attitudes between the two groups. From the PSSS results, extremely significant statistical differences were found for U2 (t=5.95, p<0.0001) and U3 (t=4.01, <0.0001). U1 (t=0.72, p = 0.47) and U4 (t=0.48, p=0.64) were considered statistically insignificant, implying equal probability of using the U1 and U4 strategies by both groups.

**Table 3:** Comparisons between group 1 and group 2 for PSSS on their likeliness to apply unrestricted strategies

| Data Tool | Strategy | Group | n | M | SD | df | t | p |
|---|---|---|---|---|---|---|---|---|
| PSSS | U1 | 2013 | 84 | 3.8 | 0.98 | 205 | 0.72 | 0.47 |
| | | 2014 | 123 | 3.89 | 0.93 | | | |
| | U2 | 2013 | 84 | 4.13 | 0.83 | 205 | 5.95 | < 0.0001 |
| | | 2014 | 123 | 4.7 | 0.54 | | | |
| | U3 | 2013 | 84 | 3.74 | 0.78 | 205 | 4.01 | < 0.0001 |
| | | 2014 | 123 | 3.12 | 1.25 | | | |
| | U4 | 2013 | 84 | 4.27 | 0.91 | 205 | 0.48 | 0.64 |
| | | 2014 | 123 | 4.33 | 0.65 | | | |

The summary of the results indicate that:

- There was poor application or non-use of strategies even though learners claim to use them. This was evident in both groups.
- Learners tend to resort to formula based approach to problem solving rather than conceptual approach. The fact that only 31% and 46% in group 1 and group 2 respectively managed to successfully solve the two problems can be attributed to the omission of application of a qualitative analysis process involving other representations (Maloney, 1997). The results confirm that learners in both groups identified and chose a solution path quickly and then stuck to it, irrespective of whether there was progress or not (Garofalo & Lester, 1985).
- Despite an average low success rate of 46% for group 2, it was higher than that of the group 2, indicating an improved performance from the CAPS approach to teaching physical science. However the overall low success rate for such standard and routine mechanics problems servers as a reminder of the work that still needs to be done to develop good teaching practices in South African schools (Gaigher et al., 2007; Heller & Heller 2010).

## DISCUSSION

A closer look at the unrestricted strategies shows that the most likely used strategy is U2:" *Think about relevant physical science concepts that are required to correctly solve the problem"*. 61% of the learners claim to apply this strategy whereas 14% consider the use of this strategy as a possibility. This strategy characterises an expert's way of solving physics problems. The importance of understanding physical science concepts has been over time, emphasised by many physical science education researchers. One of the basic fundamental prerequisite for expert problem solving is a good understanding of the laws and principles of physics (Hestenes, Wells, & Swackhamer, 1992; Holingworth & Mcloughlin, 2001; Kuo, Hull, Gupta, & Elby, 2013; McDermott & Redish, 1999; Docktor, Mestre & Ross, 2012; Heller & Heller, 2010). Problem solving skills should be developed and enhanced in schools at junior levels; and for this development and enhancement process to be effective it must include (Gaigher, Rogan, & Braun, 2007):

- Teaching explicit problem solving strategies with more emphasis on qualitative analysis ( Huffman, 1997). This problem solving process may seem to be time consuming, but is very efficient and effective in solving the problem successfully, thus in the long term saving time. More efforts should be made to ensure that learners are able to qualify the problem before they can quantify it.
- Encouraging group problem solving approach as per recommendations of (Heller & Hollabaugh, 1992). Group based solutions are always better than individual.
- Employing qualitative strategy writing where learners will give a descriptive account on how they will approach a given problem. This has proved to improve conceptual understanding.(Leonard, Dufresne, & Mestre, 1996).
- Application of modelling instruction (Hestenes, 1987; Docktor, Mestre & Ross, 2012).
- Applying the variation technique in problem solving (Fraser, Linder, & Pang, 2004; Gaigher et al., 2006). This strategy was one of the poorly applied strategies in this study. In this technique, learners are required to apply different physical science principles to solve a given problem. This technique will help the learners to understand the connections between different physical science principles.
- Using problem familiarity strategy which according to (Alant, 2004) enhance conceptual understanding and familiarise the learners with underlying physical science principles.
- Exposing learners to structured problem-solving strategy (Gaigher et al., 2007) as a means of improving conceptual understanding of physical science and conceptual approach to problem solving.

This study provide evidence that the learners have poor and limited conceptual understanding of physical science and problem solving skills in both groups, even though there has been a change in the approach to teaching physical science in schools. It should however be noted that there seem to be a change in attitude and approach within the CAPS group (group 2), and hence an improvement compared to the NSC group (group 1). This improved performance by the CAPS group, can be attributed to the fact that more time and focus were invested on this group since the introduction of the new curriculum statement and approach to teaching and learning in grade 10.

## CONCLUSION

The way problem solving is traditionally practiced within physical science education lacks efficiency and effectiveness when coming to assisting learners develop true expertise (Selvaratnam, 2011). As per CAPS document, problem solving should remain central to teaching physical science. However the way it is currently being practiced, does not sufficiently develop students' critical thinking ability and therefore must change as part of a fundamental remodelling of the teaching and learning process from NCS to CAPS. Learners lack proper training to enable them to solve problems that are formulated to have great parameter freedom, more than one solving options and different solution evaluation criteria. Assessment criteria and processes must not dictate how learning should be conducted, but should serve as a learning tool.

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