REFLECTIONS OF PROBLEM SOLVING STRATEGIES AMONGST SENIOR AND JUNIOR PHYSICS STUDENTS

Leelakrishna Reddy
University of Johannesburg, South Africa
krishr@uj.ac.za

ABSTRACT – Solving complex problems requires one to have an adequate repertoire of problem solving skills. Teaching such skills is not enough to solve complex problems, because most teachers or lecturers reinforce the idea of finding an appropriate formula for well-constructed problems (Ogilvie, 2009) but the problem solving skill fails for ill-structured problems. In this paper, the students have reflected in their problem solving strategies whilst solving physics problems. A questionnaire with categorized problem solving strategies was administered to junior and senior university students, who are taking physics as part of their core curriculum. This research was towards the end of the semester, with the idea of getting a holistic perspective of their problem solving strategies in physics. The results of this study revealed that the senior students employed more of the "expansive" problem solving strategies, compared to the juniors who had used only a few of the "limiting" and "expansive" strategies. Typically, seniors were in the habit of breaking up a problem into sub-problems, frequently used free-body diagrams and thought about the concepts involved in problem solving. The only "expansive" strategy used by the juniors was the breaking up of a problem into sub-problems.

Keywords: expansive strategies, limiting strategies, physics, and problem-solving skills

INTRODUCTION

Physics by its very nature is a difficult subject as it deals with a large amount of problem solving. For there to be progress in any technological society, there needs to be individuals in the work place empowered with strong problem-solving skills (Ogilvie, 2009). According to Altun (2001), problem solving is "to know what to do when you don't know what to do" (cited in the reference of Caliskan et al., 2010). In this case, problem solving is a cognitive process that relies on the memory to select appropriate activities, make use of them and work with it systematically to achieve the desired outcome (Caliskan et al., 2010). It is commonly known from literature that many students struggle with open, complex and ill-structured (problems without a clear solution) problems, because the problem solving strategies they learnt from high school is highly formula driven (Ogilvie, 2010). In order to solve ill-structured or complex problems, one needs to make use of higher order metacognitive skills. Students know the laws of physics when applied to a problem of a similar nature done previously but fail when confronted with new problems of different dynamical features (Ince, 2018). It is further reported in literature (Marlina et al., 2014) that students who use metacognitive (higher order thinking skills) skills in problem solving are successful at solving problems (Ince, 2018).

In the research by Reddy and Panacharoensawad (2017), it was reported that students' poor mathematical understanding has become an obstacle in their problem solving abilities. From a physics point of view, the problem that students face in problem solving is their conceptual knowledge of both mathematics and physics that is a requirement to solve quantitative problems (Ogilvie, 2009). Whenever a student has to solve a problem, an equation is required (or derived), and what unfolds is a manipulation of the equation, and that is where one's efficacy in mathematics becomes important.

Other researchers have clearly demarcated the behaviours of the problem solving abilities of two types of people; namely, expert and novice problem solvers (Chi et al., 1981). Expert problem solvers have a highly organized conceptual understanding of the field and are quickly able to analyze the essence of the task, while novice problem solvers are known to apply a known set of procedures or algorithms to solve problems (Ogilvie, 2009). In the latter scenario, having a knowledge of these procedures will not be sufficient to solve ill-structured problems in physics. It is a desire of teaching to bridge the gap between novice-type behaviors to expert-type behavior, because the origins of problem solving beliefs may be deeply rooted in classroom instruction (Ogilvie, 2009).

It is the aim of this paper to give a reflection of the students' problem solving strategies that they have used during their course of their studies while solving a broad range of problems in physics. This is converse to determining students' problem solving strategies for a specific problem and for a specific topic in a fixed period. Many studies have focused on specific problem solving strategies but lesser studies is focused on the holistic problem solving strategies in physics. Since the complexity of problem solving in physics increases with each year of study at a university, our study is undertaken include both juniors and seniors with the idea of probing their problem solving strategies.

RESEARCH QUESTION

What strategies do senior and junior students display in their problem solving in physics at a university?

CONCEPTUAL FRAMEWORK

The framework for this study is based on students' reflections of the strategies they have used as they worked through a broad range of problems in physics. Such a framework is comprised of two categories; namely, limiting and expansive strategies, which has been taken from the work of Ogilvie (2009). In the problem solving context of Ogilvie (2009), it was used specifically for a problem problem-solving situation. The "limited" strategy is applicable to well-structured end of exercise type of problems but fails for ill-structured or open problems (Ogilvie, 2009). On the other hand, the "expansive" strategy refers to students' confidence in working through ill-structured and challenging problems. In this sense, such problems solvers are appropriately characterized as expert problem solvers. There are many types of problem-solving strategies, as will be seen in the questionnaire, but each of the strategies can be categorized into one of two broad strategies; namely Expansive and Limiting. Such categories are further tabulated in the table below (Snetinova & Koupilova, 2012).

Table 1: Categories used to classify student's reflections

Limiting Strategy	Expansive Strategy
Rolodex equation matching	Rational thought
Listing known and unknown quantities	Sub-problems
Prior examples in text or lecture	Diagrams
Prior experiments in lecture	Concept first
	Real situation

METHODOLOGY

This research instrument was of a modified questionnaire presented in the paper of Snetinova and Koupilova (2012) but developed by Ogilvie (2009). The questionnaire, which is shown in the results section, consists of 9 questions and has options for responses such as often, seldom, rarely and never. This questionnaire has been administered to the first year combined Emergency and Podiatry group (61 students) and the second year Analytical Chemistry group (25 students) at a South African university. Students had to choose from one of the strategies in the questionnaire to reflect their problem solving strategies when they solved physics problems. These strategies are then compared to one of the strategies in Table 1 above for comparisons. Further, the problem solving strategies between the juniors and seniors were then compared to each other. Permission was sought from the students (verbally) before conducting this research. The task took no more than 15 minutes to complete and was done towards the end of the semester.

RESULTS AND DISCUSSION

Differences between the junior and senior students' problem solving strategies

Comparison between the juniors and seniors reflective problem solving strategies are shown in Table 2 below (Snetinova & Koupilova, 2012). Results between the junior and senior students' reflections are given for the options: Often (O), Seldom(S), Rarely (R) and Never (N). In the table below, the first row represents the number of students while the second row represents the respective percentages.

Table 2: Questionnaire with problem solving strategies and descriptions of it are shown.

No	Strategy	Description	Juniors				Seniors			
			O	S	R	N	O	S	R	N
1	Rolodex equation matching	Selection of an appropriate equation that has the same variables as the list of knowns and unknowns	43	13	3	2	16	8	1	0
			71 %	21 %	5 %	3 %	64 %	32 %	4 %	0 %
2	Rational thought	Solving a problem in the mind before	20	25	13	3	12	10	4	0
			33 %	41 %	21 %	5 %	48 %	40 %	16 %	0 %
3	Listing of knowns and unknown quantities	After reading the problem, a list knowns and unknowns are made	37	16	6	2	18	6	1	0
			61 %	26 %	10 %	3 %	72 %	24 %	4 %	0 %
4	Use of a prior example from the lecture or textbook	Finding a similar example that was used previously solved in class or textbook	16	49	10	2	13	12	0	0
			26 %	80 %	16 %	3 %	52 %	48 %	0 %	0 %
5	Use of a prior experimental idea	Use is made of some idea from an experiment that is closely related to the example done in class	20	32	6	3	13	9	2	2
			33 %	52 %	10 %	5 %	52 %	36 %	8 %	8 %
6	Breaking of a problem into sub-problems	Breaking up of a problem into small manageable steps	35	16	9	1	17	8	0	0
			57 %	26 %	15 %	2 %	68 %	32 %	0 %	0 %
7	Diagram representations	Use of a free-body diagram or sketches or charts to solve the given problem	14	24	17	6	3	13	7	1
			23 %	39 %	28 %	10 %	12 %	52 %	28 %	4 %
8	Conception first	Thinking of the problem in the mind before solving it	16	20	23	2	15	9	1	0
			26 %	33 %	38 %	3 %	60 %	36 %	4 %	0 %
9	Real-life situation	Solving the given problem in context of a real-life situation	11	26	13	11	7	13	4	1
			18 %	43 %	21 %	18 %	28 %	52 %	16 %	4 %

It is quite evident from Table 2 that most students in both groups think that the use of the Rolodex equation matching (71% for juniors and 64% for seniors) is the correct procedure to use when solving problems in physics. In this sense, they would have selected an equation that was appropriate for the given variables. A possible outcome of this strategy would be a plug and chug method in the manipulation of their chosen equations. An item that is closely related to the use of an equation and which is appropriate for the given variables is item 3, whereby students were required to list the knowns and unknowns (seniors 72% and juniors 61%). These two items are categorized as a limiting strategy in their problem solving. The down side of these two strategies is that once the complexity of the problem increases, conventional methods may fail. According to Ogilvie (2009), once the complexity of the problem expands, listing of all the variables may not be adequate. On the other hand, listing of the unknowns may not give the information of what the goal of the problem is intended to be. Students in the research of Snetinova and Koupilova (2012), have achieved the highest for this item in the questionnaire, and further their performance for this item exceeds 80%. Although this was a good result, it was pointed out by them that it was an unsurprising result, because students from primary school were taught a similar type of procedure.

The next item in the hierarchy for which both groups of students have performed well is item 6 (juniors 57% and seniors 80%). This item, which reflects students' way of breaking down a problem into small manageable steps, is considered an "expansive" strategy in problem solving. In this case, students feel that breaking down a problem into sub-problems may bring about some sense of self-achievement for them and is typically a way that experts would follow in their problem solving. An item for which there is a large discrepancy in the results is item 4. For this item 26% of the juniors have reflected that they have seldomly used an example form their lectures (or textbook) to solve a physics problem, while on the other hand, at least more than 50% of the senior students have used such methods or other resources to solve problems. According to Ogilvie (2009), this "limited" strategy of solving a physics problem may be detrimental to the students since they may struggle to solve more novel problems for which there is no working model to proceed. In the other research of Snetinova and Koupilova (2012), less than 30% of the students have used such strategies in solving physics problems and this research correlates well with that research.

An item for which both cohorts of students have displayed similar trends in reflective behaviors is item 5. For this item, only 33% of the juniors have used some idea from an experiment that was closely related to the problem at hand, while on the other hand, at least 50% of the senior students have tried to solve the physics problem likewise. This strategy, although scientifically sound, is a 'limiting" approach to problem solving. A further examination of an expansive strategy that is quite evident amongst the seniors is their reflections to think about the physics concepts (item 8) whilst solving physics problems. A mere 26% of the juniors have adopted this approach in comparison to 60% of the seniors. Expert problem solvers typically follow a conceptual approach.

Another "expansive" strategy for problem solving is the use of diagrammatic representations. Expert problem solvers extensively use this method. For example, in force diagrams, the use of free body diagrams to represent the various forces acting on a body provides an easier alternative to solving a physics problem. In this scenario, a correct force representation in the free body diagram could lead to the correct use of Newton's Second Law of Motion. For this item (7) in the questionnaire, 23% of the juniors and surprisingly only 12% of the seniors have used such an approach. On the other hand, it is reflected that 39% of the juniors and 52% of the seniors have seldomly used such an approach in problem solving. Students are unaware of the valuable information that is provided in these quantitative representations (Harper, 2006).

A small percentage of students (seniors 28% and juniors 18%) have tried to imagine the problem at hand to a real-life situation (item 9), whilst a further 43% of the juniors and 52% of the seniors have seldomly approached the problem in this fashion. This strategy, which is an "expansive" one reflects the students' reluctance to solve it in this fashion, but is typically followed by expert problem solvers.

Finally, a strategy called the use of Rational thought (item 2) in problem solving, which is "expansive" by its very nature, is used very sparingly by students. In this case, students were expected to solve the problem in their minds before attempting to do the arithmetic. Only 48% of the seniors and 33% of the juniors have explored this method.

Comparisons of the students' problem solving strategies in physics between the junior and senior groups of students

Table 3 provides the students' reflections that can be compartmentalized into one of two categories of problem solving; namely, "limiting" and "expansive" strategies (Snetinova & Koupilova, 2012). The criteria used in the demarcation of the various strategies in Table 3, was obtained by taking student's responses of 50% and above in Table 2 of their reflective strategies.

Table 3: Comparison of the problem solving strategies used by both junior and senior students

Juniors		Seniors	
Limiting strategy	Expansive strategy	Limiting strategy	Expansive strategy
Rolodex equation matching	Breaking up a problem into sub-problems	Rolodex equation matching	Breaking up a problem into sub-problems
List of knowns and unknowns		List of knowns and unknowns	Concept first
		Prior examples in lecture	
		Prior experiment in lecture	

It is interesting to see that the senior students use many "limiting" strategies and a few "expansive" strategies in their problem solving. As far as the juniors are concerned, they only use one "expansive" strategy and that is breaking up of a problem into small manageable parts. It might seem that they may be indoctrinated this method way back in their school days. The "limiting" and "expansive" strategies used by the seniors may not be sufficient for them to be called expert problem solvers but a borderline between expert and novice type problem solvers.

CONCLUSION

Students' reflection of their problem solving strategies between the juniors and seniors is average to weak, and indicative of similar beliefs they hold about problem solving (Ogilvie, 2009). Some "limiting" strategies commonly used by both cohorts of students are the Rolodex equation matching and the other strategy that is closely related to this one is the listing of known and unknown variables. Further, there appears to be only one type of "expansive" strategy that was commonly used by both cohort of students and that was breaking up of a problem into sub-problems. This could be because of the teachers reinforcing this idea during their classroom instruction sessions. Besides the strategy relating to the breaking up of a problem into sub-problems, the only other strategy that separates the juniors from the seniors is thinking about the concepts that are involved in the problem before solving it.

One suggestion of improving the problem solving strategies of students is to allow students with an "expansive" mindset to share their skills with those that have a "limiting" mindset of problem solving or mix students with "limiting" and "expansive" strategies to share common problem solving strategies.

REFERENCES

Altun, M. (2001). *Matematik ogretimi*. Istanbul: ALFA Basim Yayin Dagitim.

Caliskan, S., Seluk, G. S., & Erol, M. (2010). Effects of the problem solving strategies instruction on the students' physics problem solving performances and strategy usage. *Procedia Social and Behavioral Sciences*, 2, 2239-2243.

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices, *Cognitive Science*, 5, 121-152.
Harper, K. A. (2006). Student Problem-Solving Behaviors. *The Physics Teacher*, 44(4), 250-251.
Ince, E. (2018). An overview of Problem Solving Studies in Physics Education. *Journal of Education and Learning*, 7(4), 191- 200.
Marlina, a., Nor Hasniza, I., Abdul Halim, A., Johari, S., & Nurshamela, S. (2014). Physics Problem Solving: Selecting More Successful and Less Successful Problem Solvers. *International Conference of Teaching, Assessment and Learning*, 186-191.
Ogilvie, C. A. (2009). Changes in students' problem-solving strategies in a course that includes context-rich, multifaceted problems. *Physical Review Special Topics- Physics Education Research*, 5, 020102-1-020102-14.
Reddy, M. V. B., & Panacharoensawad, B. (2017). Students Problem-Solving Difficulties and Implications in Physics: An Empirical Study on Influencing Factors: *Journal Of Education and Practice*, 8(14), 59-62.
Snetinova, M. & Koupilova, Z. (2012). Students' difficulties in Solving Physics Problems. *WDS' 12 Proceedings of Contributed Papers*, Part III, 93-97.