Effects of Diminishing Problem-solving Prompts on Students' Conceptual Understanding and Problem-solving Skills in Physics

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This study investigated the effects of Diminishing Problem-solving Prompts (DPP) on students' conceptual understanding and problem-solving skills in physics. It utilized a quasi-experimental pretest-post-test research design with two heterogenous intact classes. DPP was a teaching approach developed by the researcher using prompts during problem-solving tasks. A researcher-made Physics Achievement Test (PAT) was used to assess students' conceptual understanding and problem-solving skills. To determine if the teaching approach was effective, the post-test scores were subjected to a one-tailed t-test for independent samples.

The normalized gains of high- and low-performing students were also computed. Finally, the Pearson product-moment correlation was computed to assess the relationship between students' conceptual understanding and problem-solving skills in physics. The statistical analyses showed that there was no significant difference between the mean post-test scores of the DPP and CP groups. Further analyses of the qualitative data suggested that high-performing DPP students exhibited expert-like behaviors in their problem-solving solutions.

A strong positive correlation existed between students' conceptual understanding and problem-solving skills in physics. Thus, the use of problem-solving strategies and prompts enhanced the conceptual understanding of students during problem-solving tasks. Further studies can be undertaken by using think-aloud interviews to investigate how students integrate physics concepts while solving problems using DPP.

Keywords: *problem-solving, problem-solving skills, conceptual understanding, diminishing prompts, achievement, physics education*

Introduction

Physics is a fundamental science that explains how the natural world works. It uses the language of mathematics as a way to understand these behaviors. Students studying physics are expected to learn not only the mathematical component of physics, but also the principles and concepts of physics. The traditional mode of instruction where the teacher introduces the concept, solves sample problems, and gives practice problems to develop problem-solving skills does not help students in their understanding of physics (Halloun & Hestenes, 1985). Evidence suggests that extensive solving of word problems may not be sufficient because students tend to focus their efforts on finding the equation and solving the problem (Dufresne et al., 1992), rather than focusing their attention on the concept and the underlying principles of physics (Chi et al., 1981). Most students cannot solve problems at their expected level of proficiency (Foster, 2000) as the traditional classroom approach in physics makes students obsessed with mathematical formulas. Based on these studies, students leave a physics course without understanding the important concepts or even acquiring the needed problem-solving skills. Instead, there should be a connection between the concepts (qualitative) and the mathematical equations (quantitative) in order to develop students' problem-solving abilities and scientific conceptual understanding.

Problem-solving is a necessary skill needed in daily life. It equips the students for the challenges in their academic tasks and eventually in their workplaces. Science education research recognizes that the central component for science proficiency is students' problem solving skills as it helps them to learn about science and learn to do science (Beal & Stevens, 2011). Thus, extensive research has been carried out for the past decades to develop effective general instruction on the use of problem-solving strategies to help students acquire expert-like behaviors when solving physics problems. According to Neto and Valente (1997), problem-solving strategies must focus more on qualitative and metacognitive approaches to help students acquire the necessary knowledge and problem-solving skills. To activate these metacognitive processes in students, using prompts in suitable classroom activities trains the students to focus on the concepts and principles while solving problems (Kramarski et al., 2002). The effectiveness of prompts on the problem-solving processes depends on the design and intention of the intervention (Ifenthaler & Schmidt, 2010). Prompts can be presented before, during, or after a learning sequence to help students perform desired skills optimally. However, like all instructional scaffolding, prompts must be faded out to promote problem-solving skill acquisition (Jones & Fleischman, 2001; Kalyuga et al., 2003; Renkl et al., 2000;). Gradually fading a solution step creates a temporary obstacle to help students focus their attention on their own problem-solving strategies, thereby improving their problem-solving performance.

Considering the numerous research on expert-novice differences, use of problem-solving strategies and prompts in physics problem-solving, much less is known about the effect of fading problem-solving prompts to help students transition from novice to expert-like problem-solvers during problem-solving tasks. There is also a limited amount of studies that focus on the use of diminishing problem-solving prompts as a teaching strategy to help students acquire the necessary conceptual understanding and problem-solving skills in physics. Thus, this research was conceptualized to fill in these gaps.

The study focused on the effects of diminishing problem-solving prompts on students' conceptual understanding and problem-solving skills in physics. Specifically, this study sought to answer the following questions:

1. Do students exposed to Diminishing Problem-solving Prompts (DPP) have higher mean post-test scores compared to students exposed to Conventional Problem-solving (CP)?
2. Is there a significant relationship between students' conceptual understanding and problem-solving skills?

Problem-solving in Physics

Problem-solving is an important skill that needs to be acquired by all students. One of the goals of education is to make our students problem solvers, since problem-solving is the driving force of the thinking process (Dewey, 1933). According to UNESCO (2004), it is necessary for schools to teach students to become proficient problem-solvers. Among the 21st century skills, problem-solving is the most important skill (Carlgren, 2013) in both academic and industrial jobs.

Since problem-solving is an essential component of physics learning, most physics education research focuses on the obvious differences between expert and novice problem-solvers in terms of the way they classify problems, organize their knowledge, and apply different approaches in solving a problem. Thus, addressing the task of teaching expert-like behaviors to students is crucial (Phang, 2010).

Expert problem-solvers employ a top-down approach before applying the procedures to generate a solution (Larkin et al., 1980). They plan their approach using qualitative analysis like pictorial representations or verbal descriptions to serve as a guide in planning and evaluating the problem before writing down any mathematical equation (Larkin, 1979). They tend to look forward from the known quantities to the desired quantities by thinking of concepts to apply and constantly evaluating their solution. Expert problem-solvers take an additional step when solving a problem by regularly monitoring their progress throughout the solution (Schoenfeld, 1985). Checking of one's work is a hallmark of an expert (Foster, 2000).

Novice problem-solvers, on the other hand, have fragmented knowledge and focus on specific quantities causing them to spend very little time understanding the problem. They first identify the unknown in the problem and then rearrange the equation in terms of the unknown (Larkin et al., 1980). Sometimes, they quickly jump into solving the problem by stringing together equations or recalling matching solutions (Reif et al., 1976). They use means-ends analysis to solve the problem. Lastly, pictorial representations are usually absent in most novices' solutions (Schultz & Lochhead, 1991).

To guide students in their problem-solving process, the problem-solving strategy is necessary according to Mayer (1985). It consists of steps needed to solve a problem where each preceding step helps guide the students to plan for their next approach in completing the task (Johnson & Johnson, 1994).

According to Reif et al. (1976), Polya's problem-solving strategy was first used in physics by being taught to a handful of students extracted from a class. The researchers noticed that those students who used figures and diagrams in their solution were more proficient. The students also improved in their mathematical skills and showed progress in their solution, even if they were unsuccessful in getting the final answer.

Wright and Williams (1986) developed the WISE problem-solving strategy, where the students were asked to draw a diagram of the problem, select appropriate physics principles to use, plan their solution and execute their plan algebraically. The students were also asked to check inconsistencies in their units and examine their intuition about their answers. After conducting the study, 80% of the students reported that the WISE strategy was helpful in their problem-solving, especially in communicating with their instructors and classmates when working in groups by following the steps above.

The Minnesota problem-solving strategy developed by Heller and Heller (1995) was based on how expert problem-solvers solve real physics problems. It is a detailed problem-solving strategy taught to college students in a large introductory physics class where the problem-solving strategies were used by the students in cooperative groups and on their own to solve physics problems.
The problem solutions produced by the experimental group during collaborative learning were more expert-like than those produced independently by the best student of the group. There was also evidence where the individual problem-solving abilities of students improved over time for the experimental group.

Gaigher et al. (2007) designed a problem-solving strategy to develop students' conceptual understanding and enhance their problem-solving performance. The emphasis of this strategy is on the qualitative aspects of the problem and not entirely on the algebraic or mathematical solution. Determining the appropriate physics concepts involved in solving the problem and constructing the diagram that represents the problem is the focus of the strategy. The students are tasked to incorporate the given information together with the missing quantity of the problem in their diagram. By grouping related quantities together, students are guided in analyzing the problem and in establishing the connections to the different parts of the problem.

Lastly, Çaliskan et al. (2010) developed a problem-solving approach where implicit problem-solving strategies used by expert problem solvers were taught to student teachers through the explicit strategy instruction approach. The results of the study show positive effects on the student teachers' physics achievement and self-efficacy. The explicit problem-solving instruction guided the students in applying good problem-solvers' strategies and helped them to improve both their cognitive and metacognitive awareness.

In summary, for any problem-solving strategy to reflect expert-like behaviors in students, they must be able to: (1) connect relevant physics concepts while analyzing the problem, (2) make a visual representation of the problem showing the relationship of the physical quantities, (3) express in their own words how they understood the problem, and (4) determine the appropriate equations to use to solve the problem (Maloney, 1993).

Prompts

Prompting is an effective teaching strategy that can be used to train students to acquire new skills during their learning process. Its main goal is to help students plan their course of action by motivating them to reflect on their next steps. Prompting increases their awareness by monitoring, controlling, and regulating their problem-solving strategy in a given situation. (Ifenthaler & Schmidt, 2010).

Prompts are a type of scaffolding (Rosenshine & Meister, 1992) that assists students in engaging in activities like making inferences, elaborating on their thinking, and monitoring and evaluating their own learning process (Lin et al., 1999). Prompts are guides that help students to reflect on their thought process by elaborating on specific details of the problem (Peters, 2008). Prompts can be generic or directed, where the former asks students to simply stop and think about their learning process; the latter provides students with more elaborate hints or directions. Research shows that students who frequently pause to reflect and check on their work perform better because they tend to analyze their process (Schoenfeld, 1985). Prompts can be presented as a simple question, an incomplete sentence, or as a procedure. Prompting students with appropriate questions can foster different cognitive and metacognitive behaviors (Ge & Land, 2004).

Question prompts could help students by reminding them on how to accomplish their activities, which can lessen their cognitive load. For students who are preoccupied in quickly answering complex problems by searching for equations to use, question prompts are necessary (Lin et al., 1999). Students can temporarily rely on prompts until they can complete a particular task using their own internal structures (Scardamalia & Bereiter, 1985).

The use of prompts is more advantageous to students if the purpose of the intervention is specific (Ifenthaler & Schmidt, 2010) because the exact placement, sequencing and mixing of different prompt types is uncertain, according to Davis (2000). If the intention is to develop the students' own technique in approaching an activity, it is best to present the prompts before the learning sequence (Davis, 2003). If the prompt is intended to guide the students while they are doing the activity, it is best to use prompts while the students are accomplishing the tasks. If the intention is to help the students evaluate and check their learning, it is appropriate to use prompts right after completing the tasks (Ifenthaler & Schmidt, 2010). Well-designed and well-placed prompts are also important aspects to help students perform the desired activity optimally.

Question prompts can be classified into procedural prompts, elaboration prompts, and reflection prompts. Procedural prompts assist students in finishing their tasks in an orderly manner and at the same time, acquiring the necessary cognitive skills. Meanwhile, elaboration prompts help them formalize their thinking and justifications (Ge & Land, 2004). On the other hand, reflection prompts can encourage students to think about processes they are using on a metacognitive level that they do not generally think about (Davis, 2000). Procedural and elaboration prompts enhance the cognitive skills of students while reflection prompts foster metacognitive skills. The successful use of question prompts is dependent upon prior knowledge of students. If no relevant prior knowledge exists, students will not benefit from question prompts; thus, they cannot elaborate on their learning. Also, question prompts are more effective for students at the beginning of a learning sequence because these guide them to finish their tasks efficiently (Ge & Land, 2004). As students progress and become more knowledgeable in their learning, the use of prompts must be faded out to encourage independent thinking.

Diminishing Problem-solving Strategies

From the studies on improving student problem-solving skills, some researchers have noted that in some problem-solving strategies, the positive effects of developing expert-like behaviors in students are reversed if treatment is prolonged over time. In a study conducted by Kalyuga et al. (2001), they observed that students in the initial phase of learning (novice phase) benefited more from complete example prompts. However, as ample experience increased (expert phase) where the students gained substantial knowledge, solving the problems by themselves was deemed more effective; hence, the phenomenon of expertise reversal effect. According to Kalyuga et al. (2003), the expertise reversal is a type of redundancy effect. As the level of students' knowledge increases, problem-solving with complete procedural prompts becomes redundant and tedious; thus, students develop negative feelings toward the problem-solving strategy. Renkl et al. (2000) suggested that there should be a gradual shift from step-by-step procedural prompts, to partially guided problem-solving prompts, and then to unaided and autonomous problem-solving. They believe that fading of strategies can encourage students to self-explain for the next step.

To test this fading strategy, Renkl et al. (2002) conducted three consecutive studies, namely, (1) backward fading approach vs traditional problem-solving in a high school classroom setting, (2) forward fading approach vs traditional problem-solving in a college laboratory setting and (3) backward fading vs forward fading vs traditional problem-solving in a college classroom setting. This was done to explore the effectiveness of fading the solution steps using completed example problems.

The results of the studies show that both fading approaches yielded a positive effect on the near transfer performance of the students when compared to the traditional problem-solving classes. To further compare the relative effectiveness of the two fading strategies, a third study was conducted in which the three approaches were used, namely: (1) backward fading, (2) forward fading and (3) traditional problem-solving. Comparing the two fading approaches yielded no significant difference in terms of students' learning. However, students in the backward fading approach needed less time understanding and solving the example problems without compromising their learning compared to students in the forward fading approach. Thus, Renkl et. al (2002) concluded that the most beneficial and effective method was the backward fading approach. Lastly, there was a significant improvement on the performance of the students in their post-test in terms of similar and novel problem-solving tasks compared to the traditional group.

However, Jones and Fleischman (2001) suggest that the strategy that faded out is the most crucial because impasses play a central role in triggering productive learning events. An impasse happens

when the student realizes they lack complete understanding of a piece of knowledge.
They believe that examples with faded strategies temporarily produce an impasse. Because of this, students focus their attention on the strategy which triggers self-explanation, thus fostering acquisition of knowledge for the solution of that specific strategy. From their findings, they were able to confirm their assumption that the position of the fading strategy is not crucial, but the type of faded strategy is what determines learning.

Methodology

The study was designed to investigate the effects of diminishing problem-solving prompts on conceptual understanding and problem-solving skills in physics of Grade 9 students.

Research Design

This study used a quasi-experimental two-group pretest-post-test design with two intact classes. The students were already in existing sections so random sampling was not possible.
The experimental group was exposed to Diminishing Problem-solving Prompts (DPP), whereas the conventional group was exposed to Conventional Problem-solving (CP).

The research design of this study is represented below.

		Teaching Approach	
DPP	O	X_1	O’
CP	O	X_2	O’

where:

O and O’ = Physics Achievement Test (PAT) administered as pretest and post-test to the two groups exposed to DPP and CP, respectively

X_1 = exposure to Diminishing Problem-solving Prompts (DPP) teaching approach

X_2 = exposure to Conventional Problem-solving (CP) teaching approach

The Sample

The study was conducted at a laboratory school in Quezon City during the fourth grading period of Academic Year 2012-2013. Two intact heterogeneous Grade 9 classes were involved in the study. One class of 31 students was exposed to the diminishing problem-solving prompt (DPP) teaching approach while another class of 33 students was exposed to the conventional problem-solving (CP) teaching approach. The assignment of the two classes as DPP group and CP group was determined randomly by tossing a coin. Both classes were taught by the teacher-researcher. Table 1 shows the distribution of the participants.

Table 1

Distribution of the Participants

Physics Achievement Test (PAT)

Group	Males	Females	Total
DPP	16	15	31
CP	18	15	33

The Physics Achievement Test (PAT) was a researcher-constructed, 24-item multiple-choice and problem-solving type of test that assessed students’ conceptual understanding and problem-solving skills in circular motion, torque and static equilibrium, energy, work and power. The PAT was evaluated by three physics education experts and the instrument was field-tested on 73 high school students enrolled in a public science high school. The conceptual understanding part of the test had 20 multiple-choice items, where the highest possible point for each item was equivalent to 1 point. The Cronbach’s alpha coefficient for the 20-item conceptual understanding questions was .857. This shows that the conceptual understanding component of the PAT has a high internal consistency.

On the other hand, the problem-solving part had four items with DEPIC problem-solving labelled steps, where the highest possible point for each item was equivalent to ten points. The four problem-solving items were graded using a scoring rubric by the researcher and two other high school physics teachers to form a reliable scale for measuring students' problem-solving skills. The scoring rubric was based on the DEPIC problem-solving strategy, where the highest points of three points were given to the Plan step because it shows the outline of the solution, while the Describe, Explore, and Implement steps were two points each. Finally, the Check the solution step was given one point for a total of ten points per problem. The Inter-Class Correlation Cronbach's alpha coefficient was .882. The highest total score for the two-part test was 60 points. The maximum score for the conceptual understanding part was 20 points while the problem-solving part was 40 points.

Intervention Phase

Four lesson plans were prepared and implemented by the researcher for the DPP and CP groups covering the following topics: circular motion, torque and static equilibrium, energy, work, and power. Both classes were exposed to similar instructional activities such as demonstrations, discrepant events, group problem-solving, seatworks and laboratory activities. They were also given identical assessment tools (i.e., quizzes, long exams, individualized problem-solving activities (IPSA)). The teacher-researcher ensured that each class got the same contact time for every lesson. Each class met for a total of five hours, four days a week. There were two 90-minute periods and two 60-minute periods each week. The 4th quarter consisted of 8 weeks where the teacher-researcher was able to handle the classes on the 2nd meeting of the 2nd week. The 1st week was used by the assigned physics teacher to continue the unfinished physics topics from Grade 8. During this week, the teacher-researcher observed the classes and assisted the assigned physics teacher to establish rapport with the students before the instructional phase.

To monitor and to ensure unbiased implementation of the teaching, the science department head randomly observed the two classes handled by the teacher-researcher using a monitoring checklist.

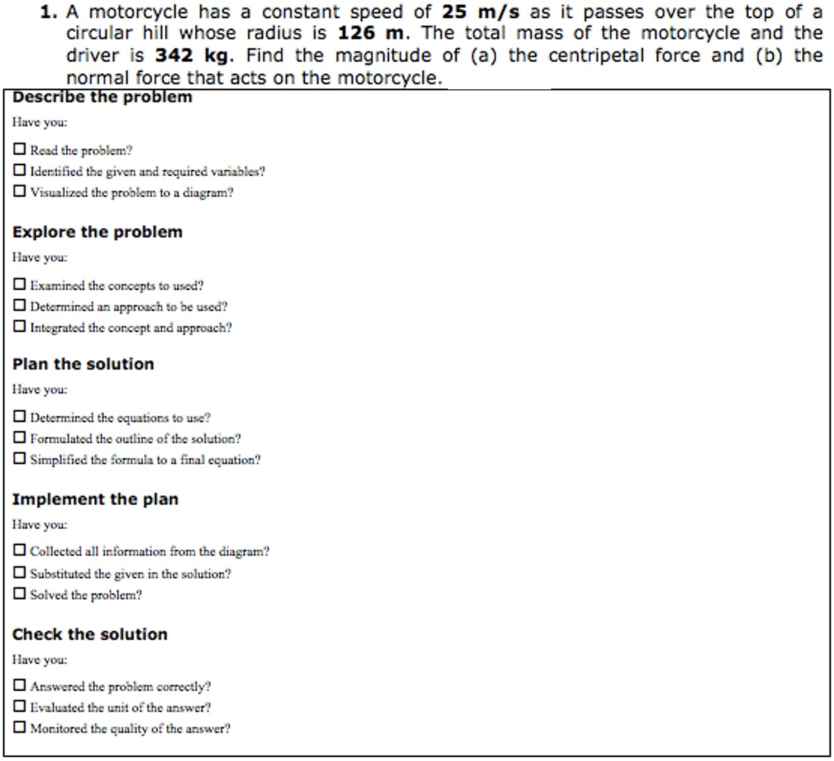
Diminishing Problem-solving Prompt Class (DPP)

The Diminishing Problem-solving Prompt (DPP) was an instructional approach designed by the researcher based on the studies mentioned above. The prompts were intended to focus the attention of students to reflect on the problem and to motivate them to think about their problem-solving strategies. The problem-solving strategy consisted of 5 steps, which are: (1) Describe the problem, (2) Explore the problem, (3) Plan the solution, (4) Implement the solution and (5) Check the solution, also known as DEPIC based on the acronym of the problem-solving steps. The DEPIC problem-solving strategy emphasized the need for vivid details (deep structure features) and faithful representation of diagrams to help students prepare in their problem-solving process using diminishing prompts. Procedural prompts were used on the first four problem-solving strategies to help the students on their problem-solving process, while the last strategy contained reflection prompts to help the students check and evaluate their final answers, which is a metacognitive skill.

The format of the worksheet allowed the prompts and the problem-solving steps to be aggregated in a single block. The worksheet contained the problem statement followed by the DEPIC problem-solving strategy. Each strategy was followed by three statement prompts, each with checkboxes. Figure 1 shows the sample of the DEPIC problem-solving worksheet.

Figure 1

Sample of the DEPIC Problem-Solving Worksheet with Complete Prompts in the Checklist



1. A motorcycle has a constant speed of **25 m/s** as it passes over the top of a circular hill whose radius is **126 m**. The total mass of the motorcycle and the driver is **342 kg**. Find the magnitude of (a) the centripetal force and (b) the normal force that acts on the motorcycle.

Describe the problem

Have you:

☐ Read the problem?
☐ Identified the given and required variables?
☐ Visualized the problem to a diagram?

Explore the problem

Have you:

☐ Examined the concepts to used?
☐ Determined an approach to be used?
☐ Integrated the concept and approach?

Plan the solution

Have you:

☐ Determined the equations to use?
☐ Formulated the outline of the solution?
☐ Simplified the formula to a final equation?

Implement the plan

Have you:

☐ Collected all information from the diagram?
☐ Substituted the given in the solution?
☐ Solved the problem?

Check the solution

Have you:

☐ Answered the problem correctly?
☐ Evaluated the unit of the answer?
☐ Monitored the quality of the answer?

Table 2 shows the timeline on how the diminishing problem-solving strategy was implemented. The first week of instruction used the worksheet shown on Figure 1 with complete prompts in the checklist. Fading of prompts started on Week 3 up to Week 6. In Week 7, the worksheet included only the fifth step, Check the Solution, together with the prompts in its checklist. However, for the post-test of the Physics Achievement Test (PAT), all the prompts for every strategy were faded out and only the problem-solving strategies were present as shown in Figure 2.

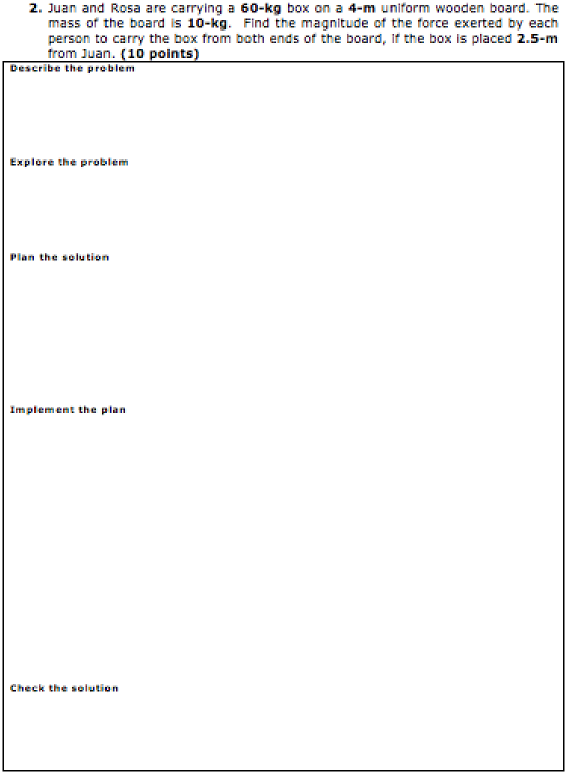
Table 2

Timeline for the Diminishing Problem-solving Prompt (DPP) Strategy

Week	Teaching Strategy
2 - 3	DEPIC problem-solving strategy with complete lists of prompts in the checklist.
4	DEPIC problem-solving strategy without prompts in the checklist of the 4th (Implement) step.
5	DEPIC problem-solving strategy without prompts in the checklist of the 2nd (Explore) and 4th (Implement) steps.
6 - 7	DEPIC problem-solving strategy without prompts in the checklist of the 1st (Describe), 2nd (Explore) and 4th (Implement) steps.
8	DEPIC problem-solving strategy without prompts in the checklist of the 1st (Describe), 2nd (Explore), 3rd (Plan) and 4th (Implement) steps.

Figure 2

Sample of the DEPIC Problem-Solving Worksheet without Prompts



2. Juan and Rosa are carrying a **60-kg** box on a **4-m** uniform wooden board. The mass of the board is **10-kg**. Find the magnitude of the force exerted by each person to carry the box from both ends of the board, if the box is placed **2.5-m** from Juan. **(10 points)**

Describe the problem

Explore the problem

Plan the solution

Implement the plan

Check the solution

The structure of the DEPIC worksheet was not only used during classroom exercises (i.e., group and individual works). The researcher also used the DEPIC problem-solving strategy during lectures especially in the presentation of sample problems by using verbal prompting. The timeline for the fading of prompts was also used by the researcher in the presentation of sample problems during lecture, in coherence with fading of prompts in the DEPIC worksheet. Quizzes and homework also used the DEPIC structure, thus, the researcher provided each student with individual worksheets. Table 3 summarizes the topics covered for each DPP lesson plan.

Table 3

Topics Covered for each DPP Lesson Plan

Lesson	Week	Topics	Teaching Strategy
1	2 - 3	Uniform Circular Motion and Center of Gravity	DEPIC
2	4	Static Equilibrium and Torque	DEPC
3	5	Work and Power	DPC
4	6 - 7	Kinetic Energy, Potential Energy and Total Mechanical Energy	PC
	8		C

Conventional Problem-solving Class (CP)

Each session of the CP group began with a motivational activity similar to that of the DPP group. After engaging with the students, the teacher presented the concept in class, solved sample word problems and gave exercises. The CP class performed individual and group tasks similar to those of the DPP class. However, no prompts were used in the solving of word problems in class by the teacher or in their individual or group activities. Instead, the problem-solving format used was the format introduced by their physics teacher in Grade 8. The format contained the following: Given, Find, Solution and Answer. Also, the group did not receive problem-solving worksheets. For group or individual seat works, the word problems were written on the board or were shown using a projector. For quizzes and long tests, they received test booklets similar to the DPP class. However, in the problem-solving (PS), only the word problems were given with no problem-solving steps. Blank spaces were provided after every word problem.

The instructional structure of the CP class was similar to the DPP class except in the presentation of the sample word problems and the presentation of exercises. Table 4 shows the instructional structure of both teaching approaches.

Table 4

DPP and CP Instructional Structure

Diminishing Problem-solving Prompts (DPP)	Conventional Problem-solving (CP)
Motivation	Motivation
Concept Development	Concept Development
Presentation of Sample Problems *DEPIC Problem-solving verbal cues and prompts*	Presentation of Sample Problems *Conventional Problem-solving format: Given, Find, Solution and Answer*
Individual and Group Exercises *DEPIC Problem-solving worksheets with diminishing prompts based on schedule of the timeline*	Individual and Group Exercises *No worksheets; Word problems written on the board or presented using a projector*
Lesson Synthesis	Lesson Synthesis

Initial Comparability in Conceptual Understanding and Problem-solving Pretest

The initial comparability of the CP group and DPP group was determined by subjecting the conceptual understanding (CU) and problem-solving (PS) mean pretest scores to two-tailed t-test for independent samples. Tables 5 and 6 show the mean, standard deviations of both groups, and the computed t-value at 5% level of significance for Conceptual Understanding (CU) and Problem-solving (PS) pretest scores, respectively.

Table 5

Independent Samples t-test on the Conceptual Understanding (CU) Pretest Scores

Group	Mean	SD	t	df	Sig (2-tailed)
DPP	12.97	2.86	-.077	62	.939
CP	13.02	1.99			

Note. **p* < .05. CU Perfect Score = 20

Levene's test of equality of variances revealed a non-significant value ($p = .111$). The t-test showed that there was no significant difference between the mean pretest scores, $t(62) = -.077$, $p = .939$ (Table 5). The results indicated that the two groups were comparable in terms of conceptual understanding prior to the intervention.

Table 6

Independent Samples t-test on the Problem-solving (PS) Pretest Scores

Group	Mean	SD	t	df	Sig (2-tailed)
DPP	1.94	1.77	1.75	62	.085
CP	1.24	1.39			

Note. **p* < .05. PS Perfect Score = 40

Levene's test of equality of variances revealed a non-significant value (*p* = .099). The t-test showed that there was no significant difference between the mean pretest scores, *t*(62) = 1.75, *p* = .085 (Table 6). The results indicated that the two groups were comparable in terms of problem-solving skills prior to the intervention.

Discussion of Findings

Effects of Teaching Approach on Conceptual Understanding and Problem-solving Skills

After the intervention, the PAT was administered as a post-test. To establish whether there was a significant difference between the CP and DPP in terms of conceptual understanding and problem-solving skills, the mean post-test scores of both groups were subjected to one-tailed t-test for independent samples.

Levene's test was performed and the results indicated that the variances for conceptual understanding (*p* = .13) and problem-solving (*p* = .09) mean post-test scores were assumed to be equal. Table 7 shows the independent samples t-test on the conceptual understanding and problem-solving post-test scores.

Table 7

Independent Samples t-test on the Conceptual Understanding (CU) and Problem-solving (PS) Post-Test Scores

Teaching Approach	M	SD	t	df	Sig. (one-tailed)
Conceptual Understanding (CU)					
DPP	16.29	3.37	-.141	62	.444
CP	16.15	4.40			
Problem-Solving (PS)					
DPP	15.50	8.83	-.118	62	.453
CP	15.74	7.59			

There was no significant difference between the conceptual understanding (CU) of the DPP group (*M* = 16.29, *SD* =3.37) and CP group (*M* = 16.15, *SD* = 4.40); *t*(62) = -.141, *p* = .444 (Table 7). These results indicate that after the intervention, there was no significant difference between the two groups in terms of conceptual understanding. It is interesting to note that the DPP students obtained a slightly higher mean compared to the CP students. However, the results were still not significant.

Similarly, there was no significant difference between the problem-solving (PS) of DPP group (*M* = 15.50, *SD* = 8.83) and CP group (*M* = 15.74, *SD* = 7.59); *t*(62) = -.118, *p* = .453 (Table 7). These results indicated that after the intervention, there was no significant difference between the two groups in terms of problem-solving in spite of CP students obtaining a slightly higher mean compared to DPP students.

It is important to note that DPP and CP groups both used problem-solving strategies during their problem-solving process. Heller and Reif (1984) assert that students become significantly better problem-solvers when following a problem-solving strategy. Based on the qualitative data, entries of some students from the CP group were describing a prompt in the DEPIC problem-solving strategy which was not introduced to them. For example, a student (CP01) wrote that drawing the forces acting on the object was easy to do; however, identifying the exact type of force acting on the object was a little difficult. This process characterized by the student was like the prompts under Describe the problem. For another student (CP12), identifying the equation to use for a given problem was easy but found simplifying the equation challenging. Again, this process was similar to the prompts under Plan the solution of the DEPIC problem-solving strategy. Even though no prompts were used with the CP group, the use of a strategy served as a guide in the process of problem-solving as affirmed by Mayer (1985) Furthermore, each step helped the students plan to complete the task as argued by Johnson and Johnson (1994).

Another explanation may be attributed to the over-prompting effect suggested by Kalyuga et al. (2003), where the students grow weary of doing prompts in almost every activity. The additional steps they needed to do to solve the problem may have had negative effects on their learning. This was evident in the qualitative entries of some DPP students. For instance, a student (DPP05) wrote that conceptualizing the problem sometimes needed more time. Another student (DPP10) stated that constructing free-body diagrams was hard while another student (DPP28) wanted to solve the problem directly and not follow the problem-solving format.

Another way of determining the effect of the DPP teaching approach is by calculating the normalized gain <g> for each group. The normalized gain can be an objective measure because it focuses on the maximum possible learning increase of students (Coletta & Phillips, 2005). The normalized gain, <g>, is given by the equation

<g> = (<post-test score> - <pretest score>) / (maximum score - <pretest score>).

To investigate the learning gain of students, the 10 high scorers and 10 low scorers in the post-test were identified, then the average normalized gain for high- and low-performing were computed as shown in Table 8.

Table 8

Normalized Gain in Physics Achievement of High- and Low-performing Students

	Normalized gain <g>			
	High-performing		Low-performing	
	DPP	CP	DPP	CP
Conceptual Understanding (CU)	0.509 (Medium Gain)	**0.595** (Medium Gain)	-0.025 (Low Gain)	-0.173 (Low Gain)
Problem-solving (PS)	**0.887** (High Gain)	0.874 (High Gain)	0.111 (Low Gain)	**0.234** (Low Gain)

Note: Values written in bold are higher.

The results showed that high-performing students achieved higher learning gains in problem-solving (PS), $\langle g\rangle_{\text{DPP high}} = 0.887$ and $\langle g\rangle_{\text{CP high}} = 0.874$, compared to the medium gain achieved in conceptual understanding (CU), $\langle g\rangle_{\text{DPP high}} = 0.509$ and $\langle g\rangle_{\text{CP high}} = 0.595$. It is also important to note that in PS, the DPP group had a slightly higher normalized gain, $\langle g\rangle_{\text{DPP high}} = 0.887$, compared to the CP group, $\langle g\rangle_{\text{CP high}} = 0.874$. This shows that the exposure to more problem-solving activities helped high-performing students of both groups achieve higher learning gains. Thus, the normalized gain by the DPP group in the problem-solving (PS) component, $\langle g\rangle_{\text{DPP high}} = 0.887$, can be attributed to the use of diminishing problem-solving prompts (DPP). Since problem-solving strategy improves student problem-solving performance, the diminishing prompts helped the DPP high-performing group achieve slightly higher gain than the CP high-performing group in the problem-solving (PS) component of the PAT. However, for the conceptual understanding (CU), high-performing students from the CP group had higher normalized gain, $\langle g\rangle_{\text{CP high}} = 0.595$, compared to the students exposed to DPP, $\langle g\rangle_{\text{DPP high}} = 0.509$. Although it is interesting to note that the CU for both low-performing groups had negative gains.

According to Miller et al. (2010), normalized gain does not account for losses because it assumes that there are no conceptual losses. However, there are instances where a student correctly guesses the answer in the pretest but answers incorrectly in the post-test, thereby producing negative values for normalized gain. So, when loss is normalized with respect to possible gain, the interpretation of <g> becomes vague (Miller et al., 2010). The item analysis of the pretest and post-test of the conceptual understanding (CU) for both groups showed that there were five DPP and seven CP students with correct answers in the pretest but ended with incorrect answers in the post-test. Thus, low-performing students exposed to DPP had more correct answers in the conceptual understanding (CU) post-test compared to their counterparts in the CP group due to lower numbers of students with negative gains. Also, some of the low-performing DPP students stated in their qualitative entries that their understanding of physics concepts helped them in their problem solving, even though they were unsuccessful in answering the problems completely. One student

(DPP13) wrote that "Physics concepts would help you understand the formula so you can answer word problems" and another student (DPP08) stated that identifying the forces in the diagram required their knowledge of the types of forces.

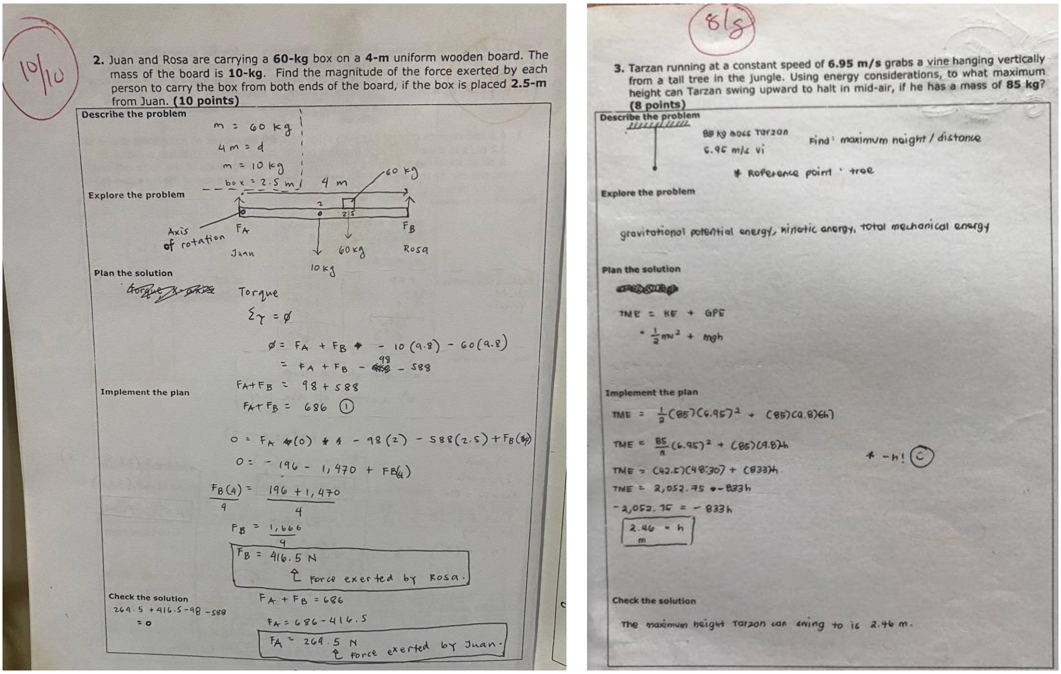
Further analysis of the problem-solving component of the Physics Achievement Test (PAT) for the high-performing students revealed that even after all the prompts were removed, more than half (six of ten students) followed the DEPIC problem-solving strategy as shown in Figure 3. However, due to space constraints, the answers of the students were not exactly in the spaces provided for each strategy. For both worksheets, the flow of the solution was similar (i.e. pictorial representation of the problem was shown and was not just limited to listing down of the given and required). Both worksheets also identified the concept involved and equation to use to solve the problem.

Lastly, monitoring the quality of the answer was also shown by summarizing the final answer for the problem by evaluating the unit of the answer.

The process of checking the answer is a metacognitive prompt not inherent in students, and is considered an expert-like behavior according to Foster (2000).

Figure 3

Sample of the DPP Students' Post-Test Worksheet without Prompts



10/10

2. Juan and Rosa are carrying a **60-kg** box on a **4-m** uniform wooden board. The mass of the board is **10-kg**. Find the magnitude of the force exerted by each person to carry the box from both ends of the board, if the box is placed **2.5-m** from Juan. **(10 points)**

Describe the problem

m = 60 kg
4 m = d
m = 10 kg
box = 2.5 m

Explore the problem

4 m
60 kg
2
2.5
Axis of rotation
F_A
Juan
10 kg
60 kg
F_B
Rosa

Plan the solution

[illegible]

Torque

$\Sigma\tau = 0$

$0 = F_A + F_B - 10(9.8) - 60(9.8)$

$= F_A + F_B - 98 - 588$

Implement the plan

$F_A + F_B = 98 + 588$

$F_A + F_B = 686$ ①

$0 = F_A(0) - 98(2) - 588(2.5) + F_B(4)$

$0 = -196 - 1{,}470 + F_B(4)$

$\frac{F_B(4)}{4} = \frac{196 + 1{,}470}{4}$

$F_B = \frac{1{,}666}{4}$

$\boxed{F_B = 416.5\ \text{N}}$ ↑ Force exerted by Rosa.

Check the solution

$269.5 + 416.5 - 98 - 588 = 0$

$F_A + F_B = 686$

$F_A = 686 - 416.5$

$\boxed{F_A = 269.5\ \text{N}}$ ↑ Force exerted by Juan.

8/8

3. Tarzan running at a constant speed of **6.95 m/s** grabs a vine hanging vertically from a tall tree in the jungle. Using energy considerations, to what maximum height can Tarzan swing upward to halt in mid-air, if he has a mass of **85 kg**? **(8 points)**

Describe the problem

85 kg mass Tarzan
6.95 m/s vi
Find: maximum height / distance
* Reference point: tree

Explore the problem

gravitational potential energy, kinetic energy, total mechanical energy

Plan the solution

[illegible]

$TME = KE + GPE$

$= \frac{1}{2}mv^2 + mgh$

Implement the plan

$TME = \frac{1}{2}(85)(6.95)^2 + (85)(9.8)(h)$

$TME = \frac{85}{2}(6.95)^2 + (85)(9.8)h$

* −h! ©

$TME = (42.5)(48.30) + (833)h$

$TME = 2{,}052.75 - 833h$

$-2{,}052.75 = -833h$

$\boxed{2.46\ \text{m} = h}$

Check the solution

The maximum height Tarzan can swing to is 2.46 m.

As for the other DPP students, 13 of the remaining 20 students showed expert-like behaviors in their solution even if some were unable to solve the problem correctly. The common expert-like behavior in their problem-solving solutions were pictorial representations or sketches of the problem (Schultz & Lochhead, 1991) and integration of physics concepts to their problem-solving approach (Larkin et al, 1980).

Although there were no significant differences between the DPP and CP groups in terms of conceptual understanding and problem-solving based on the quantitative results, the DPP group, nevertheless, recognized the importance of the DEPIC problem-solving strategy as reflected in their end-of-quarter qualitative entries. A student (DPP02) reported that drawing the diagram helped in solving the problem quickly as it identified all the needed forces to be used in the equation. Another student shared that "Physics class helped me to learn more about the techniques on how to solve problems and how to apply it while answering word problems".

Correlation between Students' Conceptual Understanding and Problem-solving Skills

A Pearson product-moment correlation coefficient was computed to assess the relationship between conceptual understanding and problem-solving skills of DPP and CP students in physics. Table 9 shows the correlation between conceptual understanding and problem-solving skills of students in physics.

Table 9

Pearson Correlation of Conceptual Understanding and Problem-solving Skills of Students in Physics

		Conceptual Understanding	Problem -solving Skills
Conceptual Understanding	Pearson Correlation	1	.619**
	Sig. (2-tailed)		.000
	N	64	64
Problem-solving Skills	Pearson Correlation	.691**	1
	Sig. (2-tailed)	.000	
	N	64	64

** Correlation is significant at the .01 level (2-tailed).

Results of the Pearson correlation indicated that there was a strong positive correlation between conceptual understanding (CU) and problem-solving skills (PS), *r*(64) = 0.619, *p* = 0.000. Increases in students' conceptual understanding were significantly related with increases in students' problem-solving skills.

As Gaigher et al. (2007) mentioned in their study, the use of problem-solving strategies improved problem-solving performance of students and at the same time developed their conceptual understanding. Since both DPP and CP groups used problem-solving strategies, it contributed to the positive correlation between the two variables. Similarly, studies by Kramarski et al. (2002) have shown that conceptual knowledge and problem-solving skills can be enhanced by employing metacognitive processes like prompting.

To further investigate which group contributed to the positive correlation between the two variables, Pearson correlation coefficients were each computed for DPP and CP groups. Table 10 shows the correlation between conceptual understanding and problem-solving skills in physics of each group.

Table 10

Pearson Correlation of Conceptual Understanding and Problem-solving Skills of DPP and CP Students in Physics

		Problem-solving Skills	
		DPP	CP
Conceptual Understanding	Pearson Correlation	**.711****	.577**
	Sig. (2-tailed)	.000	.000
	N	31	33

** Correlation is significant at the .01 level (2-tailed).
Note: Value written in bold is higher.

Results of the Pearson correlation indicate that there was a strong positive correlation between conceptual understanding (CU) and problem-solving skills (PS) for students belonging to the DPP group, *r*(31) = 0.711, *p* = 0.000, while Pearson correlation for the CP group indicates that there was only a moderate positive correlation between the two variables, *r*(33) = 0.577, *p* = 0.000. The use of problem-solving prompts to facilitate the learning process of DPP students as they elaborated on their learning during problem-solving tasks (Greene & Land, 2000) significantly contributed to the strong positive correlation of the two variables. For the CP group, since they did not benefit from the use of any prompts, the conceptual understanding and problem-solving skills only had a moderate positive correlation even though they used a problem-solving strategy. Thus, the strong positive correlation between conceptual understanding and problem-solving skills can be attributed to the use of problem-solving prompts by the DPP group.

Conclusion and Recommendations

Based on the statistical analyses, it was established that there was no significant difference between the mean post-test scores of DPP and CP groups in terms of conceptual understanding and problem-solving. However, high-performing students exposed to DPP had slightly higher normalized gains compared to the high-performers in the CP group in problem-solving (PS). In addition, high-performing DPP students showed improvement in their problem-solving skills by exhibiting expert-like behaviors in their problem-solving solutions. On the other hand, low-performing students exposed to DPP had more correct answers in the post-test for conceptual understanding (CU) compared to their counterparts in the CP group due to lower numbers of students with negative gains. These show that DEPIC problem-solving strategy has the potential to motivate students to exhibit expert-like behaviors in their problem-solving tasks and enhance their conceptual understanding.

There was also a strong positive correlation between conceptual understanding (CU) and problem-solving skills (PS) of DPP and CP students in physics. The use of problem-solving strategies improved the problem-solving performance and developed conceptual understanding for both DPP and CP groups. However, correlation of the two variables within each group showed that DPP had a strong positive correlation while CP only had a moderate positive correlation. These show that diminishing problem-solving prompts can improve the physics achievement of students because it can build their conceptual knowledge and their problem-solving skills as they perform their problem-solving tasks.

These results may serve as a guide for teachers regarding the use of problem-solving prompts in their lessons and activities to achieve positive effects on the conceptual understanding and problem-solving skills of students in physics.

It is recommended that since the study lasted for only seven weeks, this may be replicated and conducted for a longer period to give ample time for students to master the problem-solving strategy before prompts are diminished or removed. Moreover, to prevent expertise-reversal and saturation, teachers should design the fading of prompts according to the knowledge acquisition and problem-solving skills of their students.

It is also recommended that a similar study be conducted on an introductory problem-solving class in mathematics, specifically Grade 7 for topics in distance, age and solution problems, or motion problems in Grade 8 physics classes to improve the results of the study, as the students in this study were already exposed to conventional problem-solving strategies.

Future researchers can include the use of a think-aloud protocol while students solve problems using the DPP instructional approach to investigate how they integrate physics concepts in their problem-solving process. Researchers can also conduct student interviews while the intervention is ongoing to correctly evaluate the mastery of the students in using the DPP problem-solving prompts so as to properly schedule the fading of prompts.

Lastly, researchers can investigate the effect of diminishing problem-solving prompts on conceptual understanding and problem-solving skills by exploring other qualitative research methods like video recordings during problem-solving sessions and analyzing other student artifacts like worksheets, homework, and seatwork.

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Author Note

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