The relationship between students’ views and performance of solving physics problems

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Abstract. Science education researchers argue that students’ attitudes and beliefs toward science affect students’ learning. In physics education research, questionnaires have been developed to measure students’ views about physics learning and to investigate the relationship between views and conceptual understanding. This paper examines the relation between students’ views about problem solving and students’ performance in solving force problems. First year students who are being prepared to be physics teachers were involved in this study. For data collection, students were asked to fill out the Physics Problem Solving Questionnaire (PPSQ) and to solve two open questions of force topic at the end of the instruction. The PPSQ has 30 items which covers what students think about the role of math, representation, strategy during solving problems. The context of force problem addresses an object is placed on inclined plane and horizontal surface. The results indicate that students’ attitude and performance have a positive correlation (r = 0.6; p < 0.01). Furthermore, students who have positive views about representations in the survey have high performance of drawing free body diagram as one of physics representations (the correlation is significant). Meanwhile, students’ perception about math has not statistically significant with mathematical performance solving force problems.

1. Introduction

Science education researchers have sought to investigate students’ attitudes towards science, arguing that students’ views influence how successfully they learn science. A number of instruments have been designed to measure students’ views toward science such as the Behaviours Related Attitudes and Intentions toward Science (BRAINS) [1], the My Attitudes Toward Science (MATS) [2], and the Views about Science Survey (VASS) [3], which can be used for both primary and secondary school students. While these surveys are composed of different items, they all share the same five-point Likert scale. Researchers have also examined university students’ perceptions of science courses such as chemistry [4], geoscience [5], and physics [6-9], and even towards mathematics [10]. These surveys are intended to gauge students’ views towards and/or beliefs about the characteristics of specific subjects (such as science) that might affect their learning.

The instruments generally used to assess students’ views about learning physics are the Colorado Learning Attitude Science Survey (CLASS) [6] and the Maryland Physics Expectation Survey (MPEX) [9]. CLASS consists of 42 items that cover students’ beliefs about learning physics, divided into the following categories: independence, coherence, concepts, links to reality, links to math, and effort. The MPEX is comprised of 34 items that address eight indicators: real-world connection, personal interest, sense-making or effort, conceptual connections, applied conceptual understanding, general problem-solving, problem-solving confidence, and problem-solving sophistication. These surveys are typically administered to students both before and after physics lesson to see whether the
students’ views have changed. A review by Madsen et al. Madsen et al. summarised the use of these surveys for physics instruction [11]. Their meta-analysis found a small correlation between students’ beliefs about physics and their conceptual understanding in mechanics, with the students who evinced expert-like beliefs showing more conceptual knowledge. This being so, the possibility as to whether students with positive views about specific aspects of physics such as problem-solving demonstrate a higher level of performance remains to be tested.

Some students report that physics – a common science course – is an interesting subject, but nevertheless difficult [7], assuming that it is almost identical to mathematics and requiring mastery of many equations and formulas. When solving physics problems in the course of exercises or exams, students need to grapple with mathematical equations and manipulate them to determine the best solution. However, another aspect of this issue that has seldom been explored by researchers, even though it could influence students’ performance when solving physics problems, is students’ attitude towards the nature of problem-solving in physics, given that their beliefs about teaching and learning physics correlate to their ability to explain concepts in this field [12].

To measure students’ attitudes toward physics problem-solving, a physics problem-solving survey has been developed and translated it into various languages, such as English [13], Turkish [14], Indonesian [15], and Thai [16]. The survey addresses metacognition in problem-solving, the role of physics concepts, the role of equations and formulas, the use of representations (e.g. picture and diagrams), the use of strategies, and problem-solving confidence. The questionnaires were administered to secondary school students, university students (both undergraduates and graduates), and lecturers, and based on the participants’ responses, they were categorised into either novice or expert problem-solvers. Given this background, it is still necessary to understand the relationship between students’ views about physics problem-solving and their performance, both in terms of their conceptual understanding and their problem-solving skills.

Problem-solving in physics is defined as a series of activities or procedures used to find a solution to a problem, based on the information given [17]. Furthermore, the ability to solve problems is one of the most important skills in this subject, both while learning physics and even after completing one’s education, because these skills can be put to good use in one’s daily life or future career. For this reason, education experts have introduced problem-solving strategies in physics as a means of helping students to successfully solve problems [18-21]. The main purpose behind these strategies is to activate aspects of students’ cognition such as their ability to visualise problems in various forms (known as representations), and skill at manipulating mathematical equations in order to execute the problems. Conceptual understanding also forms a very important part of these strategies.

In addition to the cognitive realm, students’ beliefs or views can affect their ability to solve problems, and this study aims to examine the relationship between students’ attitudes to physics and their ability in this subject. The Physics Problem Solving Questionnaire (PPSQ), developed by Sirait et al. [16], has been used to measure students’ attitudes. This survey, which consists of 30 items, aims to investigate problem-solvers’ beliefs about the role of maths, representations, concepts, and problem-solving strategies, along with their interest in solving problems. Two open questions about mechanical force (Newton’s laws) were administered to assess students’ performance and ability to understand physics concepts, draw and use representations, and manipulate mathematical equations. The first question involves a block placed on a vertical surface, while in the second, the block is placed on an inclined surface.

2. Methodology
The participants in this study consisted of first-year students (n=23) in the Department of Physics Education, Tanjungpura University, 18 of whom were female, and five male. The students in this department are preparing to become physics teachers at secondary schools after completing their studies.
To elicit students’ views about physics, they were administered the PPSQ [16] at the end of a period of instruction. This survey consists of 30 items made up of seven indicators, including the use of representations, the role of mathematics, physics concepts, physics strategies, the importance of discussing and evaluating answers, and interest in solving problems. There are five possible answers to the questions in this survey (making it a Likert scale): strongly agree, agree, neutral, disagree, and strongly disagree. We then gauged participants’ performance in solving physics problems by asking them to solve two open questions regarding Newton’s laws. A rubric from Etkina et al. [22] was adapted to score the students’ answers.

**Q1**

A block having a mass of 10 kg is pressed against the wall by a hand exerting a force \( F \) inclined at an angle \( \theta \) of 30\(^\circ\) to the wall as shown. The coefficient of static friction between the block and the wall is 0.2. If \( F \) is small enough that the block tends to slide downward and if \( F \) is large enough that the block tends to slide upward. Determine the magnitude of \( F \) for the case (a) the block is just about to start sliding downward; (b) the block is just about to start sliding upward.

\[
\sin 30^\circ = 0.786, \quad \cos 30^\circ = 0.61, \quad \tan 30^\circ = 1.27, \quad \text{gravitational acceleration on earth } = 10 \, \text{m/s}^2
\]

**Q2**

A box having a mass of 2.2 kg is sliding down with constant acceleration 1.2 m/s\(^2\) from the top of inclined plane. The angle between inclined surface and horizontal surface is 30\(^\circ\). Determine the magnitude of the coefficient kinetic friction between the box and the ramp.

\[
\sin 30^\circ = 0.5, \quad \cos 30^\circ = 0.86, \quad \tan 30^\circ = 0.57, \quad \text{gravitational acceleration on earth } = 10 \, \text{m/s}^2
\]

**Figure 1.** Force questions

| Representations | Score | Descriptions |
|----------------|-------|--------------|
| Picture        | 3     | Picture contains all key items with the majority of labels present. Physical quantities have appropriate subscripts |
|                | 2     | Picture has no incorrect information but has either no or very few labels of given quantities. Majority of key items are drawn in the picture |
|                | 1     | Picture is drawn but it is incomplete with no physical quantities labeled, or important information is missing, or it contains wrong information, or coordinate axes are missing |
|                | 0     | No picture is constructed |
| FBD            | 3     | The diagram contains all appropriate force and each force is labeled so that one can clearly understand what each force represents. Relative lengths of force arrows are correct |
|                | 2     | Force diagram contains no errors in force arrows but lacks a key feature such as labels of forces with two subscripts or forces are not drawn from single point |
|                | 1     | Force diagram is constructed but contains major errors: missing or extra forces (not matching with the interacting objects), incorrect directions of arrows or incorrect relative length of force arrows |
|                | 0     | No force diagram is constructed |
| Math           | 3     | Mathematical representation contains no errors and it is easy to see progression from the first step to the last step. The final answer is reasonable in terms of magnitude, has correct units and is makes sense for the limiting cases |
|                | 2     | There are no errors in the reasoning, however they may not have fully completed steps to solve problem or one needs effort to comprehend the progression |
|                | 1     | Mathematical representation lacks the algebraic part (the student plugged the numbers right away) has the wrong concepts being applied, signs are incorrect, or progression is unclear. The first part should be applied when it is appropriate |
|                | 0     | No mathematical representation is constructed |
3. Results and discussion

Data were collected from physics education students taking a basic physics course in the first semester of 2017. This course focuses on mechanics: kinematics, Newton’s laws, momentum and impulse, work, and energy, and takes the form of a basic curriculum that consists of three activities: lectures, recitation classes, and labs. The recitation class is a new activity in the physics education department. Here, students are divided into several groups, each of which is provided with a mini-whiteboard. The students are then given problems and told to work in groups, using a physics representation worksheet (PRW), and writing down their work on a mini board. As they work through the problems, students are able to ask for help from teaching assistants (TAs) (who are senior students), if they have difficulties. However, the TAs only provide scaffolding to stimulate the students to think critically themselves. At the end of the session, the students present their work to other groups. An example of a recitation session is shown in Figure 2, in which the students are seen discussing Newton’s laws and their applications.

The average scores of the students’ responses were analysed for all items and the seven indicators, and their scores for the force problems have been measured via the rubric shown in Table 1. In addition to the total score, students’ performance at representing force diagrams and manipulating mathematical equations were also calculated, and both average scores (students’ responses and performance) were analysed using the Statistical Package for Social Science (SPSS) version 24. The correlation between students’ views about problem-solving and their performance was found to be 0.601 and statistically significant at the level 0.01. This indicates that 36% of the students’ performance at solving the force problems can be explained by their perceptions about problem-solving in the field of physics.

| Measures correlated                        | Correlation coefficient | Significance         |
|--------------------------------------------|-------------------------|----------------------|
| PPSQ and performance                       | 0.601                   | 0.002 (p<0.01)       |
| Representation and performance             | 0.371                   | 0.081                |
| Math and performance                       | 0.170                   | 0.437                |
| Rechecking answer and performance          | 0.402                   | 0.057                |
| Concepts and performance                   | 0.337                   | 0.116                |
| Discussion and performance                 | 0.407                   | 0.054                |
| Strategies and performance                 | 0.498                   | 0.015 (p<0.05)       |
| Interest and performance                   | 0.108                   | 0.625                |
| Representation and FBD performance         | 0.408                   | 0.050 (p<0.05)       |
| Math and mathematical performance          | 0.052                   | 0.813                |
Table 2 shows the correlation between students’ attitudes (whole items) and their performance; between students’ attitudes (for each indicator) and their performance; and between students’ attitudes (two indicators: the role of representation and maths) and their ability to draw diagrams and mathematical performance while solving force problems. As can be seen, there is a positive relationship between students’ attitudes to the application of strategies and problem solving, and this is also statistically significant with students’ performance at solving problems (0.498 p<0.05); this means that students with different strategies or approaches to solving problems can successfully do so. To solve work and energy problems, for example, students can apply either the Newtonian or the momentum approach, and therefore students need to be equipped with various qualitative problem-solving strategies [21] and conceptual approaches [18]. Hamdani et al. [23] found that students with expert-like attitudes to problem-solving strategies achieve higher grades in physics.

Of the various indicators, the role of maths and interest in solving physics problems had the lowest correlation index with students’ performance, at 0.170 and 0.108, respectively. This indicates that students who are positive about using maths and have an interest in solving problems do not necessarily show a higher performance in solving force problems. One of the statements in the questionnaire about students’ interest in solving problem is “I like to solve the physics problems, even though they are relatively difficult and time-consuming.” A total of 65% of the students reported a favourable response to this expert-like response. A student’s interest in solving physics problems does not guarantee that he/she will be able to do so well; according to Kulgemeyer and Riese [12], preservice teachers’ beliefs about teaching do not necessarily lead to good performance at teaching a subject in the classroom.

Furthermore, about 80% of students agreed that the most important part of the problem-solving process is the ability to successfully handle the mathematics involved, revealing that students are more concerned about manipulating equations than physics concepts or principles, when solving problems. There is also a weak correlation between students’ perceptions about the mathematics of problem-solving and their ability to mathematically solve force problems, with a correlation index of only 0.052. This is supported by Angel et al. [7], who found that students believe that mathematics is necessary in physics to describe physical phenomena and solve problems. However, many students find it difficult to manipulate formulas and complete calculations involving symbols.

One interesting finding is that students’ perceptions about representations in problem-solving correlate positively (0.371) with their performance, even though this does not have a statistically significant value. Moreover, students’ views about the role of representation is statistically significant (0.408 p<0.05) with their performance in drawing free body diagrams while solving force problems.

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problems. It appears that the use of representations such as free body diagrams makes a positive contribution to students’ attempts to solve force problems. As shown in Table 3, over 75% of the participants always drew representations at the beginning of the problem-solving process for both multiple-choice and essay questions, and when solving both homework problems and exams. Sirait et al. [24] found that many students find it difficult to identify and draw forces correctly; however, students who correctly draw free body diagrams can also correctly select equations and successfully determine the final answer. In this way, students can be taught by constructing representations when learning science, to help them as they gain knowledge [25].

4. Conclusion
Students’ views toward physics problem-solving correlate positively and significantly with their performance at solving force problems. Of the various indicators in the survey that were used in this investigation, the role of strategies and the use of representations show the highest correlation with students’ ability to solve problems, while their views about using representations significantly contribute to their ability to draw free body diagrams. Educators and teachers should therefore seek to boost students’ ability to construct and use representations in physics instruction as a means of enhancing their understanding of physics concepts, as well as their performance in solving problems.

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