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Pre-Service Science Teachers' PCK: Inconsistency of Pre-Service Teachers' Predictions and Student Learning Difficulties in Newton's Third Law

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There is widespread agreement that science learning always builds upon students' existing ideas and that science teachers should possess knowledge of learners. This study aims at investigating pre-service science teachers' knowledge of student misconceptions and difficulties, a crucial component of PCK, on Newton's Third Law. A questionnaire was designed and conducted to 143 pre-service science teachers enrolled in a normal university in China. A comparison between participants' predictions and student actual outcomes was detected. The result revealed a tendency for pre-service science teachers to under-predict the problem-solving ability of senior high school students. Furthermore, most pre-service science teachers neglected two common learning difficulties in Newton's Third Law. It seems that there is a need to help pre-service science teachers be aware of their own misunderstandings about students.

Keywords: pre-service teachers, knowledge of students, newton's third law, student difficulties

INTRODUCTION

There is widespread agreement that science learning always builds upon students' existing ideas and that science teachers should possess knowledge of learners, e.g., student learning difficulties, to facilitate student learning (Shulman, 1986). Thus, much effort has been made to probe and enhance pre-service science teachers' understanding of student difficulties, as shown in previous researches

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concerning teachers' Pedagogical Content Knowledge (PCK) (Shulman, 1986; Grossman, 1990; Park & Oliver, 2008; Even & Tirosh, 1995; Erbas, 2004; Hill, Ball & Schilling, 2008; Schmelzing et al., 2013; Manizade & Mason, 2011; Depaepe, Verschaffel & Kelchtermans, 2013).

Knowledge of students, as introduced by Shulman (Shulman, 1986), is "an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and background bring with them to the learning of those most frequently taught topics and lessons" (p. 9). Several analogue concepts in the later studies are: knowledge of students' understanding (Grossman, 1990; Park & Oliver, 2008), knowledge about students (Even & Tirosh, 1995), knowledge of student thinking (Erbas, 2004), knowledge of content and students (KCS) (Hill, Ball & Schilling, 2008), and student learning and conceptions (Schmelzing et al., 2013). In particular, knowledge of student learning difficulties has been broadly identified as a crucial part of PCK that deserves in-depth researches (Manizade & Mason, 2011; Depaepe, Verschaffel & Kelchtermans, 2013).

State of the literature

- Researches on teachers' Pedagogical Content Knowledge (PCK) have suggested that pre-service science teachers show little consideration for students and have poor knowledge of students' learning difficulties.
- Most previous researchers tried to expand pre-service teachers' understanding of students (a crucial part of PCK) through teaching practices, whereas pre-service teachers always did not have many opportunities to teach.
- The ability to predict students' ideas or performances is commonly seen as an indicator to measure teachers' knowledge of students' difficulties and misconceptions. However, there are few well-specified descriptions on this ability in science domain.

Contribution of this paper to the literature

- A paper-and-pencil questionnaire has been designed to detect pre-service teachers' knowledge of students' difficulties and misconceptions in the domain of Newton's Third Law.
- The result reveals that pre-service science teachers' predictions about student performance on problem-solving and learning difficulties did not always correspond with students' outcomes. Most pre-service science teachers underestimated the problem-solving ability of senior high school students.
- The present study raised the issue of pre-service science teachers' blind spots that most of them failed to recognize some misconceptions that were extensively common among junior secondary school students.

LITERATURE REVIEW

Pre-service science teachers' knowledge of student learning difficulties

Researches on teachers' PCK for different science topics have suggested that pre-service science teachers show little consideration for students and have poor knowledge of students' learning difficulties. For example, only a small number of prospective secondary chemistry teachers would concern about student learning or difficulty when preparing lessons (De Jong, 2000; De Jong & van Driel, 2001). Also, trainee secondary physics teachers have been reported to underestimate student learning difficulties or be not able to identify students' misconceptions in physics (Halim & Meerah, 2002). Likewise, novice science teachers are unaware of student prior knowledge and its role in instruction to effectively implement constructivist teaching practices (Meyer, 2004).

Science teacher educators have sought to raise pre-service science teachers' concern about students thinking and to assist them in learning about students through teaching practices, as shown in a number of studies concentrating on pre-service teachers' PCK development (Halim, Meerah & Buang, 2010; Heller et al., 2012; Hanuscin, 2013). These researches have demonstrated the effectiveness of several tools in deepening science teachers' knowledge of student difficulties, such as reflection on teaching practice, group discussion or analysis of student conceptual understanding and students' work. These may benefit in-service science teachers in the long run as they might make conscious effort to expand their understanding of students during their years of service. However, pre-service science teachers' could only gain a handful of knowledge of students during the preparation programs because they have not many opportunities to teach.

We notice that well-specified descriptions are needed on the discrepancy between pre-service science teachers' understanding of student learning difficulties in specific science topics and student actual ideas. However, there are few similar attempts in science domain.

Large-scale studies based on paper-and-pencil instruments for PCK

In order to detect a common trend, that is, the pre-service teachers' common thinking about students in certain science topic, a special and demanding measurement technique is required. Researchers and teacher educators have developed multimodal approaches to evaluate teachers' PCK. Various techniques to PCK often include multiple-choice questions, concept mapping, structured/semi-structured interviews, stimulated recall interviews, pictorial representations, and (video-)observations (Schmelzing et al., 2013; Hill et al., 2007; Mulhall, Berry & Loughran, 2003; Loughran et al., 2001; Piburn et al. 2000; Park et al., 2011; Demirdogen, Aydin, & Tarkin, 2015). These methods have provided fruitful outcomes of pre-service and in-service teachers' PCK. However, as Kagan (1990) noted, the challenge was to develop, administrate and analyze these pedagogical content knowledge methodologies. For instant, concept mapping needs the interpretation of involved coding systems. In the interview, participants may not possess the language to express their thoughts and its process generates lengthy transcripts to be analyzed. Observational data could not be exclusively relied on, as a small part of the participants' accumulated store of examples may be embedded in a particular teaching episode. Furthermore, most of these approaches are time-consuming and labor-intensive for both data collection and analyses (Schmelzing et al., 2013). This limitation results in a small group of participants in a study. Therefore, paper-and-pencil test would be an indicator-oriented method to assess teacher' PCK in large-scale studies.

There are only a few large-scale studies via paper-and-pencil tests available (Even & Tirosh, 1995; Schmelzing et al., 2013; Rowan et al., 2001), especially in the field of physics (Etkina, 2010). To gain an insight into the methodology of paper-and-pencil questionnaire, related studies were classified into two groups and specifically reviewed as follows.

Earlier attempts to examine PCK (knowledge of students' learning difficulties as a crucial part) with paper-and-pencil instruments were made in field of mathematics (Even & Tirosh, 1995; Hill, Ball & Schilling, 2008; Etkina, 2010; Stacey et al., 2001; Isiksal & Cakiroglu, 2011). The tests consisted of subject-matter problems and open-ended questions about students or teaching strategies. The open-ended questions often involved what misconceptions students might possess, why students had such confusion when solving particular problems, or further questions about how to help students overcome these difficulties (Even & Tirosh, 1995; Stacey et al., 2001). Similar methodology has been used recently in the fields of science (Etkina, 2010) as well as mathematics (Isiksal & Cakiroglu, 2011).

Instead of simply presenting problems, several researchers developed more complex questionnaire items by means of constructing scenarios. Some set up classroom scenarios. The exploratory study conducted by Rowan et al. (Rowan et al., 2001) measured knowledge of student thinking reliably using classroom scenarios and four-point Likert items. Schmelzing et al. (Schmelzing et al., 2013) developed 15 open-ended items with scenarios of teaching biology. The items asked participants to list students' preconceptions and misconceptions, which would be justified as valid if they might be in accord with the findings of the video-observations and interview studies with students and teachers or if they might be backed up by literature.

Some exploited problem-solving scenarios. Nathan and Petrosino (Nathan & Petrosino, 2003) designed a ranking task and the accuracy of participants' predictions was determined by comparing the predictions with students' actual performances. Hill et al. (Hill, Ball & Schilling, 2008) focused on explanations or diagnosis of students' errors and interpretations of students' productions. Manizade and Mason (Manizade & Mason, 2011) also created a test using the item with a geometry problem, hypothetical student solutions, and a series of open-ended questions.

According to the review above, the ability to predict students' ideas or performances is commonly seen as an indicator to measure teachers' knowledge of students' difficulties and misconceptions. In another study, this competency is also recognized as a key difference between novice science teachers and expert science teachers (Meyer, 2004). These indicated a need to concentrate on teachers' predictions of students.

The present study

Most previous researchers tried to expand pre-service teachers' understanding of students through teaching practices, whereas pre-service teachers always did not have many opportunities to teach. We noticed that well-specified descriptions of pre-service teachers' misunderstanding about students could help to modify their thinking about students efficiently through preparation courses. Furthermore, in order to detect a common trend, large-scale studies via paper-and-pencil would be more suitable. However, there are few similar attempts in science education field.

Taken all above into account, the present study aims to find out pre-service science teachers' fallacy of student misconceptions and difficulties. We chose to focus on Newton's Third Law (NTL), not only because of its common existence of student difficulties in this topic, but also because we could compare our measure of pre-service teacher data with student performance data, as reported by Zhou et al. (Zhou, Zhang, & Xiao, 2014). Our previous study (Zhou, Zhang, & Xiao, 2014) had addressed junior secondary school and senior high school students' general difficulties in NTL, especially in gravity interaction contexts. The present study is the extension of our previous research.

This study addresses the following questions: for junior secondary school and senior high school students, do pre-service science teachers correctly predict (a) student problem-solving ability, (b) the misconceptions students are more likely to have, and (c) student learning difficulties.

METHODS

Sample

All participants (N=143) were pre-service science teachers (major in physics) who enrolled in a normal university in China. The data for this study were collected at the end of 2012-13 academic year. All participants had taken all their physics courses, such as Mechanics, Electricity and Magnetism, Optics, Thermodynamics, and Quantum Physics during their second year. Almost all participants had finished teacher education programs related to physics teaching and learning, include theory study, i.e. Curriculum and Instruction Course, and pedagogical training, i.e. Microteaching.

Instrument

A paper-and-pencil questionnaire comprised of three items within a problem-solving scenario was designed. The questionnaire stem provided context information about two imaginary learning groups (of a certain grade belonging to a school at a certain level), the topic of action and reaction (i.e. NTL), the learning status of students, and the problem related to NTL. Participants were asked to predict the percentage of each group that chose each option in the problem presented. Besides, they were required to analyze student learning difficulties according to their prediction (See Figure 1).

Three problems related to NTL were selected from the instrument in our previous study [22]. That instrument was given to students at different grade levels to investigate their actual misconceptions and difficulties in NTL. The description about the selected problems is shown in Table 1.

Data analysis

We would like to compare the differences between the percentage predicted by pre-service teachers and the actual percentage of students who choose an option. We considered this kind of differences as prediction error. Using a standard that does not expect an exact match, we set up our own criteria: Predictions would be considered unacceptable if the prediction error is more than 20%. We reason that a qualified teacher should not overlook students' learning difficulties or misconceptions more than 20% of the class. By this criteria, we determine predictions as acceptable (-20%≤ prediction error ≤ 20%), over-predicted (prediction error > 20%) or under-predicted (prediction error < -20%). In particular, the prediction error of each option is defined:

Predition error=Ptea - Pstu (*)

Ptea : percentage predicted by pre-service teachers of students choosing certain option

Pstu : actual percentage of students choosing certain option

To compare pre-service teachers' responses and student actual performance, we

Imagine two classes belonging to a middle-level school, one in the 8th grade and the other in the 10th grade. Students in both classes have just learned the knowledge of action and reaction.

Please predict the percentage of each class that chose each option in the problem: *What is the reaction force of the gravitational force acting on the ceiling lamp (see Fig. a)?*

Options	Percentage of each class	
	Grade 8	Grade 10
a. The attraction of the lamp on the earth		
b. The pull of the string on the lamp		
c. Other incorrect responses		

***Fig. a.* A ceiling lamp suspended from a string**

According to your prediction, please analyze the difficulties students may have in this problem.

Figure 1. Item sample for measuring pre-service science teachers' knowledge of student learning difficulties

Table 1. Description about three items in the questionnaire

Item	Problem contexts	Number of objects	Situations
1	A ceiling lamp suspended from a string	2 (ceiling lamp-string)	Gravity associated interaction
2	A floating wood pressed by hand	3 (wood-water-hand)	
3	A collision between a small and a big car, the other collision between two identical cars	2 (car-car)	Non-gravity associated interaction

firstly calculated the percentage of each option chosen by students. Secondly, we got each pre-service teacher's prediction error using formula (*). Thirdly, we obtained the proportion of acceptable prediction (-20%≤ prediction error ≤ 20%), over-prediction (prediction error > 20%) or under-prediction (prediction error < -20%), and also the frequency distribution describing pre-service teachers' prediction trend.

For clearer analysis, the data were divided into two categories as follows: (a) the percentage of correct responses, which indicated student problem-solving ability, and (b) the percentage of students choosing each incorrect option, which implied the likely misconceptions.

An open-ended question was set to ask pre-service teachers to give explanations for student learning difficulties in each problem and in-depth interviews were conducted to learn more about pre-service teachers' knowledge about students' learning difficulties.

FINDINGS

Pre-service teachers' predictions of student performance on problem-solving

Insight into the contrast between pre-service teachers' predictions and student data in each problem was gained by looking into the frequency distributions of predictions of each problem. Each pre-service science teacher's prediction of the three problems was determined as acceptable (-20% ≤ prediction error ≤ 20%), over-predicted (prediction error > 20%) or under-predicted (prediction error < -20%).

A. Predictions of student problem-solving ability

Figure 2 shows frequency distributions of predictions concerning correct responses, which indicate pre-service teacher's predictions about student problem-solving ability of NTL.

Pre-service science teachers tended to over-predict 8th grade student problem-solving ability of NTL in all the problems. Almost no 8th grade students' performances were over-predicted. Most pre-service science teachers failed to realize that identifying the reaction of the gravitational force was of great difficult for 8th grade students. Specifically, 56.4% of pre-service science teachers considered that 8th grade students possessed problem-solving ability in the situation of item 1 situated in gravity interaction context.

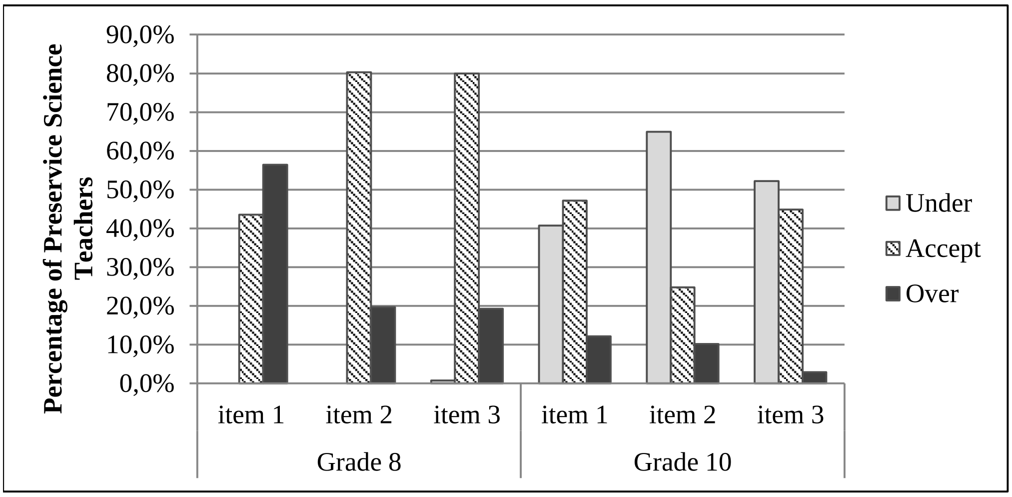

Figure 2. Frequency distributions of predictions concerning correct responses to each problem

10th grade students' performances were commonly under-predicted by pre-service science teachers in all the problems (Fig. 2), 40.7%, 52.2%, and 65.0% for item 1, item 2 and item 3 separately. The greatest contrast lied in item 2 situated in gravity interaction context. Student performance in solving item 2 was under-predicted by most pre-service science teachers while only a handful of predictions (24.8%) were within acceptable range.

B. Predictions of misconceptions

Frequency distributions of predictions concerning incorrect options were also examined and three particular options were incorrectly predicted by the majority of pre-service teachers: option B on item 1, option D on item 2 and option C on item 3.

For the problems situated in gravity associated interactions (See Figure 3), option B on item 1 and option D on item 2 were incorrectly predicted by most pre-service teachers. Specifically, in the problem context of item 1 (Fig.3(a)), option B stated that the pull of the string on the lamp was the reaction force of the gravitational force acting on the ceiling lamp. In the context of item 2 (Fig.3(b)) , option D indicated that the vector sum of the gravitational force acting on the wood and the tension force from the hand to the wood was the reaction force of the buoyant force on the wood. These two options revealed the misconception that "action and reaction forces are a pair of forces that balanced each other". For the problem situated in non-gravity associated interaction, option C on item 3 revealed the misconception that "the larger the effect of a force, the larger the magnitude of a force".

Distributions that indicate pre-service science teachers' incorrect predictions of student misconceptions are presented in Figure 4.

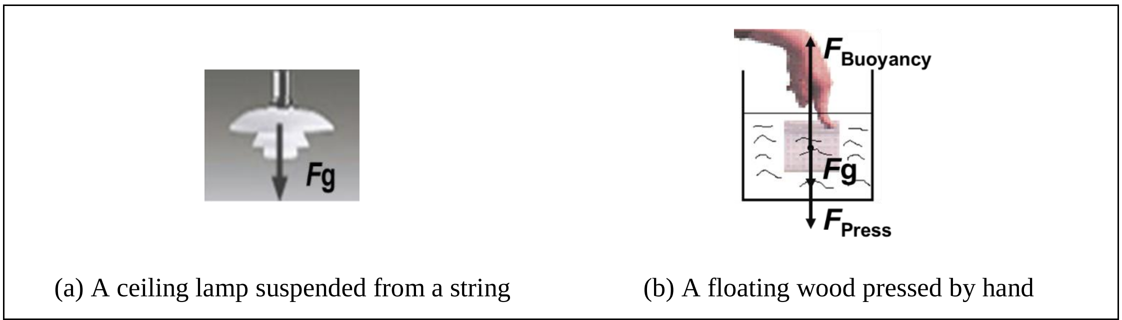

Figure 3. Problems situated in gravity associated interaction

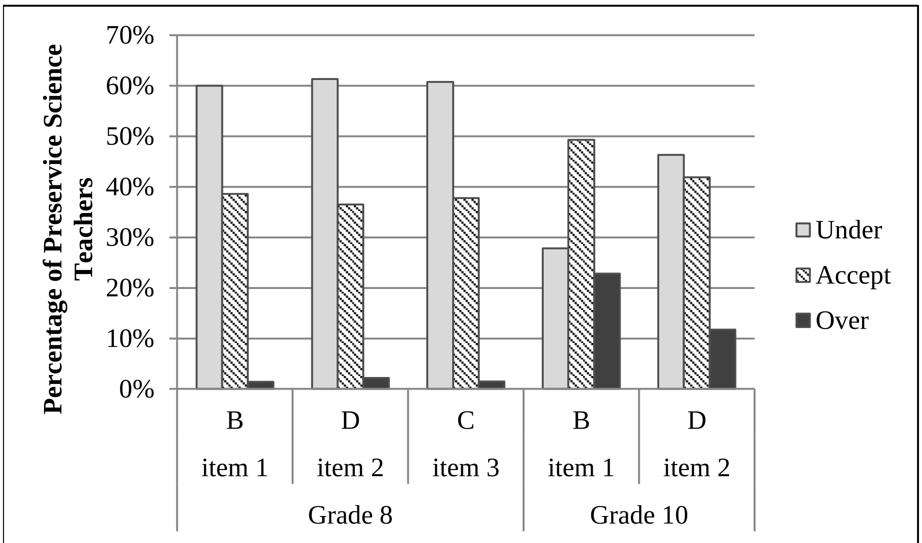

Figure 4. Frequency distributions of predictions concerning particular incorrect responses

For predictions about the 8th grade students, pre-service teachers showed consistent prediction error in both gravity and non-gravity associated interactions. About 60% of predictions of each option were under-predictions and nearly 0% of predictions were over-predictions. It indicated that the majority of pre-service teachers failed to realize that the 8th grade students would commonly regard action and reaction forces as a pair of forces that balanced each other. Pre-service teachers also under-predicted the common existence of student misunderstanding that "the larger the effect of a force, the larger the magnitude of a force".

While for predictions about the 10th grade students, half of the predictions of either option were unacceptable, among which there were a number of over-predictions and under-predictions. As shown by our previous research (Zhou, Zhang, & Xiao, 2014), the main misconception of the 10th grade students was that "action and reaction forces are a pair of forces that balanced each other", which was revealed in problems situated in gravity associated interactions. But quite a number of pre-service teachers (51% of item 1 and 58% of item 2) might overlook or overemphasize this misunderstanding among the 10th grade students.

Pre-service teachers' analysis of student learning difficulties

To deeply probe pre-service science teachers' understandings about student difficulties, an open-ended question was set to ask pre-service teachers to give explanations for student difficulties in each problem. Furthermore, 40 pre-service science teachers were asked to generate some teaching strategies to help students overcome the difficulties in the later interview.

For the analysis of the open-ended question, pre-service science teachers' responses were classified into five different categories, according to the accuracy and logicality of the answers: 1. Pre-service teachers realized that students might not comprehend the concept of the action and reaction forces, but without specifying and explaining what it was; 2. pre-service teachers considered that students were confused with interaction forces and balanced forces, however, the responses did not drill down into more details about where the confusion lied; 3. pre-service teachers thought that students solved problems based on the daily experience rather than the law of action and reaction forces; 4. pre-service teachers suggested that students might make incorrect answers, because they did not construct appropriate free-body diagrams of forces; 5. pre-service teachers argued that students might make a conclusion that interaction forces were related to the weight of the objects or the friction of the ground; 6. other unrelated responses. Regarding to the analysis of the interviews, our purpose was to learn whether pre-service science teachers could put forward specific and feasible instructional strategies on students' misconceptions of interaction forces. Therefore, each strategy in the interviews was labeled as valid or invalid strategy. For instance, "provide conditions for students to distinguish the body exerting a force and the body acted on by this force" was identified as a valid strategy. While, "students could make sense by doing more exercises and thinking it over again and again" was considered as an invalid strategy.

A common learning difficulty was to distinguish interaction forces and balanced forces in gravity associated interaction situations (Zhou, Zhang, & Xiao, 2014). Only a few pre-service teachers were able to find out student learning difficulties on NTL concerning gravity interactions. Take item 2 as an example, only 29.3% pre-service teachers gave satisfactory explanations of student difficulties. Among them, some (14.2%) stated that "student difficulty in recognizing action and reaction forces was that they confused 'interaction forces' with 'balanced forces' ". More explicitly, some (15.1%) pointed out that "students always forgot the essential element of NTL that 'action and reaction forces act on two interacting bodies, but not a single body' ".

Most pre-service teachers who gave the answers above could generate effective teaching strategies in the later interview. For example, “provide conditions for students to distinguish the body exerting a force and the body acted on by this force”; or “ask students to compare the concept of Balanced Forces with another concept of Action and Reaction Forces”; or “make some examples, e.g., a horse pulling a cart, to help students make sense of action and reaction forces, especially the key point about a third-law force pair acting on two interacting bodies”.

More pre-service teachers (32.1%) simply pointed out that students did not grasp NTL, without further analysis of how students might misunderstand the law, such as, “students are not good at NTL”, or “students have a week understanding of the NTL”, or “students lacks of the awareness of NTL”, and so on. In the later interview, some of these pre-service teachers always thought that “students could make sense by doing more exercises and thinking it over again and again”. Such teaching strategies were inefficient. There were other invalid teaching strategies, e.g., “teachers are required to clearly point out the object, and show free-body diagrams of the forces to students” and “teachers should train students to learn the scenario and create the physics model”. Those strategies were not targeted with the scenario in the given problem. Nevertheless, a large proportion of pre-service teachers (35.7%) gave unrelated answers. For instance, “students are not smart enough”, “students do not learn seriously”, “students are not strong with abstract thought”, “students are poor in cognition”, and “students have weak content knowledge”.

For the problem in non-gravity associated interaction situation, a larger proportion of pre-service teachers (36.2%) could find that it was difficult for students to distinguish the magnitude of force and the effect of force. As pre-service teachers pointed out, students might think “the larger the effect of a force, the larger the magnitude of a force”, or “objects have different magnitudes of the forces because of the different effects of the force”, or “when the cars have different extents of the damage, they have different magnitudes of the forces”. However, the data were also frustrating as the majority of pre-service teachers did not know it. Most pre-service teachers (40.4%) also simply pointed out that students did not thoroughly understand NTL. Some (5.3%) considered analyzing forces as the main difficulty. One pre-service science teacher stated that “students have learning difficulty as they could not construct the free-body diagrams according to the Newton’s First Law”. The rest of pre-service teachers (18.1%) gave unrelated answers.

DISCUSSIONS

Our results presented a noticeable contrast between pre-service science teachers’ predictions and student actual performance, in line with some research findings in other contexts (Nathan & Petrosino, 2003).

Potentially, the most worrying result occurred in pre-service teacher’s obvious trend of under-predictions about 10th graders’ problem-solving ability of NTL. It indicated a tendency for pre-service science teachers to be pessimistic about 10th grade students’ problem-solving ability. Teachers’ under-evaluations of student ability might lead to inappropriate teaching objectives. Pre-service science teachers should raise their expectations of senior high school student ability.

The present study raised the issue of pre-service science teachers’ blind spots about students. Two common student misconceptions were “the larger the effect of a force, the larger the magnitude of a force” and “the larger the effect of a force, the larger the magnitude of a force” in NTL concerning gravity and non-gravity associated interactions. However, the existence of these two misconceptions was neglected by most pre-service science teachers. Our findings support previous studies where teachers are found to have unawareness of students' misconceptions which they have learned (Berg & Brouwer, 1991; Hashweh, 1987). More explicitly, as another research reported, pre-service teachers tended to make incorrect judgments about students' likely misconceptions (Halim & Meerah, 2002). It seems that there is a need to help pre-service science teachers be aware of their own misunderstandings about students.

More importance should be attached to the information about student learning difficulties. In this study, the majority of pre-service science teachers knew little about student learning difficulties in NTL, given that their analyses of student learning difficulties were vague or unrelated. We also found in the later interview that those who could gIve explicit explanations of student learning difficulties in NTL were more likely to generate effective teaching strategies. While, those who are unaware of students' likely learning difficulties provided invalid strategies to enhance student learning. It may be deduced that pre-service teachers' knowledge of student learning difficulties may contribute to their teaching ability to some extent. It suggests that development of PCK is crucial for pre-service science teachers. Teacher training program needs to expose pre-service science teachers to student misconceptions with some special topics. In the view of some researchers, the value of PCK lies essentially in its relation with specific topics (Sperandeo-Mineo, Fazio, & Tarantino, 2006). Pre-service science teachers are encouraged to express their ideas about student learning difficulties on particular topics from a teaching perspective. For instance, pre-service science teachers are required to provide instructional design with teaching strategies on a certain topic. From the instructional design, it can be learned whether they could identify students' likely misconceptions on the topic and provide valid strategies. Then, forward amendments about pre-service science teachers' knowledge of student learning difficulties should be put by expert teachers. As pointed out in the previous researches, teachers need to be made aware of the teaching strategies that cope with student learning difficulties (Berg & Brouwer, 1991) and instructional strategies to overcome student learning difficulties could significantly add to the evolution of pre-service science teachers' PCK (Shulman, 1986 ; Halim & Meerah, 2002; Driel et al. 1998; Demirdogen, Aydin, & Tarkin, 2015).

CONCLUSIONS AND IMPLICATIONS

In this study, pre-service science teachers' predictions about student performance on problem-solving and learning difficulties did not always correspond with students' outcomes. First, pre-service science teacher underestimated the problem-solving ability of senior high school students. Second, most pre-service science teachers failed to recognize two misconceptions that were extensively common among junior secondary school students: the misconception that "action and reaction forces are a pair of forces that balanced each other" in the gravity associate interactions, and that "the larger the effect of a force, the larger the magnitude of a force" in the non-gravity associate interactions. As for senior high school students, pre-service science teachers falsely estimated (either over- or under-predicted) student misconceptions in the gravity associated interactions. Third, the majority of pre-service science teachers were not able to accurately spot student learning difficulties: distinguishing interaction forces and balanced forces in gravity associated interaction situations, and discriminating between the magnitude of a force and the effect of a force in the non-gravity associated interaction situation.

This study also holds implications for future researches about pre-service science teachers' knowledge of student difficulties: (a) pre-service teachers' erroneous expectations of student misconceptions in diverse science topics, (b) the fallacy of pre-service teachers' reasoning about student difficulties, such as what makes it difficult for students in different grades, and (c) the effects of varied teaching strategies on improving or rectifying pre-service science teachers' understanding of students in these topics. Such researches are anticipated to contribute to enhancing pre-service teachers' preparation for teaching science.

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REFERENCES

Berg, T., & Brouwer, W. (1991). Teacher awareness of student alternate conception s about rotational motion and gravity. *Journal of Research in Science Teaching, 28*, 3-18. doi: 10.1002/tea.3660280103

De Jong, O. (2000). The Teacher Trainer as Researcher: Exploring the initial pedagogical content concerns of prospective science teachers. *European Journal of Teacher Education, 23*(2), 127-137. doi: 10.1080/713667273

De Jong, O. & van Driel, J. (2001). The development of prospective teachers' concerns about teaching chemistry topics at a macro-micro-symbolic interface. *Research in Science Education-Past, Present, and Future* (Springer Netherlands), pp 271-276. doi: 10.1007/0-306-47639-8_37

Demirdogen, B., Aydin, S. & Tarkin, A. (2015) Looking at the Mirror: A Self-Study of Science Teacher Educators' PCK for Teaching Teachers, *Eurasia Journal of Mathematics, Science and Technology Education, 11*(2), 189-205. doi: 10.12973/eurasia.2015.1315a

Depaepe, F., Verschaffel, L., & Kelchtermans, G. (2013). Pedagogical content knowledge: A systematic review of the way in which the concept has pervaded mathematics educational research. *Teaching and Teacher Education, 34*, 12-25. doi:10.1016/j.tate.2013.03.001

Erbas, A. K. (2004). Teachers' *knowledge of student thinking and their instructional practices in algebra* (Doctoral dissertation, University of Georgia).

Etkina, E. (2010). Pedagogical content knowledge ad preparation of high school physics teachers. *Physical Review Special Topics - Physics Education Research 6*, 020110. doi: 10.1103/physrevstper.6.020110

Even, R., & Tirosh, D. (1995). Subject-matter knowledge and knowledge about student as sources of teacher presentations of the subject-matter. *Educational Studies in Mathematics 29*, 1-20. doi: 10.1007/BF01273897

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.

Halim, L., & Meerah, S. M. M. (2002). Science trainee teachers' pedagogical content knowledge and its influence on physics teaching. *Research in Science & Technological Education, 20*(2), 215-225. doi:10.1080/0263514022000030462

Halim, L., Meerah, T. S. M., & Buang, N. A. (2010). Developing pre-service science teachers' pedagogical content knowledge through action research. *Procedia - Social and Behavioral Sciences, 9*, 507-511. doi:10.1016/j.sbspro.2010.12.188

Hanuscin, D. L. (2013). Critical Incident in the Development of Pedagogical Content Knowledge for Teaching the Nature of Science: A Prospective Elementary Teacher's Journey. *Journal of Science Teacher Education, 24*, 933-956. doi: 10.1007/s10972-013-9341-4

Hashweh, M. Z. (1987). Effects of subject matter knowledge in the teaching of biology and physics. *Teaching and Teacher Education, 3*, 109–120. doi: 10.1016/0742-051X(87)90012-6

Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. *Journal of Research in Science Teaching*, *49*(3), 333-362. doi: 10.1002/tea.21004

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education, 39*(4), 372-400.

Hill, H. C., Ball, D. L., Blunk, M.., Goffney, I. M. & Rowan, B. (2007). Validating the ecological assumption: The relationship of measure scores to classroom teaching and student learning. *Measurement, 5*(2-3), 107-118. doi: 10.1080/15366360701487138

Isiksal, M. & Cakiroglu, E. (2011). The nature of prospective mathematics teachers' pedagogical content knowledge: the case of multiplication of fraction *Journal of Mathematics Teacher Education, 14*, 213-230. doi:10.1007/s10857-010-9160-x

Kagan, D. M. (1990). Ways of evaluating teacher cognition: Inferences concerning the Goldilocks Principle. *Review of Educational Research, 60*(3), 419–469. doi: 10.3102/00346543060003419

Loughran, J., Milroy, P., Berry, A., Gunstone, R., & Mulhall, P. (2001). Documenting science teachers' pedagogical content knowledge through PaP-eRs. *Research in Science Education, 31*(2), 289-307. doi: 10.1023/A:1013124409567

Manizade, A. G. & Mason, M. M. (2011). Using Delphi methodology to design assessments of teachers' pedagogical content knowledge. *Educational Studies in Mathematics, 76*, 183-207. doi: 10.1007/s10649-010-9276-z

Meyer, H. (2004). Novice and expert teachers' conceptions of learners' prior knowledge. *Science Education*, *88*(6), 970-983. doi: 10.1002/sce.20006

Mulhall, P., Berry, A., & Loughran, J. (2003). Frameworks for representing science teachers' pedagogical content knowledge. *In Asia-Pacific Forum on Science Learning and Teaching,* *4*(2), 1-25. Retrieved from http://www.ied.edu.hk/apfslt/v4_issue2/mulhall/index.htm

Nathan, M. J. & Petrosino, A. (2003). Expert blind spot among pre-service teachers. *American Educational Research Journal*, *40*(4), 905-928

Park, S., and Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education,* 38, 261-284. doi:10.1007/s11165-007-9049-6

Park, S., Jang, J., Chen, Y., & Jung, J. (2011). Is pedagogical content knowledge (PCK) necessary for reformed science teaching? Evidence from an empirical study. *Research in Science Education, 41*, 254–260. doi: 10.1007/s11165-009-9163-8

Piburn, M., Sawada, D., Turley, J., Falconer, K., Benford, R., Bloom, I., & Judson, E. (2000). *Reformed teaching observation protocol (RTOP) reference manual* Tempe, Arizona: Arizona Collaborative for Excellence in the Preparation of Teachers.

Rowan, B., Schilling, S. G., Ball, D. L., & Miller, R. (2001). *Measuring teachers' pedagogical content knowledge in surveys: an exploratory study* (Ann Arbor: Consortium for Policy Research in Education, University of Pennsylvania) .

Schmelzing, S., van Driel, J. H., Jüttner, M., Brandenbusch, S., Sandmann, A., & Neuhaus, B. (2013). Development, evaluation, and validation of a paper-and-pencil test for measuring two components of biology teachers' pedagogical content knowledge concerning the "Cardiovascular System". *International Journal of Science and Mathematics Education., 11*, 1369-1390. doi: 10.1007/s10763-012-9384-6

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher, 15*(2), 4-14.

Sperandeo-Mineo, R. M., Fazio, C., & Tarantino, G. (2006). Pedagogical content knowledge development and pre-service physics teacher education: A case study. *Research in Science Education, 36*(3), 235-268. doi: 10.1007/s11165-005-9004-3

Stacey, K., Helme, S., Vicki, S., Baturo, A., Irwin, K., & Bana, J. (2001). Pre-service teachers' knowledge of difficulties in decimal numeration. *Journal of Mathematics Teacher Education, 4*, 205-225. doi: 10.1023/A:1011463205491

Van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*(6), 673-695. doi: 10.1002/(sici)1098-2736(199808)35:6<673::aid-tea5>3.0.co;2-j

Zhou, S., Zhang, C., & Xiao, H. (2015). Students' Understanding on Newton's Third Law in Identifying the Reaction Force in Gravity Interactions. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(3), 359-369. doi: 10.12973/eurasia.2015.1337a

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