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PRE-SERVICE SCIENCE TEACHERS' PREDICTIONS ON STUDENT LEARNING DIFFICULTIES IN THE DOMAIN OF MECHANICS

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Abstract. *The ability to predict students' ideas or performances is commonly recognized as an indicator to measure teachers' knowledge of student learning difficulties. This research focuses on identifying pre-service science teachers' knowledge of student learning difficulties on Mechanics, as well as comparing pre-service science teachers' predictions to student reasoning on the causes of their learning difficulties. The populations consist of 479 pre-service science teachers and 1,020 students taking physics as a separate science course. Two versions of the questionnaires are designed, with teacher- and student- oriented questions separately. From the results, inconsistencies are observed between two groups of populations. Pre-service science teachers either over- or under-predict student learning difficulties in some special domains. The results show that the physics content knowledge factor attracts great attention from both students and pre-service science teachers as the cause of student learning difficulties. The research results are important for pre-service science teachers to realize the gap between their own perspectives and students' actual learning difficulties.*

Keywords: *mechanics domain, students` knowledge, pre-service science teachers' predictions, student learning difficulties.*

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Introduction

In the field of science education, the issue of student misconceptions is a research hotspot and is highly emphasized by researchers. There is an open research question as to whether student misconceptions are considered as obstacles or resources (Larkin, 2012). As obstacles, student misconceptions indicate a barrier to student learning and would lead to a severe lack of learning interest to students. Baser and Geban (2007) stated that one of their research objectives was to "facilitate meaningful learning and avoid misconceptions" (p. 247). The perspective that student misconceptions are considered as obstacles stands in stark contrast to the point of view that misconceptions could be served as resources for teachers and students. As resources, misconceptions could be used for the motivation of deeper thinking and more meaningful learning to students and could be used for guiding instruction and pedagogy to teachers (Minstrell, 1982; Scott, Asoko, & Leach, 2007). To teach explicitly for conceptual change, student conceptions steer the teaching tasks and pedagogy of the classroom and are closely tied with formative assessment efforts (Wiliam, 1998; Black & Wiliam, 1998; Hewson et al., 2012). Students may make justification, comparison, and evaluation to their own ideas (e.g., Duckworth, 2006) and teachers may seek to leverage student ideas for further learning gains (e.g., Rivet & Krajcik, 2010).

It is widely recognized by science education researchers and practitioners that student conceptions play a significant role in science learning. In the United States, the National Science Teachers Association regularly publishes designed materials to teachers for helping K-12 science teachers assess their students' existing conceptions and integrate into their planning lessons some fashion (e.g., Keeley, Eberle, & Farrin, 2005). In some projects, student conceptions about scientific phenomena have been situated as central to the teaching and learning of science (Sadler, Coyle, Cook-Smith, & Miller, 2006; Schneps, 1997). In addition, for identifying student preconceptions of science, a comprehensive database of assessment items has recently been established as part of Project 2061 for use by teachers and researchers (American Association for the Advancement of Science [AAAS], 2011). Obviously, the effect of student learning is correlated with alternative conceptions, which indicates that instruction must be carefully designed to address existing conceptions (AAAS, 2011, p. 384).

Literature Review

Pre-service science teachers' knowledge of student learning difficulties

In previous research works, the issue that students have difficulty in physics classes has been underlined (Williams et al2003, Kessels et al2006, Gebbels et al. 2010). There is widespread agreement that science learning always builds upon students' existing ideas. Therefore, science teachers are required to possess knowledge of learners, e.g., student learning difficulties, to facilitate student learning (Shulman, 1986). Knowledge of students, as introduced by Shulman, 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). In the later studies, several analogue concepts include: 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 Pedagogical Content Knowledge (PCK) that deserves in-depth researches (Depaepe, Verschaffel & Kelchtermans, 2013; Manizade & Mason, 2011).

Much effort has been exerted to probe and enhance pre-service science teachers' understanding of student learning difficulties in previous researches (Depaepe, Verschaffel & Kelchtermans, 2013; Erbas, 2004; Even & Tirosh, 1995; Grossman, 1990; Hill, Ball & Schilling, 2008; Manizade & Mason, 2011; Park & Oliver, 2008; Schmelzing et al., 2013; Shulman, 1986). Researches on teachers' knowledge of students for different science topics have suggested that pre-service science teachers show little consideration for students and have poor knowledge of student learning difficulties. For example, only a small number of prospective secondary chemistry teachers would concern about student learning or difficulties 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). In a study of four experienced secondary science teachers described as "exemplary" by district administrators, Morrison and Lederman (2003) found that participants felt that it was important to learn what students had already known prior to instruction, but non-exemplary teachers would be even less likely to diagnose student ideas. Therefore, the authors concluded that pre-service teacher education had a role to play in preparing teachers to elicit and work with student preconceptions.

Why does pre-service science teachers' knowledge of students attract our concerns?

Oon and Subramaniam (2011) investigated the factors influencing the comprehension of physics and highlighted significant results. For instance, the results of their research reflected that from the point of view of teachers, students held the prejudice that physics subjects were too difficult and abstract to comprehend. Moreover, teachers also considered that students who were good at mathematics could understand physics concepts better.

Researchers (Davis, 2006) found that pre-service science teachers always "tend to focus on content and tend to sometimes view instruction as a transmission process". Lemberger et al. (1999) noted that transmissionist notions of teaching overwhelmingly occupied pre-service science teachers' conceptions about teaching. Also, as pointed out in some studies, correct or accurate information was forced on to students by pre-service science teachers (de Jong et al., 1998). Mellado (1997) noted that when student ideas were conflicted with science ideas, pre-service science teachers might take those ideas as mistakes to be corrected or eliminated.

It has been shown that higher quality instruction could be provided by teachers with strong content-specific pedagogical knowledge. Instructions are planned in the form of higher-level questions, accurate representations and explanations, and encouraging students to discuss the content and think about applications (Carlsen, 2010; Druva & Anderson, 1983; Hashweh, 1987; Hill & Ball, 2009). Thompson, Braaten, and Windschitl (2009) noted that pre-service secondary science teachers might have upper and lower anchors to learn about the role and value of student ideas, described as a learning progression. The lower anchor might be represented by an acceptance that students' ideas had a role to play in science learning. However, a more sophisticated view of student ideas was considered as the upper anchor, that pre-service secondary science teachers could successfully incorporate student ideas into their teaching (Meyer, 2004). In another study, the competency to predict students' ideas was also recognized as an indicator to distinguish science teachers from novice level to expert level.

Levin, Hammer, and Coffey (2009) described that student thinking was supposed to serve as the goal for pre-service teacher education, and they documented the experiences from interns in their teacher education program. Science teacher educators attempted to raise pre-service science teachers' concern about students thinking, as shown in a number of studies concentrating on pre-service science teachers' PCK development (Halim, Meerah & Buang, 2010; Heller et al., 2012; Hanuscin, 2013). Otero et al. found that teachers knowledgeable in both science and pedagogy were the key factor for successful science education in primary and secondary schools (Otero et al., 2006).

Research Focus

As reported in our previous research, the ability to predict students' ideas or performances was commonly recognized as an indicator to measure teachers' knowledge of students' difficulties and misconceptions (Zhou at al., 2016). In the analyses, there were some inconsistencies of pre-service science teachers' predictions and student learning difficulties in Newton's Third Law. More broadly, the purpose of this study is to investigate pre-service science teachers' concern about student learning difficulties extending the content coverage from Newton's Third Law to Mechanics. Another interest of the present research is to compare pre-service science teachers' predictions to student reasoning on the causes of their learning difficulties.

Methodology of Research

Background

In China, students are required to take physics courses each year from grade 8 through grade 12 by following a standard physics curriculum, as mentioned in the previous research (Zhang & Ding, 2013). In middle school at grade 8 and grade 9, students are instructed with basic physics concepts to describe, explain, and predict common physical phenomena. In high school from grade 10 to grade 12, students are taught to express physics ideas with mathematics, similar to algebra-based introductory physics in university. The content knowledge of Mechanics could be divided into two parts and Mechanics 1 is set for the 10th graders to study according to the standard of the compulsory physics curriculum requirement. It includes eight chapters covering: 1. Description of Motion, 2. Straight-line Motion with Constant Acceleration, 3. Force, 4. Newton's Laws, 5. Projectile Motion, 6. Circular Motion, 7. The Law of Universal Gravitation, and 8. Application, and Mechanical Energy and Energy Development. There are sixty-seven sections in total. The topic headlines and the subheadings of Mechanics 1 are given in Appendix.

Sixty-seven sections are labeled in order from one to sixty-seven in the booklet for the convenience of choices selected by students and pre-service science teachers. For instance, Inertial Reference Frame is labeled as No. 1 and Energy Development and Utilization is labeled as No. 67.

Research Design

As a means of identifying pre-service science teachers' knowledge of student difficulties on Mechanics 1, the assessment questions are designed to investigate four areas of the research: (1) student ideas about the most remarkable learning difficulties on Mechanics 1; (2) factors having an effect on student comprehension of Mechanics 1 from the point of view of students; (3) comparison between pre-service science teachers' predictions and students' actual learning difficulties on Mechanics 1; (4) differences between pre-service science teachers' predictions and students' expressions on the reasons affecting their understanding on Mechanics 1.

To address the research question regarding pre-service science teachers' understanding of student learning difficulties on Mechanics 1, the views from pre-service science teachers and students are respectively needed to be obtained in the assessments. For achieving the target, two versions of the questionnaires are designed, with teacher- and student- oriented questions separately. Both questionnaires are distributed with a booklet in order to remind readers of the content knowledge in Mechanics 1. In the booklet, 67 subheadings of Mechanics 1 in the compulsory physics curriculum are listed.

In the student-oriented questionnaire, one question is designed to ask students to choose the most difficult subjects among the given subheadings of Mechanics 1 in the booklet (see Appendix). Followed by the question, there is an open response field for students' explanations, which could be used for the deeper analysis of the reason

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why students have difficulty in each subject. To encourage students to positively write down their point of view, little hint is given to them. They can not only think about the subjective aspect with their personal reasons, but also take into account some objective factors, such as teaching approach, textbook contents setting and so on.

In order to obtain pre-service science teachers' knowledge of student learning difficulties on Mechanics 1, pre-service science teachers' predictions and students' actual learning difficulties are compared in the present research. A teacher-oriented questionnaire is designed based on questions in the student-oriented questionnaire. Firstly, pre-service science teachers are asked to predict the most difficult subjects from the listed sixty-seven subheadings in Mechanics 1 for students. Secondly, pre-service science teachers are required to offer an explanation of why students would choose the subject as the most difficult one from their own perspective. In contrast to students' responses, it could be explored to what extent pre-service science teachers understand student learning difficulties in Mechanics 1.

Data Collections

To explore the difference between pre-service science teachers' view on student learning difficulties and students' actual perceptions on their learning difficulties in Mechanics 1, two populations are studied in the present research. One sample consists of 1,020 high school students at grade 10 from five different provinces in China. All of them participate in the questionnaire before the final examination of the second semester. They all take physics as a separate science course and have finished the study of the content knowledge in the compulsory physics curriculum of Mechanics 1. The student population is chosen to explore the learning difficulties in the after-teaching procedure. The other sample, up to 479 pre-service science teachers, is randomly selected in South China Normal University to participate in the teacher-oriented questionnaire before the final examination. They have completed a series of pedagogical courses and are preparing to get the Teacher Certification.

Data Analysis

According to the collecting data from students' responses to the most difficult subject in the content knowledge of Mechanics 1, the frequency of each subject chosen by students is calculated. Then, the frequency distribution of all 67 subjects revealing student learning difficulties is analyzed. Meanwhile, another frequency distribution describing pre-service science teachers' prediction trend is also acquired from the data. By the comparison of these two frequency distributions, the difference could be found between pre-service science teachers' predictions and student actual learning difficulties. One of the research aims is to figure out the subjects which represent student learning difficulties but are misestimated by pre-service science teachers.

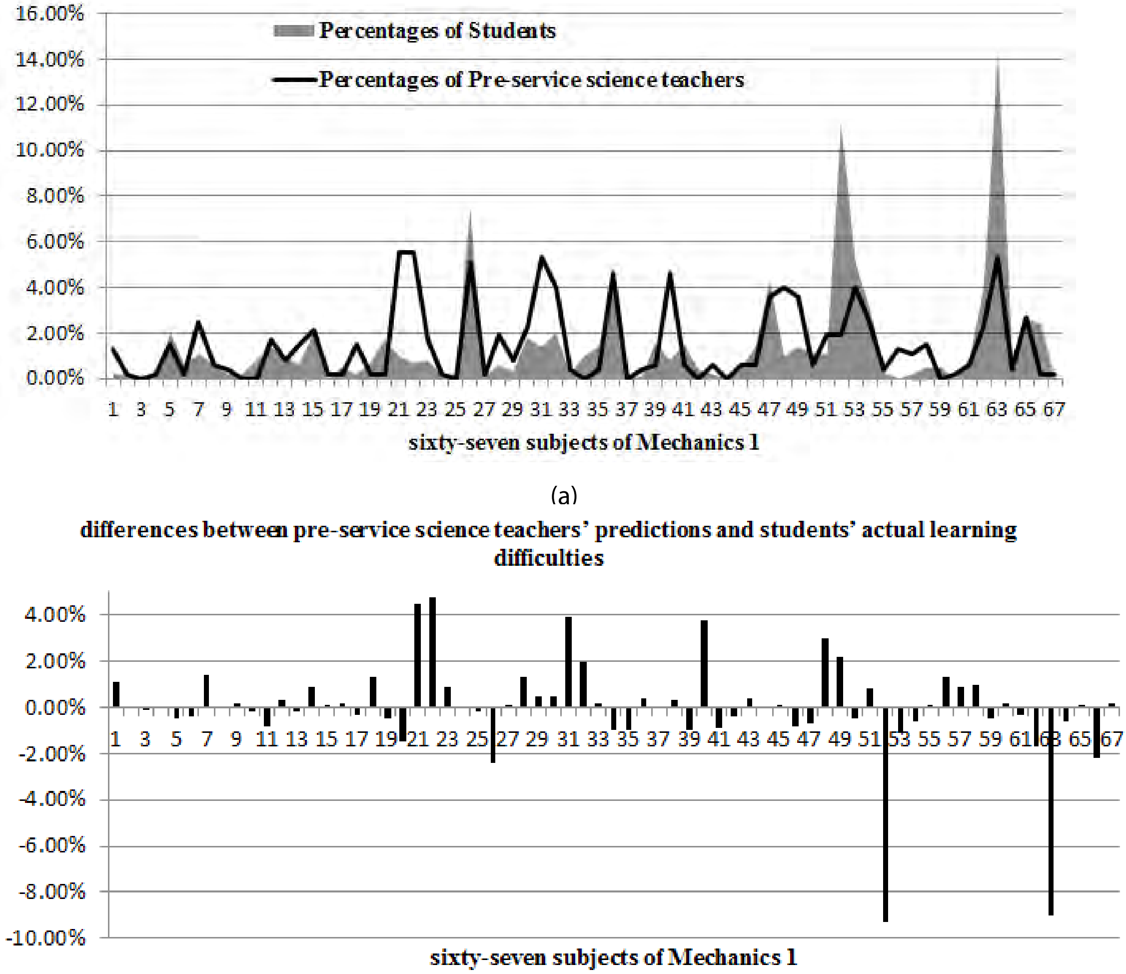
For analyzing the reasons for the choices, students' responses are classified into several categories in terms of subjective and objective factors. The percentage of each factor reasoned by students is calculated and compared with that of pre-service science teachers' predictions of student reasoning for their learning difficulties.

Results of Research

Comparison between Pre-service Science Teachers' Predictions and Student Actual Learning Difficulties

Figure 1 illustrates the frequency distributions of all 67 subjects revealing both pre-service science teachers' predictions and students' actual learning difficulties, and the difference between the two groups. The gray shadow in Fig.1 (a) shows students' actual perceptions about their learning difficulties based on the given 67 subjects in Mechanics 1. For each subject, the ordinate of the figure describes the percentage of students who consider it as the most difficult subject among all of the 67 subjects. From the gray shadow it could be seen that most of the subjects attract a small part of students (less than 2%) who choose one of them as the most difficult one in Mechanics 1. However, there are several sharp peaks on the curves for student learning difficulties, including Conservation of Mechanical Energy, Newton's Law of Universal Gravitation, Force Synthesis and Decomposition, Measurement of Planet Mass, with the percentages of 14.30%, 11.20%, 7.50%, 5.10% separately.

The black line in Fig.1 (a) reveals pre-service science teachers' predictions on student learning difficulties in Mechanics 1. The ordinate of the figure also provides the percentage of pre-service science teachers who predict the subject as the most learning difficulty for each subject. Compared to the students' curve with several high peaks, the distribution curve of pre-service science teachers' the prediction shows much smoother. Some subjects have a little higher percentage than others among these 67 subjects. These subjects are Frictional Forces, Static Frictional Forces, Overweight and Weightlessness, Conservation of Mechanical Energy, Force Synthesis and Decomposition, Motion Synthesis and Decomposition, Oblique Projectile Motion, Newton's Third Law, Centrifugal acceleration, and Measurement of Planet Mass, but none of them reaches 6%.



(a)

(b)

Figure 1. **(a) The frequency distributions of all 67 subjects revealing both pre-service science teachers' predictions and students' actual learning difficulties. (b) The distribution of percentages difference between pre-service science teachers' predictions and student actual learning difficulties.**

The next step is to compare predictions from pre-service science teachers about student learning difficulty among 67 subjects in Mechanics 1. There were a number of over-predictions and under-predictions (see Figure 1 (b)). Table 1 illustrates seven subjects with the greatest differences between two groups of populations. Among these seven subjects, the top two subjects with the difficulty levels underestimated by pre-service science teachers include Newton's Law of Universal Gravitation and Conservation of Mechanical Energy. Especially for Newton's Law of Universal Gravitation, 11.20% of students consider it as their learning difficulties, ranking the second in 67 subjects. But only 1.90% of pre-service science teachers are aware of the actual circumstance about students' perceptions on Newton's Law of Universal Gravitation. It contributes to be the greatest difference (-9.30%) between the two groups of populations. Besides, Conservation of Mechanical Energy is the hot subject for most of the students and pre-service science teachers who consider it as students' learning difficulty. It reaches 14.30% and rank the first in the percentages of students' choices and reaches 5.30% and rank the third in the percentages of pre-service science teachers' predictions. However, the difference reaches -9 percent between the two groups of populations.

Table 1. Seven subjects with the greatest differences between pre-service science teachers' predictions and students' actual learning difficulties. The difficulty levels of the top two subjects in the table are underestimated by pre-service science teachers. While, the difficulty levels of the bottom five subjects in the table are overestimated by pre-service science teachers.

Subjects in Mechanics 1	Percentages of Pre-service science teachers (P-PST)	Percentages of Students (P-ST)	Difference between P-PST and P-ST, %
(52) Newton's Law of Universal Gravitation	1.90 <21>*	11.20 <2>	-9.30
(63) Conservation of Mechanical Energy	5.30 <3>	14.30 <1>	-9.00
(22) Static Frictional Forces	5.50 <1>	0.70 <36>	4.80
(21) Frictional Forces	5.50 <1>	1.00 <27>	4.50
(31) Overweight and Weightlessness	5.30 <3>	1.40 <19>	3.90
(40) Oblique Projectile Motion	4.60 <6>	0.80 <34>	3.80
(48) Centrifugal acceleration	4.00 <8>	1.00 <27>	3.00

*<n> state the ranking sequence at the level of learning difficulties among 67 subjects from the viewpoints of students and pre-service science teachers.

On the contrary, the bottom five subjects, whose learning difficulty levels are overestimated by pre-service science teachers, include Static Frictional Forces, Frictional Forces, Overweight and Weightlessness, Oblique Projectile Motion, and Centrifugal acceleration (see Table 1). Although the prediction of pre-service science teachers on each subject is not over 6%, Static Frictional Forces, Frictional Forces, and Overweight and Weightlessness are the top three, with the percentages of 5.30%, 5.30%, and 5.50% respectively. However, much less students (0.70%, 1.00%, 1.40% respectively) find that these three subjects obstruct their understanding. In addition, 4.60% and 4.00% of pre-service science teachers make a prediction that Oblique Projectile Motion and Centrifugal acceleration are two learning difficulties for learners, but only 0.80% and 1.00% of students support pre-service science teachers' predictions for these two subjects respectively. These five subjects have a common point that students rank them in the middle at the level of learning difficulties among 67 subjects, but the percentages of pre-service science teachers' predictions rank the top. Pre-service science teachers overestimate the learning difficulty levels for these subjects.

Comparison between Pre-service Science Teachers' Predictions and Student Reasoning on the Causes of Learning Difficulties

The second aim of this study looks at pre-service science teachers' predictions to student reasoning on the causes of learning difficulties involving not only the subjective aspects but also the objective factors. Firstly, student responses to explanations on the causes related to their most difficult subject in Mechanics 1 are analyzed. Then attention is paid to pre-service science teachers' explanations on the factors that may cause student learning difficulties. All responses from both students and pre-service science teachers on the causes of the most difficult subjects are categorized into four aspects, which are the objective factor, the physics content knowledge factor, problem-solving ability factor and the subjective factor. Four aspects are specified as follows: (1) the objective factor concerns the pedagogical method or the textbook reading difficulties. (2) the physics content knowledge factor includes five related reasons for learning difficulties: incomprehension about free-body diagrams, inappropriate identification of formulas, lack of understanding about the content knowledge, content knowledge confusion, and incapable comprehensive application of content knowledge. (3) the problem-solving ability factor specifies the ability of extracting effective information from the context or the ability of mathematical computation. (4) the subjective factor emphasizes students' learning attitude or their personal ways of learning.

Table 2 presents the percentages of each factor resulting in student learning difficulties from both students' personal views and pre-service science teachers' predictions. The data are from valid responses of 982 students and 475 pre-service science teachers. As shown in table 2, the physics content knowledge factor attracts great attention from both students and pre-service science teachers, 81.0% and 88.6% for two groups separately, with the difference of 7.6%. The objective factor is not a hot concern for students that only 3.4% of them consider the pedagogical method or the textbook reading difficulties as the causes of their learning difficulties. The prediction of pre-service science teachers is very close to students' actual data, with the frequency of 17 (3.5%) for the objective factor. For the problem-solving ability factor, the proportion of students is 3.2% higher than that of pre-service science teachers' prediction. Besides, there are 5.0% of students concentrating on the subjective factor and considering that learning attitude and their personal ways of learning may hinder their learning effect in Mechanics 1. However, it is underestimated by most of the pre-service science teachers, and only two of them take into account students' learning attitude and personal ways of learning. The difference between two populations is -4.6%. A Chi-square statistic is used to test whether pre-service science teachers' prediction is consistent with students' actual reasoning on four factors resulting in their learning difficulties (see Table 2). The statistical value (χ^2=24.85, df=3, p < .001) indicates that there is inconsistency between pre-service science teachers' prediction and student reasoning on the causes of learning difficulties in Mechanics 1. A statistically significant difference is found for the two populations at 0.05 significance level. The analysis provides another strong support to the previous research (Zhou at al., 2016).

Table 2. Pre-service science teachers' predictions and students' actual views on the causes of learning difficulties in Mechanics 1, and the Chi-square result on the difference between pre-service science teachers' predictions and students' actual reasoning on the causes of their learning difficulties within four categories.

Categories	Specifying the causes of **learning difficulties**	Frequency of Pre-service science teachers (F-PST)		Frequency of Students (F-ST)		Difference between F-PST and F-ST	Pearson Chi-square	df	p-value
The objective factor	Pedagogical method	14 (2.9%)	3.5%	15 (1.5%)	3.4%	1.4%	24.85	3	p < .001
	Textbook reading difficulties	3 (0.6%)		19 (1.9%)		-1.3%			
Physics content knowledge factor	Incomprehension about free-body diagrams	147 (30.9%)	88.6%	220 (22.4%)	81.0%	8.5%			
	Inappropriate identification of formulas	43 (9.1%)		125 (12.7%)		-3.7%			
	Lack of understanding about the content knowledge	93 (19.6%)		176 (17.9%)		1.7%			
	Content knowledge confusion	59 (12.4%)		75 (7.6%)		4.8%			
	Incapable comprehensive ap-plication of content knowledge	79 (16.6%)		199 (20.3%)		-3.6%			
The problem-solving ability factor	Exacting effective information from the context	19 (4.0%)	7.4%	66 (6.7%)	10.6%	-2.7%			
	Mathematical computation	16 (3.4%)		38 (3.9%)		-0.5%			
The subjective factor	Learning attitude and personal ways of learning	2 (0.4%)	0.4%	49 (5.0%)	5.0%	-4.6%			
Total frequencies		475		982					

Then, the analysis focuses on the five specific aspects of the physics content knowledge factor, which performs a core role in all four factors resulting in student learning difficulties. The difference between students' actual reasoning and pre-service science teachers' predictions is reflected in variations of the overall frequency proportions, which shows a 7.6% difference (88.6% for PST and 81.0% for ST) between two groups. Among students' reasoning on the causes of their learning difficulties in the physics content knowledge factor, three sub-factors which are significantly concerned include incomprehension about free-body diagrams (22.4%), lack of understanding about the content knowledge (17.9%), and incapable comprehensive application of content knowledge (20.3%). Another two sub-factors also possess high percentages, with 12.7% for the factor of inappropriate identification of formulas, and 7.6% for the other factor of content knowledge confusion. From pre-service science teachers' predictions, among the five specific aspects involved in the physics content knowledge factor, the prediction of incomprehension about free-body diagrams occupies the highest proportion of 30.9%. It suggests that pre-service science teachers have positive understanding about the significant learning difficulty of free-body diagrams. However, their frequency proportion (30.9%) of predictions is obviously higher than that of students (22.4%), with the difference of 8.5%, which contributes the most significant difference in all of the causes of learning difficulties. For the other four aspects of the physics content knowledge factor, the differences between two populations seem small, -3.7%, 1.7%, 4.8% and -3.6% respectively for inappropriate identification of formulas, lack of understanding about the content knowledge, content knowledge confusion and incapable comprehensive application of content knowledge.

Table 3. Chi-square result on the difference between pre-service science teachers' predictions and students' actual reasoning on five specific aspects of the physics content knowledge factor.

	Frequency of Pre-service science teachers (F-PST)	Frequency of Students (F-ST)	Pearson Chi-square	df	p-value
Incomprehension about free-body diagrams	147	220	20.80	4	p < .001
Inappropriate identification of formulas	43	125			
Lack of understanding about the content knowledge	93	176			
Content knowledge confusion	59	75			
Incapable comprehensive application of content knowledge	79	199			
Total frequencies	421	795			

Analysis using Chi-square statistic in Table 3 reveals a significant difference between pre-service science teachers' predictions and students' reasoning on five aspects of the physics content knowledge factor that cause their learning difficulties in Mechanics 1 (χ^2=20.80, df=4, p < .001).

Discussion

This research is an extension of the previous research to identify the inconsistency of pre-service science teachers' predictions and student learning difficulties (Zhou at al., 2016). The study not only extends the content coverage from Newton's Third Law to the broader content knowledge of Mechanics 1, but also compares pre-service science teachers' predictions to student reasoning on the causes of learning difficulties. To summarize the above findings, inconsistencies are observed between two groups of populations.

The Difference of the Knowledge Reserve between Two Groups of Populations

From the above analysis, Newton's Law of Universal Gravitation and Conservation of Mechanical Energy are two main knowledge topics beyond students' understanding in Mechanics 1, with the highest percentages of school students voting for this point of view. For Newton's Law of Universal Gravitation, plenty of students explain that they are confused with Gravitational Force, Weight and Centripetal Force. Students perform worse when the problem needs to be figured out combining Gravitational Force with Linear velocity, Angular velocity and Period. They are usually hampered by the lack of comprehensive application of Newton's Law of Universal Gravitation and other related content knowledge. For Conservation of Mechanical Energy, the explanation of learning difficulties with the highest frequency is the conservation of mechanical energy constraints. It is difficult for students to figure out the forces which could achieve the conservation of mechanical energy. Students are also confused with three types of conservations: conservation of momentum, conservation of mechanical energy, and conservation of energy. However, they are underestimated by a great number of pre-service science teachers, who rarely consider Newton's Law of Universal Gravitation and Conservation of Mechanical Energy as the difficult topics for students to learn. In the courses of general physics in Chinese universities, Newton's Law of Universal Gravitation and Conservation of Mechanical Energy are two significant modules of the content knowledge. Pre-service physics teachers receive deeper instructions in university and possess richer knowledge reserve than high school students on these two topics (Flores, Kanim, & Kautz, 2004), so that many of them rarely choose these two topics as difficult content knowledge in our test. On the other side, for some content knowledge, such as Static Frictional Forces, Frictional Forces, and Overweight and Weightlessness, very few high school students learn with difficulty and vote for them as difficult subjects. On the contrary, there are the top of three content knowledge points that pre-service science teachers select as student learning difficulties. Some pre-service science teachers state that they have forgotten this content knowledge over time, even though the knowledge is easy to learn when they are taught. Therefore, memory loss of knowledge is one of the reasons that prevent pre-service science teachers from accurately predicting students' learning difficulties.

Discussion about Viewpoints on Four Causes of Students' Learning Difficulties between Two Groups of Populations

In this research, the second aim looks at pre-service science teachers' predictions on student reasoning about the causes of learning difficulties involving four factors, which are the objective factor, physics content knowledge factor, the problem-solving ability factor and the subjective aspect. The data analysis shows that both students and pre-service science teachers' predictions concentrate on the second factor about the comprehension and application of physics content knowledge. This factor attracts 81.0% and 88.6% for students and pre-service science teachers separately. The other three factors attract much less attention from both two groups of populations. The incomprehension and incapable application of physics content knowledge, which easily runs through students' mind when they think about their learning difficulties, could be derived from other three factors of learning difficulties. For instance, in the objective factor, textbook reading difficulty could directly lead to incomprehension about the content knowledge. While, if the pedagogical method does not best fit students' needs, it would also bring about incomprehension and incapable application of physics content knowledge. But both populations do not pay much attention to the factor of pedagogical method. It is probably due to the traditional reception teaching style in China classrooms, where students almost accept all but refute none of what they are taught. For another factor of the problem-solving ability, both students and pre-service science teachers do not consider that mathematical computation obstructs their learning of physics, because most students in China are good at calculation and computing. Besides, about 5.0% of students attribute their poor performances of learning physics to their own negative learning attitude, which has been reported in the previous literature (Zhang & Ding, 2013). While, almost all of the pre-service science teachers do not differentiate the beliefs about student learning from their own learning and ignore the factor in the subjective aspect (Brauer & Wilde, 2016). Supposing that the problem of students' poor learning attitude is unvalued by pre-service teachers, students need to take a correct attitude towards learning.

Specify Perspectives on the Physics Content Knowledge Factor of Students' Learning Difficulties between Two Groups of Populations

The physics content knowledge factor which is the major reason for both students and pre-service science teachers, includes five related aspects for learning difficulties: incomprehension about free-body diagrams, inappropriate identification of formulas, lack of understanding about the content knowledge, content knowledge confusion, and incapable comprehensive application of content knowledge. Among them, incomprehension about free-body diagrams occupies the significant position. In China, although teachers spend a lot of time to instruct the knowledge of free-body diagrams and students receive many related exercises, students (22.4%) feel frustrated at constructing and analyzing free-body diagrams. Surprisingly, a greater number of pre-service science teachers (30.9%) predict that students would take free-body diagrams as the significant learning difficulty. Obviously, pre-service science teachers excessively emphasize the significant learning difficulty of free-body diagrams. Possibly, constructing free-body diagrams seemed to pose a stumbling block when those pre-service science teachers studied force and motion in high school (Hinrichs, 2005). They received many teachings and did a lot of exercises on the free-body diagrams. Therefore, they believe it must be the major learning difficulty for students. However, the prediction of pre-service science teachers deviates far from students' actual data. If pre-service science teachers fail to realize the deviation of their prediction, they will still overemphasize the teaching of free-body diagrams when they become physics teachers in the upcoming future. Besides, 12.7% students are stuck with inappropriate identification of formulas when solving problems related to Mechanics 1. Pre-service science teachers have a similar proportion of about 10% to predict the learning difficulty of identification of formulas. What is interesting is that, in China teachers spend half the class time to teach problem-solving skills using formulas. Even so, a number of students could not identify an appropriate formula yet when solving problems (Kim & Pak, 2002). Fortunately, pre-service science teachers have realized the issue before they become to be teachers.

Conclusions

This research is an extension of the previous research to identify the inconsistency of pre-service science teachers' predictions and student learning difficulties. The study not only extends the content coverage from Newton's Third Law to the broader content knowledge of Mechanics 1, but also compares pre-service science teachers' predictions to student reasoning on the causes of learning difficulties. Inconsistencies between two groups of populations are observed from the results of this study. Some content knowledge as Newton's Law of Universal Gravitation and Conservation of Mechanical Energy are the top two subjects with the difficulty levels underestimated by pre-service science teachers. On the contrary, some subjects, whose learning difficulty levels are greatly overestimated by pre-service science teachers, include Static Frictional Forces, Frictional Forces, Overweight and Weightlessness, Oblique Projectile Motion, and Centrifugal acceleration. Then, the analysis of the responses from both students and pre-service science teachers on the causes of learning difficult subjects are categorized into four aspects, which are the objective factor, the physics content knowledge factor, problem-solving ability factor and the subjective factor. It is striking that the second factor about the comprehension and application of physics content knowledge attracts the most attention. The physics content knowledge factor is specified into five aspects: incomprehension about free-body diagrams, inappropriate identification of formulas, lack of understanding about the content knowledge, content knowledge confusion, and incapable comprehensive application of content knowledge. Chi-square statistic in Table 3 reveals a significant difference between pre-service science teachers' predictions and students' reasoning on the five aspects of the physics content knowledge factor (χ^2=20.80, df=4, p < .001).

The results of the research are important for pre-service science teachers to realize the gap between their own perspectives and students' actual learning difficulties and reasoning. With the help of these results, pre-service science teachers could attach enough importance to the improvement of their Pedagogical Content Knowledge. Furthermore, it suggests that the instruction and curriculum for pre-service science teachers training program should be better planned regarding specific targets and treatments on Pedagogical Content Knowledge. In addition, the result that physics content knowledge factor of learning difficulties on Mechanics 1 attracts much attention from two groups of populations, implies that students have a difficult feeling for the content. The result triggers the introspection about the compulsory physics curriculum establishment for secondary schools in China, where students are required to take physics courses each year from grade 8 through grade 12 under the school policy requirements. Subsequently, physics should be offered as an elective course for students who grow greatly interested in it. Last but not least, the research could enrich the literature and motivate a broader range of future research on pre-service science teachers' knowledge of student learning difficulties.

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APPENDIX

There are sixty-seven subjects of Mechanics 1 labeled in order from one to sixty-seven:

1. Description of Motion {(1) Inertial Reference Frame, (2) Particle, (3) Time Interval and Moment, (4) Displacement and Distance, (5) Use of Ticker Tape Timer, (6) Velocity and Speed, (7) Acceleration, (8) Uniform s-t Graph, (9) Uniform v-t Graph}.
2. Straight-line Motion with Constant Acceleration {(10) Free-fall Motion, (11) Gravitational acceleration, (12) the Law of Straight-line Motion with Constant Acceleration, (13) Constant Acceleration s-t Graph, (14) Constant Acceleration v-t Graph, (15) Driving Safety}.
3. Force {(16) Weight, (17) Elastic Deformation, (18) Elastic Force, (19) Normal Force, (20) Hooke's Law, (21) Frictional Forces, (22) Static Frictional Forces, (23) Kinetic Friction, (24) Elements and Graph of Force, (25) Equivalent Force, (26) Force Synthesis and Decomposition, (27) Concurrent Forces}.
4. Newton's Laws {(28) Newton's First Law, (29) Experiment on Factors Affecting Acceleration, (30) Newton's Second Law, (31) Overweight and Weightlessness, (32) Newton's Third Law, (33) System of Mechanical Units}.
5. Projectile Motion {(34) Projectile Motion, (35) Curvilinear Motion, (36) Motion Synthesis and Decomposition, (37) Vertically Downward Projectile Motion, (38) Vertically Upward Projectile Motion, (39) Horizontal Projectile Motion, (40) Oblique Projectile Motion}.
6. Circular Motion {(41) Uniform Circular Motion, (42) Linear velocity, (43) Angular velocity, (44) Period, (45) Linear Velocity and Angular Velocity, (46) Linear/Angular Velocity and Period, (47) Formula of Centripetal Force, (48) Centrifugal acceleration, (49) Centrifugal Motion, (50) Application of Centrifugal Motion}.
7. The Law of Universal Gravitation and Application {(51) Kepler's Three Laws, (52) Newton's Law of Universal Gravitation, (53) Measurement of Planet Mass, (54) Geostationary Satellite, (55) The First Cosmic Velocity}.
8. Mechanical Energy and Energy Development {(56) What is Work, (57) Positive and Negative Work, (58) Work and Energy, (59) Kinetic Energy, (60) Gravitational Potential Energy, (61) Elastic Potential Energy, (62) Work-Kinetic Energy Theorem, (63) Conservation of Mechanical Energy, (64) Experiment of Conservation of Mechanical Energy, (65) Law of Conservation of Energy, (66) Power, (67) Energy Development and Utilization}.

You are required to select the most difficult subject that is considered as your learning difficulty and choose the number from the booklet. Then offer the reason to your choice. You can think about the subjective aspect with your personal reasons, or some objective factors, such as teaching approach, Textbook contents setting and so on.

The most difficult one (   ) (*Please choose the number from the booklet*)

Please write down your reason:

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