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Examination the Knowledge of Student Understanding of Pre-Service Science Teachers on Heat and Temperature

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Abstract

The aim of this study is to examine the "Knowledge of Student Understanding (KSU)" of pre-service science teachers on "Heat and Temperature" topics. The sample of the research consists of 268 pre-service teachers studying at the 4th grade in the science teaching program of five different universities in Turkey. This research is a case study. The data of the study are collected with "Student Thinking Comprehension Test" and "Interview Form". "Scoring Rubrics for Knowledge of Student Thinking" and "Rubric for Analysis of Interviews" are used for the analysis of data. The data of the research are analyzed descriptively on the basis of these rubrics. The results of the study reveal that the vast majority of pre-service science teachers cannot effectively diagnose the student's inaccurate knowledge that emerges in solving specific problems in "Heat and Temperature" topics. In addition, it is shown that the majority of pre-service science teachers have a little knowledge regarding the difficulties and limitations of students while learning "Heat and Temperature" subjects. According to these results, the KSU of the pre-service science teachers in "Heat and Temperature" topics is insufficient in the process of starting their profession.

Introduction

Teachers and their professional knowledge are one of the main factors that determine the quality of education (Evens, Elen, Larmuseau, & Depaepe, 2018). The quality of teachers' professional knowledge depends largely on the education they receive in the prevocational period. Today, the policy about raising qualified teachers in the world is defined as the preparation of individuals who have a strong structure in terms of pedagogical content knowledge for all of their career (Wallace & Loughran, 2012). Today, the concept of "Pedagogical Content Knowledge (PCK)" stands out as the structure that represents the professional knowledge of a successful teacher. This definition, which draws attention to the professional knowledge structure of teachers, is first put forward by Shulman (1986). Shulman (1986) describes PCK as "*It is a blend of content and pedagogy to understand how specific topics, problems and situations are organized, presented and adapted to the different interests and abilities of students* (p.9)." However, many researchers have reinterpreted the PCK structure in time (Geddis, 1993; Gess-Newsome, 1999; Gess-Newsome, 2015; Grossman, 1990; Loughran, Berry & Mullhall, 2006; Magnusson, Krajcik & Borko, 1999; Mishra & Koehler, 2006; Park & Oliver, 2008a). When these researchers' definitions of PCK are reviewed, it is understood that a teacher emphasizes these teaching activities as the most effective learning by shaping them in line with the needs of students. However, it is understood that the PCK concept stands out much more in the field of science than other fields. It is seen that especially PCK modeling is mostly concentrated on the field of science. Within these models, various sub-informations about PCK is defined (Grossman, 1990; Gess-Newsome, 1999; Magnusson et al., 1999; Abell, 2007; Park & Oliver, 2008a). When these models are examined, "Knowledge of Student Understanding (KSU)" is seen as the most basic information area within the PCK, and it stands out in almost all PCK models. The KSU of the teachers in the field of science includes the variety of ideas that students adopt about a particular science subject, the misconceptions about that subject and their knowledge about what learning difficulties may be (Park & Oliver, 2008a).

Today's student-centered education approach requires pre-service science teachers to build a professional knowledge based on KSU in the preparation process before starting their profession (Hume & Berry, 2011; Nilsson & Loughran, 2012; Zhou & Xiao, 2018). It is found out that there are many different studies examining the professional knowledge structures of science and pre-service science teachers in the international literature. Among these studies, it is observed that especially the examinations of science teachers' knowledge of teaching strategies and their content knowledge become prominent (Aydeniz & Gurcay, 2018; Park, Suh & Seo, 2018; Zhou, Wang & Zhang, 2016). In addition, it is understood that a limited number of studies focus on the KSU of science and pre-service science teachers (Gess-Newsome et al., 2019; Nilsson & Karlsson, 2019; Park et al., 2018; Sanchez-Matamoros, Fernandez, & Llinares, 2015).

There is no doubt that a science teacher plays a key role in improving the learning outcomes of his students. This is because students' misconceptions in science are closely related to the way they teach (Hill, Loewenberg Ball, & Schilling, 2008; Rollnick, Bennett, Rhemtula, & Ndlovu, 2008). The correct understanding of scientific concepts and content at the secondary school level is necessary for them effectively to learn science at higher levels. For example, correctly learning "Heat and temperature" topics in secondary school makes easier to understand concepts and principles related to thermodynamics at high school and university (Yeo, Lim, Tan & Ong, 2020; Yeo et al., 2020). However, the research shows that many students at secondary school have difficulty in understanding heat and temperature subjects (Soeharto, Csapo, Sarimanah, Dewi & Sabri, 2019). Moreover, "Heat and Temperature" subjects in science are one of the most difficult subjects for students to learn (Bakirci & Ensari, 2018; Paik, Cho & Go, 2007; Sukarelawan, Jumadi & Rahman, 2019; Taqwa et al., 2019). Moreover, "Heat and temperature" subjects are one of the most common science subjects that students misunderstand (Doige & Day, 2012; Soeharto et al., 2019; Uzoglu & Akturk, 2019). The fact that the students have such learning problems about the subjects of "Heat and temperature" can be attributed to many factors. The most important of these factors is the KSU professional knowledge structures that teachers have to develop students' conceptual understanding of heat and temperature (Aydeniz & Gurcay, 2018).

It is known that as the professional experience of science teachers increases, their awareness of KSU increases (Yang, Liu & Gardella Jr, 2018). Nonetheless, before science teachers get involved in the professional process, their KSU structures should be developed (Kellner, Gullberg, Attorps, Thoren & Tarneberg, 2011). This is because, many science contents are taught by the teachers who are incapable about KSU (Park et al., 2018).

Moreover, science teachers reflect their inadequacies in many subjects into teaching processes even if they receive good training in terms of field and pedagogical knowledge during the undergraduate period. This situation causes various learning difficulties and misunderstanding for students (Lucero, Petrosino & Delgado, 2017; Sabel, Forbes & Flynn, 2016; Zhang, Parker, Koehler & Eberhardt, 2015). Hence, it is necessary to identify and improve the pre-service teachers' situation regarding these knowledge structures before they start their professional life. In the related literature, it is emphasized the fact that pre-service teacher should form a professional knowledge about the learning difficulties of students in science should constitute the focus of teacher education programs (Kind, 2019; Nilsson, 2013). "Heat and temperature" is a fundamental topic in the science education curriculum. This subject is taught to the students in secondary and high school in Turkey. There are important learning challenges on this subject. The researcher is decisive to choose especially this subject since it is one of the most difficult subjects for students to learn in the field of science. In spite of the fact that there is a limited number of studies in the related literature, it is seen that there are studies on the field knowledge of science and pre-service teachers on "Heat and temperature". Nevertheless, it is determined that there is no study on examining pre-service science teachers' KSU regarding ''Heat and temperature" in the world and Turkey. In this context, the research is conducted to reveal the KSU levels of Heat and Temperature of the fourth-grade pre-service science teachers studying at the faculties of education in Turkey and in this respect, it is thought that it can contribute to the literature, science teacher educators and program makers. The studies conducted with pre-service science teachers are very important in terms of improving the quality of teacher education programs. Therefore, this research is a starting point for science teacher educators in Turkey to contribute to the application based on student learning difficulties for pre-service teachers who are enrolled in the existing teacher training program or who will register in the future. On the other hand, this research may inspire other researchers to reveal the preservice science teachers' in capabilities about KSU in different science subjects before they start their profession.

Theoretical Framework

The Knowledge of Students' Understanding (KSU) of Science Teachers

Shulman (1986) defines a teacher's PCK as "the ways of presenting and formulating a subject in an understandable way for students through the strongest analogies, explanations, and examples" (p.9). Shulman (1987) indicates that becoming the best teacher needs strong PCK. Shulman has conceptualized a teacher's professional knowledge as PCK. Shulman's challenging claim leads to many discussions and enables PCK to be reinterpreted by other researchers within the framework of the teacher knowledge model (Geddis, 1993; Grossman, 1990; Gess-Newsome & Lederman, 1995; Gess-Newsome, 2015; Marks, 1990; Loughran, Mullhall & Berry, 2008; Magnusson et al., 1999; Park & Oliver, 2008a; Van Driel, Verloop & De Vos 1998). The general belief on the PCK is that teachers can organize the best ways of understanding a particular subject content in order to teach their students (Loughran, Mulhall & Berry, 2004). The models suggested on PCK represent the interaction of different knowledge dimensions (Appleton, 2008; Brown, Friedrichsen & Abell, 2013). When these models including the sub-information dimensions of the PCK are examined, it is understood that the Knowledge of Students' Understanding (KSU) represents the common professional knowledge dimension in almost all models. This knowledge structure of teachers includes understanding the cognitive, affective and psychomotor learning situations of their students and creating teaching processes accordingly (Chan & Yung, 2018; Jüttner & Neuhaus, 2012; Magnusson et al., 1999; Schneider & Plasman, 2011). The fact that this information is used by the teachers who teach a content in science allows students to learn new content better. For instance, when the teacher is planning a lab session about heat and temperature, s/he knows whether the students have the ability to read the thermometer and interpret the scale (Gullberg, Kellner, Attorps, Thoren & Tarneberg, 2008).

Magnusson et al. (1999) focuses on the students' problems related to abstract concepts and pre-teaching knowledge fields that are contrary to scientific explanations in the context of KSU. KSU is the knowledge of teachers about concepts regarding certain science subjects that students have difficulty or misunderstand (Canbazoglu, 2008). It includes the knowledge of teachers about understanding students, the variety of students' ideas which are adopted about a particular science subject, prior knowledge about that topic, misconceptions and learning difficulties in the field of science. This knowledge structure also covers information about students' differences in learning, learning styles, development levels and their needs (Park & Oliver, 2008b). Magnusson et al. (1999) explain KSU on the basis of what kind of pre-knowledge and skills science teachers should have in order for students to learn subjects, what difficulties are the challenges that can prevent them to learn, and their understanding of what students' misconceptions can be related to the subjects. According to Park & Oliver (2008), this field is the knowledge structure that teachers have about students' misconceptions, learning difficulties and needs, motivation and interests. Schneider and Plasman (2011) describe this structure as a way for teachers to understand the difficulty of science ideas for students. Learning is defined as a process of change in the mental structures of individuals. Students actively form meaningful knowledge structures based on their previous knowledge. It is important that teachers have previous knowledge of students in order to create a discourse that will encourage the student to develop understanding of a scientific concept. It is also important that teachers are aware of the diversity of ideas that students adopt while planning appropriate activities in the classroom (Gullberg et al., 2008).

Teachers should have knowledge on what the students know about a topic and what their possible uneasiness is in order to use PCK effectively. However, the studies show that most of the science teachers focus on only themselves while preparing for their lessons and do not deeply think about student education or what kind of problems students will encounter when they face new content (Brown et al., 2013; Kellner et al., 2011). Moreover, Hill et al. (2008) indicate that teachers have little information about how students think in their study. Teachers should not only show their knowledge and teaching skills to achieve their learning goals, but also show the knowledge and skills that can involve students in the learning process in science classes. Teachers should be familiar with the learning difficulties faced by the students from different backgrounds and should be able to flexibly plan, implement and evaluate the teaching process accordingly (Nurmatin & Rustaman, 2016). The fact that the student-dependent learning difficulties and students' concepts can be understood by teachers in science can significantly contribute to making decisions about how the content is ideally presented to students especially during the planning phase of the lesson (Nilsson & Vikström, 2015). Magnusson et al. (1999) emphasizes that teachers are in need of information about students' understanding and beliefs in this issue so that a teacher can plan to teach a particular subject effectively. A teacher should also have knowledge about various forms of representation and critical aspects of learning a particular subject in order to respond to students' different ways of understanding and learning. Moreover, it should be taken into account by teachers that student learning is largely influenced by pre-teaching information (Gullberg et al., 2008).

KSU of Science and Pre-service Science Teachers on "Heat and Temperature" Subjects

"Although the knowledge, which is a product of human mental processes, is often sufficient for a person to survive in the environment in which he lives; is it compatible with natural laws and physics?" It is not possible to answer "yes" to this question for all of the knowledge structured in the human mind while making sense of what is happening in the environment. One of the most important reasons for this inconsistency is the fact that the knowledge structured in the mind and the knowledge created by using scientific methods may have different meanings and features (Gunes, 2017, s. xi). Many possible factors from personal experiences, family, friends, media, teachers and textbooks contribute to the student's misunderstanding of concepts and difficulties in learning (Doige & Day, 2012; Wong, Chu & Yap, 2014).

The subject of "Heat and Temperature" is defined within the "Matter and Change" unit at the 5th grade level in the secondary school science course curriculum in Turkey. It is aimed that students explain melting, freezing, boiling, condensation, vaporization, sublimation, and deposition that occur during the change of state on the basis of heat exchange and they distinguish pure substances by using melting, freezing, and boiling points in this unit. In addition, it is aimed that the students understand the basic differences between the concepts of heat and temperature and interpret their results by making experiments showing that there is heat exchange as a result of mixing fluids with different temperatures (Ministry of National Education [MNE], 2018).

Taber (2000) emphasizes that the teachers should take into account learning disabilities while teaching about "Heat and Temperature". Students often cannot distinguish between these two concepts as the concepts of "Heat and Temperature" are often used interchangeably in daily life. There are important challenges in learning these two concepts (Duit, Niedderer & Schecker, 2007). As a result, many students can develop many alternative insights that are not true about "Heat and Temperature" (Aydogan, Gunes & Gulcicek, 2003; Baser & Geban, 2007; Jasien & Oberem, 2002; Sozbilir, 2003). Lewis and Linn (1994) argue that even scientists have difficulty in explaining certain events (e.g. daily events) related to the concepts of "Heat and Temperature".

Gunes et al. (2017) put forward a highly effective source on the important conceptual inaccuracies highlighted in the literature on "Heat and Temperature" topics. Five misconceptions in this resource that cover the subjects of "Heat and Temperature" and the correct thoughts put forward in order to correct these mistakes are as follows:

1. Temperature is the average kinetic energy of randomly moving molecules in a system. This is wrong. One of the possible reasons for this may be that the scientific definition of the concept of temperature includes the concept of kinetic energy. Temperature is an indicator of the average kinetic energy of the atoms or molecules of a substance that are in translatory motion.
2. The temperature of 40˚C is twice as hot as 20˚C. It is false. One of the possible reasons for this is that the

unit of Celsius (˚C) is considered proportional or absolute scale or the other is that they do not have enough information about the temperature units including this unit. However, it is not right to use the solid, fraction or ratio of temperature value by using the unit of Celsius. Referring such proportions with temperature is only suitable for Kelvin scale. If the temperature of a glass of substance at 0˚C is doubled, what will its temperature be? Considering the answer to this question, it does not change because twice the value of 0 is zero, so it is 0˚C. Such a result will be meaningless. It is necessary to rate such proportions only after converting to Kelvin scale: The temperature of 0˚C on the Kelvin scale will be 273 K if the temperature of this substance is doubled to 546 K. Since the temperature of 0˚C is 273 K on the Kelvin scale, it is 546 K if the temperature of this substance is doubled. The equivalent of this on the Celsius scale is 273 ˚C.

3. Heat is an energy that is owned. Heat is the intrinsic energy of a system. The heat of a cup of hot tea is higher than the heat of a cup of warm tea! These are wrong thoughts. Heat is simply the energy transferred between substances due to temperature difference. The transfer direction of this energy is from the higher to the lower temperature. While the intrinsic energy of the exothermic substance decreases, the intrinsic energy of the endothermic substance increases. It is meaningful to mention that substances have intrinsic energy, hence kinetic and potential energy. However, it is meaningless to talk about the temperature of a substance since substances do not have heat. In other words, heat is not the intrinsic energy of a system, because it cannot have heat. Therefore, it is pointless to compare the heat of a cup of hot tea with the heat of cold tea or to compare the heat of the substance with a big mass and the heat of the small one.

The misconceptions about "Heat and Temperature" have been described in numerous studies since the 1990s. In this context, some misconceptions in the related literature are shown in Table 1.

Table 1. Some Learning Difficulties in Heat and Temperature Topics

Misconceptions	References
Heat and temperature are the same	Gonen & Kocakaya, 2010
Temperature of a body does not depend on its' heat, and depends on the kind or size of it	Kirikkaya & Gullu, 2008
When two objects heated equally the temperature of the object with bigger mass increases more	Karabulut & Bayraktar, 2018
When boiling water, temperature will continue to rise. The heat required to raise the temperature of a substance is the product of	Irsyad, Linuwih, & Wiyanto, 2018
Many students seem to believe that factors that increase the rate of heat transfer always increase the amount of heat transferred as well. These misconceptions carry over to related fields such as mass transfer. Many students think that temperature is a measure of how hot or cold things feel. Many students do not understand that other factors, such as the rate of heat transfer, frequently affect how hot or cold something feels.	Prince, Vigeant, & Nottis, 2016

The misunderstandings about concepts are inconsistent with the understandings developed by experts, so students have learning difficulty. Misconceptions in science are a problem that needs to be reduced. This is because if the misunderstanding is not regarded, it could also prevent students from learning the next scientific content. It is difficult to change mislearning because every student builds knowledge with the experience they have. Misconceptions in science include: (1) They occur when students do not pursue formal learning and they have a starting concept based on their experience and daily life phenomena, (2) They occur while misinterpreting the associated terms between scientific concepts and other concepts (Suliyanah, Putri, & Rohmawati, 2018).

There is an extensive literature on the various inaccuracies and difficulties of knowledge that have arisen in the learning of many science subjects in the last thirty years (Hidayat, Siahaan, & Liliawati, 2018). It is known that students have difficulty in learning especially physics subjects. It is a fact that students cannot reach a sufficient level of learning especially in "Heat and Temperature" subjects (Bakirci & Ensari, 2018). Studies show that students have difficulty in understanding the subject of "Heat and Temperature" and that alternative concepts continue (Gurcay & Gulbas, 2015; Metioui, 2019). Teaching "Heat and Temperature" in the future is an important and challenging task for pre-service science teachers.

When a constructivist perspective on teaching and learning is adopted, teachers should know not only what conceptualizations students should become professional at the end of the teaching process, but also what the students already know about “Heat and Temperature” while entering the classroom. What is particularly important is the alternative concepts that students acquire through their contacts with the physical and social world. As a result of this thinking, pre-service science teachers should be aware of the conceptual difficulties and learning problems of students in the future on subjects related to "Heat and Temperature" (Frederik, Valk, Leite, & Thoren, 1999; Yeo & Zadnik, 2001).

Research Aim and Questions

The aim of this study is to examine the "Knowledge of Student Understanding (KSU)” of 4th grade pre-service science teachers, who study in the science teaching program of five different universities in Turkey, on "Heat and Temperature" topics. In accordance with this purpose, the questions are:

Q1. What are the understanding levels of pre-service science teachers about the ideas put forward to solve specific problems with "Heat and Temperature by the students?”

Q2. What do the pre-service science teachers know about the learning difficulties and limitations of the students about the “Heat and Temperature" subjects?

Method

Research Design

The case study, which is one of the qualitative research methods, is used in this study (Merriam, 1998; Yildirim & Simsek, 2008). The case studies are an approach that focuses on dynamics or processes built in one context

(Creswell, 2007; Huberman & Miles, 2002; Merriam, 2015). There is an in-depth understanding and discovery in case studies (Merriam, 1998).

Moreover, the most important feature of case studies is that they offer the opportunity to examine one or more situations in depth (Patton, 2002). The research is conducted according to the holistic single case study design, which is a type of case study (Yin, 2009). There is only one unit of analysis (an institution, a program, etc.) in holistic single case study designs, and there is a basis for subsequent studies of situations where no one has ever worked or reached them before (Yildirim & Simsek, 2016). The unit of analysis of the study is the 4th grade pre-service teachers studying in five science teaching programs of the faculty of education in Turkey. In this context, it is aimed to document and explore the understanding of the pre-service science teachers regarding student thoughts on a specific subject such as "Heat and Temperature" according to the holistic single case study.

Research Context

The subject of “Heat and Temperature”, which holds an important place in the science teaching curriculum in Turkey, is chosen as a subject area in the study. This topic also includes a content within the scope of "General Physics III" course in science teacher training programs. This course, which is taught to pre-service science teachers as "Thermodynamics" in the second year, covers heat and temperature, thermal properties of matter (specific heat, thermal conductivity, and thermal expansion) and thermodynamics laws.

When considering the undergraduate programs for science teaching, pre-service teachers take theoretical and practical courses of "Heat and Temperature" up to the 4th grade. In addition, preservice teachers take many learning and teaching lessons in which they will understand the pedagogical importance of student understanding in order to improve the quality of their lessons when they start their profession. Furthermore, the questions about "Heat and Temperature" are often among the difficult and eliminative questions especially in both high school and university entrance exams in Turkey.

Research Group

The sample of this research consists of 268 pre-service teachers studying at the 4th grade in the science teaching program of five different universities in 2019-2020 fall semester in Turkey. The sample includes 142 female and 126 male. Science teacher training is a four-year training program offered to those selected from the students graduating from high school with "The Transition to Higher Education Examination" applied by Student Selection and Placement Center (SSPC) throughout the country in Turkey. The placement rankings of the pre-service teachers selected for this research are the 17th, 19th, 24th, 36th, 39th and 41st among 68 existing programs in the year they enter the university (OSYM, 2016). The gender distributions of the pre-service teachers participating in this study according to the universities they are registered in are shown in Figure 1.

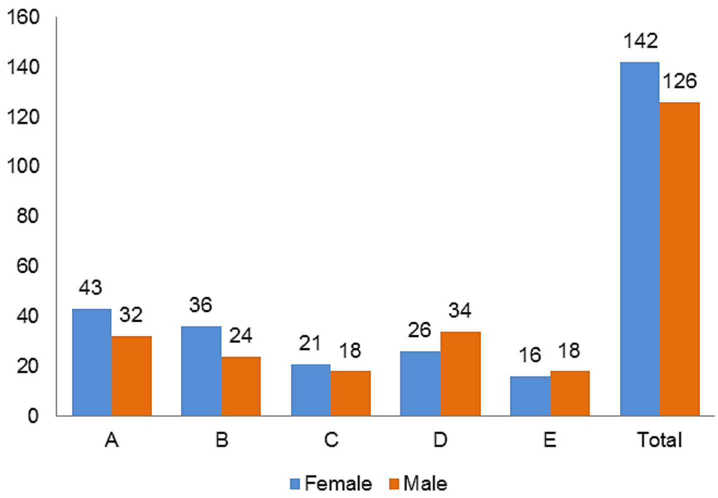


Figure 1. The Distribution of Pre-Service Science Teachers Participating in the Study According to the Universities and Gender

Data Collection and Instruments

The PCK research has been going on for about thirty-five years. However, it is obvious that the researchers make a serious effort to measure PCK reliably. Moreover, it is highlighted by the researchers that measuring and evaluating PCK is difficult (Park et al., 2018). It is known that studies of measuring PCK knowledge and sub-knowledge dimensions are especially concentrated in the field of science (Carlson, 1990; Cobern et al., 2014; Kromrey & Renfrow, 1991; Schuster et al., 2007). It is understood that science and pre-service science teachers have mostly used interview and observation methods in order to determine PCK structures until recent years. On the other hand, it is observed that researchers have used "Paper and Pencil Tests" (Jüttner & Neuhaus, 2012; Nelson & Davis, 2012; Jüttner, Boone, Park, & Neuhaus, 2013; Schmelzing et al., 2013), concept maps (Rollnick, Mundalamo & Booth, 2013), CoRe and PaP-eRs forms (Bertram & Loughran, 2012; Hume & Berry, 2011; Loughran et al.2004; Loughran et al.2008) and scenario-based PCK tests (Park et al., 2018) for the last few years. When the related literature is examined, "Knowledge of Student Understanding (KSU)", which is one of the sub-dimensions of PCK of the science and pre-service teachers, appears as the information structure on which most of the research is done by researchers (Moodley & Gaigher, 2019). However, it is indicated that many researchers use the questions which are based on the problem including the wrong knowledge and misconceptions which the students may have in a science topic in order to evaluate this knowledge structure effectively (Park et al., 2018). The "*Student Thinking Comprehension Test"* and *Interview Form"* are used to reveal the pre-service science teachers' knowledge about understanding the students on the subject of "Heat and Temperature". The data collection tools used in the research are described below.

Student Thinking Comprehension Test

It is seen that not only the interviews and observations but the different data collection methods called *"Paper and Pencil Test"* have been used to evaluate the KSU of science and pre-service science teachers in recent years (Jüttner & Neuhaus, 2012; Jüttner et al., 2013; Kellogg, 2010; Nelson & Davis, 2012; Schmelzing et al., 2013;

Park et al., 2018). The “Paper and Pencil Tests”, which are also an inspiration for the data collection of this research, include the tests which aim to diagnose these errors by pre-service teachers by using sections of the wrong or incomplete knowledge in their answers to the questions asked to the students in secondary school or high school on a particular science subject as a scenario in various question roots. This examination represents a teacher's "Knowledge of Student Understanding (KSU)", one of the sub-dimensions of PCK, in the related literature. It is questioned whether a thorough evaluation regarding the mistakes in the ideas that the student has revealed can be carried out by the teacher with these test items. The question roots of the items in these tests are often presented in the form of a scenario and then completed with a problem sentence that examines the teacher's understanding of the student. Pre-service science teachers' level of student understanding on "Heat and Temperature" is studied by using this technique in the research. The *"Student Thinking Comprehension Test"* prepared for this purpose contains five items. The items are created after a comprehensive review on the related literature. The each content of these items consists of three parts; a question measuring the knowledge of the students in secondary school on “Heat and Temperature” subjects; response section in which the student answers this question and the problem sentence in which the pre-service teacher is asked to evaluate the student's answer. In order to prepare the first and second parts of each item in the test, a written exam consisting of 10 questions is applied to measure 95 students’ knowledge on heat exchange and process change at the 8^{th} grade in a secondary school in Kars. Every question in this exam applied to students is open-ended. Both the researcher and the teacher of the course are in the classrooms during these applications. Before the application, the explanations about how the questions should be answered are made to the secondary school students in each class by the researcher. It is noted that both the teacher and the researcher do not make any explanation giving students clues in solving the questions or misleading them. This situation enables the students to write their knowledge out about this subject exactly in their written papers. The wrong information in the answers given by the secondary school students to these questions are classified to be used in the second part of the *"Student Thinking Comprehension Test"* items. In this classification, students' common wrong information in the same questions is determined for each question. Afterwards, this wrong information is scripted as the words written out by the students and placed in the second part of the test applied to pre-service teachers by the researcher. The same method is used for each item in the test by the researcher. In this context, five question items are prepared for the *"Student Thinking Comprehension Test"*. Each test item is offered for consideration of three faculty members who are experts in the field of science from different universities. These experts are sent samples of both the prepared test items and the test items prepared to use the same method in other science subjects in the related literature. The researcher asks these experts to interpret the understandability of each item and also compare it to sample test materials from the literature. Experts are asked to record this assessment on the opinion form sent to them. The expert opinion form includes sections that are appropriate, not appropriate for each item and explain the reason. As a result of expert evaluations, feedback is provided that all items are appropriate in the test. However, some suggestions are made for the understandability of some student expressions at the item roots. As a result of his evaluations with experts for each item, the researcher makes some new arrangements provided that the student responses are not denaturalized. As a result, an assessment instrument consisting of five items is developed to evaluate the knowledge of pre-service science teachers' understanding of students' thinking on “Heat and Temperature” subjects (see; Appendix A).

Interview Form

The interview form, which consists of one open-ended question, is used to reveal the opinions of the pre-service teachers about the wrong information that students often have on “Heat and Temperature”. The open-ended question in this form is taken from the "Content Representation (CoRe)" form, which is used extensively as a data collection tool to examine the PCK structures of science and pre-service science teachers in many studies (Bertram & Loughran, 2012; Hume & Berry, 2011; Loughran et al., 2008; Nilsson & Loughran, 2012; Williams, 2012; Williams, Eames, Hume, & Lockley, 2012). The CoRe form includes eight open-ended questions which represent the sub-information dimensions of PCK. The questions like “What are the difficulties/limitations connected with teaching this idea?” and “What is your knowledge about students’ thinking that influences your teaching of these ideas?” constitutes this form in order to evaluate “Knowledge of Student Understanding (KSU)” which is one of the sub-information dimensions of PCK. In this study, the open-ended question prepared to determine the knowledge of pre-service science teachers about the misunderstanding of students on heat and temperature is a blend of two questions expressed in the CoRe form. The open-ended question prepared for the research is as follows: "As a science teacher, what do you think about the difficulties and limitations of your students in terms of learning about heat and temperature?" It is applied to four pre-service science teachers out of the study group in order to test the comprehensibility of the interview question by the researcher. After evaluating the suitability of the question in terms of language, it is finalized. The interview question is distributed to the pre-service teachers in the sample as a form. Preservice teachers are asked to write their answers in this form.

Within the scope of the research, both the *"Student Thinking Comprehension Test"* and *"Interview Form"* are delivered to some faculty members who work in the science teaching programs of the universities involved in the sample. These lecturers are science teacher education experts with whom the researcher has previously worked on some research projects. The instructors implement these data collection tools at a time when pre-service teachers are not interfered during their educational processes. The researcher delivered these forms to all the universities in the sample in the first week of December 2019. The researchers received the data files from all universities at the last week of January 2020.

Data Analysis

Descriptive analysis technique is used to analyze the knowledge of pre-service science teachers 'understanding of students' thinking on “Heat and Temperature” subjects in the study. In this context, the data collected through the "Student Thinking Comprehension Test" are analyzed with the "Scoring Rubrics for Knowledge of Student Thinking" prepared by Kellogg (2010), and the data collected through the interview form are analyzed with the "Rubric for Analysis of Interviews" prepared by Heller, Daehler, Shinohara, & Kaskowitz (2004). When the PCK literature is examined, many rubrics prepared by various researchers stand out (Gardner & Newsome, 2011; Hume & Berry, 2011; Park, Jang, Chen, & Jung, 2011; Sawada et al., 2000). The researcher decides to use rubrics prepared by both Kellogg (2010) and Heller et al. (2004) to analyze the data as a result of consultations with other researchers working in the field of PCK. The teachers' understanding of students is classified in five levels as "No meaningful response, Unacceptable, Inferior, Acceptable and Model response" in the rubric named "Scoring Rubrics for Knowledge of Student Thinking" prepared by Kellogg (2010).The levels of "No meaningful response" and "Unacceptable" developed by Kellogg (2010) are combined by the researcher as a single level and are defined as "Invalid" level to analyze the data collected by the "Student Thinking Comprehension Test" in this study. Therefore, the data of the "Student Thinking Comprehension Test" are analyzed under four levels. The information that defines the knowledge levels and criteria of understanding the student thinking in this rubric is shown in Table 2.

Table 2. The Rubric for Knowledge of Student Thinking

Level	Criteria
Exemplary	Answer provides thorough insight into the student's thinking and provides complete diagnosis of student errors. A completely correct and well-articulated answer.
Acceptable	Answer provides adequate insight into the student's thinking or provides adequate diagnosis of student errors. A mostly correct and conceptually based answer.
Weak	Answer provides limited insight into the student's thinking or provides limited diagnosis of student errors. There is little correct answer.
Invalid	Answer provides no, or incorrect, insight in to the student's thinking; provides no, or incorrect diagnosis of student errors. There is no correct answer.

Note: Adapted from Kellogg (2010) "Scoring Rubrics for Knowledge of Student Thinking"

"Rubric for Analysis of Interviews" prepared by Heller et al. (2004) is used to evaluate the answers given to the open-ended interview question, which is the second data source of the study. *"Rubric for Analysis of Interviews"* is developed to evaluate teachers' level of knowledge about students' learning difficulties on *"Electric Current"* in science. The biggest advantage of this rubric for related research is that it is developed to analyze interview questions. The original of this rubric, like the previous described rubric, evaluates teachers' understanding on student thinking at five levels as *"Exemplary, Proficient, Basic, In progress* and *0"*. However, while adapting to use in this research, levels of *"In progress"* and *"0"* are combined as *"Invalid/Empty"* and defined under a single level. Therefore, the data obtained from the open-ended question of the *"Interview Form"* in this study are analyzed under four levels. The explanations defining the knowledge levels and criteria of this rubric are shown in Table 3.

Table 3. Rubric for Analysis of Interviews

Level	Focus on student thinking
Examplary	Three or more specific descriptions of what makes learning difficult in terms of science and student cognition (e.g., conceptual or perceptual difficulties)
Proficient	One or two specific descriptions of what makes learning difficult in terms of science and student cognition (e.g., conceptual or perceptual difficulties)
Weak	Mention of student difficulties related to science topics, vocabulary or general skills, or not sure what students understand
Invalid/Empty	No student diffuclties described.

The data collected in this study are analyzed descriptively and presented in graphs with frequency and percentage values. In accordance with the feature of the descriptive analysis, the direct quotations from the ideas of pre-service science teachers in the sample are included. In the research, abbreviations such as PST1 (Pre-service Science Teacher 1), PST2, PST3 are used in order to transfer the ideas of the pre-service science teachers in accordance with the privacy policy.

Validity and Reliability

The strategies of cogency, transmissibility and verifiability should be used to ensure validity and reliability in a qualitative research (Lincoln & Guba, 2013; Shenton, 2004). In this context, first of all, all steps followed in collecting and analyzing the research data are explained in detail. It is important to make mutual assessment or mark with other data analysts to ensure reliability in the analysis of qualitative research data. Thus, it is provided to determine whether the data is perceived by different evaluators in the same way. This can be done both between researchers and with an independent expert in a study with more than one researcher. It is received support from a science teacher educator working at a different university, and a science teacher with fifteen-year professional experience in order to ensure the analysis reliability of the data for this study. In this context, the researcher, instructor, and science teacher evaluated in terms of level depending on rubrics the data set obtained from both the test and the interview form of twenty-four pre-service teachers. In ensuring data analysis reliability, levels within both rubrics were scored from 0 = "*Invalid/Empty*" to 3 = "*Exemplary*". It has been supported by various studies that such an assessment is appropriate for the analysis of data obtained from both test and interview forms (Park & Oliver, 2008b; Park et al., 2011; Rowan, Schilling, Ball & Miller, 2001). In the evaluation for the test, a high level of consistency was obtained between the researcher and the scoring team formed by the instructor from another university ($r= .96$, $p <.01$). Again for the test, the same scoring process was done between the researcher and the science teacher. In this context, it was calculated that the consistency between both raters was quite high ($r= .94$, $p <.01$). This process was repeated in the interview form. In this context, the scoring between the researcher and the instructor was calculated as $r= .90$, and the consistency between the researcher and the science teacher as $r = .88$. These rates show that reliability is ensured in data analysis.

Results

The following findings are obtained in this study, which is conducted to evaluate the *"Knowledge of Student Understanding (KSU)"* of pre-service science teachers on "Heat and Temperature".

Findings on the level of pre-service teachers' diagnosing errors in the thoughts put forward by students to solve specific problems on "Heat and Temperature" issues

The findings obtained from the descriptive analysis made in order to determine the level of the pre-service science teachers to diagnose the student errors that occur in the solution of specific problems in heat and temperature topics are presented in the graphic in Figure 2.

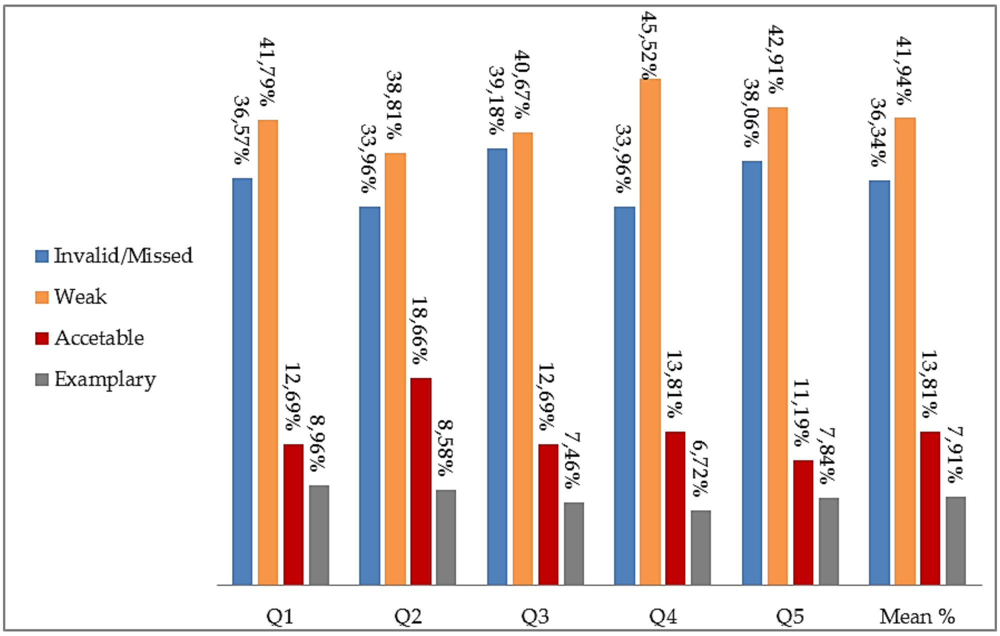
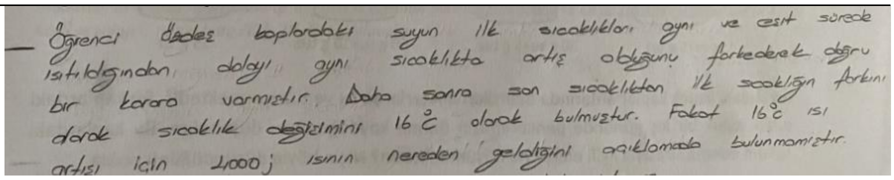


Figure 2. The Levels of Pre-Service Science Teachers to Diagnose Student Errors that Occur in Solving Specific Problems in Heat and Temperature Topics

The level at which pre-service science teachers diagnose student errors that occur in the solutions to specific problems with *"Heat and Temperature"* is shown in the graphic in Figure 2. When the graph is examined, it is seen that the pre-service teachers' knowledge of understanding student cognition in all of these problems is mostly at *Weak* (41.94%) and *Invalid / Missed* (36.34%) levels. In addition, it is understood that a very low percentage of pre-service teachers is at the *Acceptable* (13.81%) and *Exemplary* (7.91%) levels. Moreover, when the graph is examined, it is appeared that those who diagnose student errors in Q2 about change of state at the *Acceptable* (18.66%) level are higher than those who diagnose student errors in Q1 (12.69%), Q4 (13.81%) and Q5 (11.19%) heat exchange problems at the *Acceptable* (18.66%) level. However, although both of the Q2 and Q3 problems are related to the change of state, it is seen that the pre-service teachers' ability to diagnose student errors in the solution of both problems at the *Acceptable* level differs significantly. This may be due to the structure of both change of state problems. This is because the Q2 problem has been supported by the graph of change of state that every student has been familiar with since secondary school, whereas the Q3 problem is a more difficult and more confusing state of change problem created from water and salt substances. In this context, it is thought that the students' responses to the Q2 problem may be more simple and understandable. Therefore, it can be seen as a natural consequence that pre-service teachers’ levels of identifying students' errors differ in solving both problems. These findings indicate that most of the pre-service science teachers cannot effectively diagnose student knowledge errors that occur in solving specific problems about “Heat and Temperature” topics.

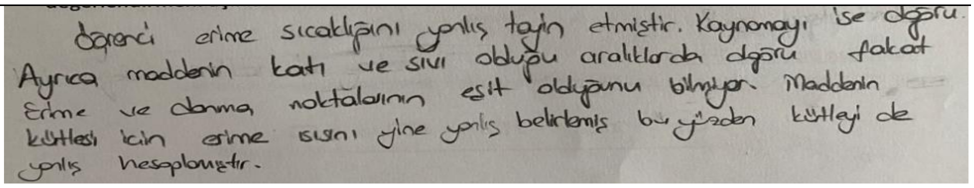
The examples of pre-service teachers' level of diagnosing student knowledge errors in solving specific "Heat and Temperature" problems are shown in Table 4.

Table 4. The examples of pre-service science teachers' levels of thought for Q1 in "Student Thinking Comprehension Test"

The pre-service teacher's level of interpretation of student understanding	Invalid
The example of pre-service teacher's interpretation of student understanding	 — Öğrenci özdeş kaplardaki suyun ilk sıcaklıkları aynı ve eşit sürede ısıtıldığından dolayı aynı sıcaklıkta artış olduğunu farkederek doğru bir karara varmıştır. Daha sonra son sıcaklıktan ilk sıcaklığın farkını alarak sıcaklık değişimini 16 °C olarak bulmuştur. Fakat 16 °C ısı artışı için 4000 j ısının nereden geldiğini açıklamada bulunmamıştır. *"The student made the correct decision by realizing that the initial temperatures of the water in identical containers were the same and that when they were heated for equal time, the same temperature increase would occur. Later, taking the difference of the first temperature from the last temperature, he found the temperature change as 16 ˚C. But he could not explain where the 4000 J heat came from for this temperature increase."* (PST97's interpretation)
Scientific explanation related to the problem diagnosis based on student understanding for Q1	When the problem in Q1 is examined, it is stated that there are 250 ml and 125 ml water in two vessels, respectively, and the initial temperatures of the water in these vessels are 140C. When these identical vessels are heated in the same amount time, the temperature of the water in the Ind vessel reaches 30˚C, in this case it is asked what the temperature of the water in the IInd vessel will be. Firstly, the student should start by calculating the mass for the amount of water in the first vessel. It should be able to be calculated that the water in the Ind vessel has a mass of 250 g by taking density of 250 ml water as 1g/ml. The student should know that a temperature of 4000 cal is required to reach the final temperature of 30˚C in the first vessel by using the formula Q = m.c.Δt. In other words, 4000 cal heat is required to increase the temperature of the water in the Ind container by 16˚C. After this step, the student should be able to calculate what the final temperature is in the Q=m.c.Δt formula for 4000 cal by understanding that there is an equal amount of heat transfer with the Ind vessel in the same amount time for the IInd vessel. Therefore, when the student applies this formula, s/he will be able to calculate that the final temperature of the vessel will reach 46˚C. Another practical way for the student is that the amount of water in the IInd vessel is half amount of water in the Ind vessel, so s/he should think that the temperature increase here will be twice as much as the Ind vessel. In addition, the student should know that the temperature increase is 16˚C in the Ind vessel, and so the temperature increase will be 32˚C in the IInd container, and s/he should think that the last temperature of the IInd vessel will be 46˚C with this temperature increase. However, there are serious errors in the ideas that the student has put forward for solving the problem. The student states that the IInd vessel will reach the same final temperature as the Ind vessel. Considering the explanations based on this idea of the student, s/he thinks that when the same amount of heat is given, it is as much as the temperature increases in the Ind vessel. The student does not consider the amount of water here. This indicates that the problem is not understood correctly. In addition, the student is unable to make the following calculations in order to solve this problem. m = d. v — IInd: m = 1.250 =250gr — Q = m.c.Δt Q = m.c.Δt — 4000 = 125.1.(T-14) Q = 250.1.(30-14) — 32= T-14 Q= 4000 cal — T = 46 ˚C

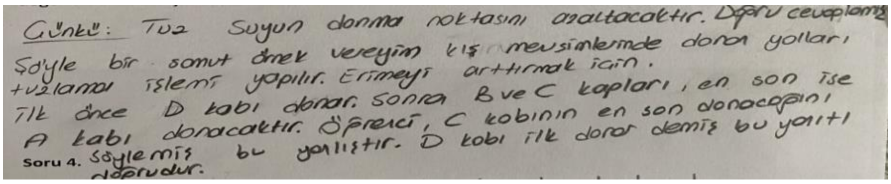
In Table 4, it is seen that the PST97 coded pre-service teacher's level of interpretation of student understanding in the question "Student Comprehension Knowledge Test" Q1 corresponds to the "Invalid" level. In his interpretation coded PST97, the pre-service teacher could not make a diagnosis that the student should consider the amount of substances in the containers. In addition, he interpreted the false statement of the student that there would be an increase in temperature at the same degree when these vessels were heated for equal time and showed that he was weak in interpreting the understanding of the student.

Table 5. The examples of pre-service science teachers' levels of thought for Q2 in "Student Thinking Comprehension Test"

The pre-service teacher's level of interpretation of student understanding	Acceptable
The example of pre-service teacher's interpretation of student understanding	 öğrenci erime sıcaklığını yanlış tayin etmiştir. Kaynamayı ise doğru. Ayrıca maddenin katı ve sıvı olduğu aralıklarda doğru fakat Erime ve donma noktalarının eşit olduğunu bilmiyor. Maddenin kütlesi için erime ısısı yine yanlış belirlenmiş bu yüzden kütleyi de yanlış hesaplamıştır. **"***The student incorrectly predicted the melting temperature. S/he predicted boiling correctly. S/he knows that it is true between the ranges of solid and liquid matter, but she does not that the melting and freezing points are equal. S/he also misidentified the heat of melting for the mass of the substance. Therefore, s/he calculated the mass incorrectly."* (PST36's interpretation)
Scientific explanation related to the problem diagnosis based on student understanding for Q2	When the problem in Q2 is examined, the change of state graph of a substance A is included. The student is asked to interpret the graph of the change of state and mass of substance A. The value of the heat of fusion of the substance A is also given at the root of the problem. The student should be able to interpret from the graphic that the substance A begins to melt at 10°C and boil at 80°C. In addition, the student should be able to understand that substance A is solid between 15°C and -10°C, and liquid between 15°C and 80°C. If the student can interpret the graph correctly, he should understand that the top horizontal line above shows that the substance A reaches the boiling point and after reaching this point, it will continue to boil in this range of the temperature for a while. On the other hand, the student should be able to find the amount of substance for the substance A by using 400 cal, which is the heat given in the melting state in the graphic above. Since the melting temperature of the substance in the problem is 200 cal / g, the student should be able to calculate that a total of 400 cal heat will be given to melt a 2 g substance here. In addition, the student should know that C_{gas} and $L_{boiling}$ cannot be calculated since $L_{boiling}$ and $L_{condensation}$ are not known for the part of this substance after evaporation and the continuation of the graph is unknown. Moreover, the student should be able to use the following calculations in order to solve this problem. When the answer of the student in Q2 is examined, it is understood that the student misinterprets the melting point of the substance A, but correctly diagnoses the solid and liquid temperatures. The student correctly interprets that the top horizontal line above reaches the boiling point for substance A, and after reaching this point, it will continue to boil at this temperature for a while. However, s/he misinterprets chart by thinking that the lowest value is -10°C, which is the melting point of this substance. Furthermore, the student makes a significant mistake in calculating the amount of the substance. Considering the heat given in the case of melting as 800 cal, s/he thinks that a substance of 4 grams is needed for this temperature. $Q = m.\,L_{melting}$; $Q = m.c.\Delta t$; $Q = m.c.\Delta t$ $800\text{-}400 = m.200$; $400 = 2.c_{solid}.[15-(-10)]$; $400 = 2.\,c_{liquid}.(80-15)$ $400 = m.200$; $400 = 2.\,c_{solid}.25$; $400 = 2.c_{liquid}.65$ $m = 2gr$; $c_{solid} = 8\ cal/g^0C$; $c_{liquid} = 6,15\ cal/g^0C$

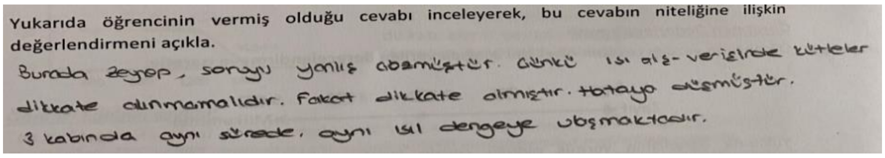
In Table 5, it is seen that the PST36 coded pre-service teacher's level of interpretation of student understanding in Q2 question "Student Comprehension Knowledge Test" corresponds to the "Acceptable" level. In the interpretation of the teacher candidate coded PST36, it is seen that the student's diagnosis that he misunderstood the melting point of the substance A in the graph and correctly answered the temperatures in which it was in solid and liquid form was appropriate. It is also seen that the PST36 student's diagnosis that he correctly understood the boiling point of the substance A in the graph, misunderstood the heat given in the melting state, and miscalculated the amount of the substance calculated for this temperature was found to be appropriate.

Table 6. The examples of pre-service science teachers' levels of thought for Q3 in "Student Thinking Comprehension Test"

The pre-service teacher's level of interpretation of student understanding	Exemplary
The example of pre-service teacher's interpretation of student understanding	 Çünkü: Tuz suyun donma noktasını azaltacaktır. Doğru cevaplamış. Şöyle bir somut örnek vereyim kış mevsimlerinde donan yolları tuzlama işlemi yapılır. Erimeyi arttırmak için. İlk önce D kabı donar. Sonra B ve C kapları, en son ise A kabı donacaktır. Öğrenci, C kabının en son donacağını söylemiş bu yanlıştır. D kabı ilk donar demiş bu yanıtı doğrudur. Soru 4. *"Salt will reduce the freezing point of water. He answered correctly. Let me give an abstract example. In order to increase melting in winter, frozen roads are salted. Coming to this question, container D freezes first. Then containers B and C will freeze, and finally container A will freeze. The student said that the C container will freeze last. This is wrong. He said that the D container freezes first and this answer is also correct."* (PST89's interpretation)
Scientific explanation related to the problem diagnosis based on student understanding for Q3	When the problem in Q3 is examined, the mixtures of different amount of water and salt are given in four identical vessels as A, B, C, D. Three of these vessels have a mixture of water and salt and there is only water in vessel D. The students are asked to interpret what the freezing order of the substances in these vessels will be when these vessels are left outside in winter. When we put these vessels in front of the window on a cold winter day, the student should think that the liquid in vessel D will freeze first, then B, then C and finally the mixture in vessel A will freeze. This is because the student should know that salt lowers the freezing temperature of water. The student should understand that the higher the salt content is, the lower the freezing temperature of the water will be. On the other hand, the student should also know that the amount of substance affects the duration of the water not the freezing temperature. Therefore, the student should understand that freezing temperature will drop evenly as the salt rates in the vessels B and C are the same. However, the student should think that the vessel B will freeze earlier because the amount of substance is low. Furthermore, the student should determine that the salt rate is the highest in vessel A. Therefore, the student should predict that this salt content represents the lowest freezing temperature, so the mixture in vessel A will freeze at the latest. When the answer of the student in Q3 is examined, the student correctly interprets that the water in the vessel D will freeze first and that there is no salt in this vessel, so the water in this vessel will start to freeze first. In addition, the student put forward the wrong idea that the mixture in vessels A and B will freeze concurrently after the vessel D, and finally the mixture in the vessel C will freeze. S/he explains this by associating it with the amount of salt in the vessels. In fact, the student knows that salt reduces the freezing temperature of the water. The student show such a misunderstanding by only considering the equal amount of salt in vessels A and B. Moreover, taking into account the excess amount of salt in vessel C, it has revealed such a misconception by not comparing the amount of water in this vessel and thus the mixing ratio with vessels A and B.

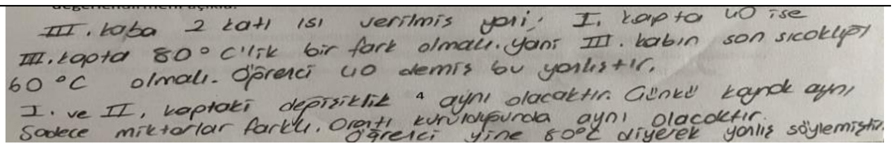
In Table 6, it is seen that the PST89 coded teacher candidate's level of interpretation of student understanding in Q3 question of "Student Understanding Knowledge Test" corresponds to the "Exemplary" level. In the interpretation coded PST89, it is seen that the student correctly diagnosed the wrong thoughts in the order of items and freezing in the containers. S/He diagnosed that the student's answer that the water in bowl D will freeze and there is no salt in this bowl, so the water in this bowl will start to freeze first, was correct. In addition, he effectively diagnosed the student's misconception that the mixture in containers A and B would freeze at the same time after container D, and that the mixture in container C would freeze at the last. In addition, when the student made serious mistakes in interpreting the amount of water and salt in the containers, it was correctly diagnosed by PST89.

Table 7. The examples of pre-service science teachers' levels of thought for Q4 in "Student Thinking Comprehension Test"

The pre-service teacher's level of interpretation of student understanding	Invalid
The example of pre-service teacher's interpretation of student understanding	 Yukarıda öğrencinin vermiş olduğu cevabı inceleyerek, bu cevabın niteliğine ilişkin değerlendirmeni açıkla. Burada Zeynep, soruyu yanlış çözmüştür. Çünkü ısı alış-verişinde kütleler dikkate alınmamalıdır. Fakat dikkate almıştır. Hataya düşmüştür. 3 kabında aynı sürede, aynı ısı dengeye ulaşmaktadır. *"Here, Zeynep solved the question wrong. Because masses should not be taken into account in heat exchange. But it has been taken into account. He has fallen into error. It reaches the same heat balance in the same time in three containers."* (PST114's interpretation)
Scientific explanation related to the problem diagnosis based on student understanding for Q4	When the problem in Q4 is examined, it is said that A, B, C tubes with masses of 400g, 300g and 200g at 90°C are sopped in three vessels filled with equal amounts of isothermal water. The student is asked to interpret what the temperature of the water will be in the vessels I, II and III when the heat exchange between the tubes and vessels is completed. The student should be able to imagine that when the heat exchange is complete, the vessel with the highest equilibrium temperature is Ist then IInd and finally IIIrd. The student knows that the temperature of each tube is equal and 90˚C. He also knows that the amount of water in the vessels (m) and its temperatures (30˚C) are equal. The student should be able to predict that the mass of the Tube A is too much here, so the amount of heat, which can transmit, will be too much. Therefore, the student should think that the temperature increase in the water of the Ist vessel is more than the temperature increase of the water in the IInd vessel and the temperature increase of the IInd will be more than the IIIrd vessel. Here, the student thinks that since the mass of the liquid in tube A is 400 g and the maximum temperature change will be in vessel I, then a little less change will be in the IInd vessel where tube B is submerged, and the least temperature change will be in the IIIrd vessel where the tube C with the smallest mass is submerged. It is seen that this cognition of the student is whole and complete.

In Table 7, it is seen that the PST114 coded pre-service teacher's level of interpretation of student understanding in Q4 question "Student Comprehension Knowledge Test" corresponds to the "Invalid" level. In the interpretation of the pre-service teacher PST114, it is seen that the student made a diagnosis that is the opposite of the correct answer given based on the amount of substance in the submerged tubes.

Table 8. The examples of pre-service science teachers' levels of thought for Q5 in "Student Thinking Comprehension Test"

<table>
<tr><th>The pre-service teacher's level of interpretation of student understanding</th><th>Exemplary</th></tr>
<tr><td>The example of pre-service teacher's interpretation of student understanding</td><td>
III. kaba 2 katı ısı verilmiş yani; I. kapta 40 ise III. kapta 80 °C'lik bir fark olmalı. Yani III. kabın son sıcaklığı 60 °C olmalı. Öğrenci 40 demiş bu yanlıştır.
I. ve II. kaptaki değişiklik aynı olacaktır. Çünkü kaynak aynı. Sadece miktarlar farklı. Orantı kurulduğunda aynı olacaktır. Öğrenci yine 80°C diyerek yanlış söylemiştir.

"The IIIth container was given twice the heat. That is, if it is 40˚C in the first container, There should be a difference of 80˚C in the IIIth container. So, the final temperature of the container IIIth should be 60˚C. The student said 40˚C, this is wrong. The change of Ith and IIth container will be the same. Because the heat source is the same. Only the quantities are different. The proportion will be the same when established. The student said it wrong, saying 80˚C again."
(PST173's interpretation)</td></tr>
<tr><td>Scientific explanation related to the problem diagnosis based on student understanding for Q5</td><td>When the problem in Q5 is examined, it is said that the same type of substances in different masses (50gr, 100gr, 50g) in three identical vessels, the one in the Ird vessel is heated for 10 minutes with a single stove, the IIrd vessel with a single stove for 20 minutes and the IIIrd vessel with two stoves for 10 minutes. It is also said that the initial temperatures of the materials in all vessels are equal and -20˚C and the final temperature of the first vessel is 20˚C. The student is asked to interpret what the final temperature of the IIrd and IIIrd vessels will be. The student should think that s/he can make a correct interpretation by using the formula $Q = m.c.\Delta t$ for all vessels in this rather confusing question for her/him. The student should first start by thinking that each heat source gives off Q heat in 10 minutes. Then a heat of Q for 10 minutes should be used in the formula $Q = m.c.\Delta t$ for vessel I, s/he should think that the c's are the same because they are the same type and also should be able to calculate that the temperature change (Δt) in the formula for this 50 gr substance is 40˚C. Furthermore, the student should take 2Q for 20 minutes in the formula $Q = m.c.\Delta t$ by following the same way for the second vessel. As a result, s/he should be able to calculate that Δt, namely the temperature change, is 40˚C in this vessel for this 100 gram sunstance as in the first vessel. Therefore, the student should be able to predict that the final temperature of this vessel will also be 20˚C in order to obtain the Δt temperature change, which is stated to be -20˚C in the vessel II. In addition, the student should take $q = m.c.\Delta t$ formula for 10 minutes following the same path for the IIIrd vessel. However, it should not be overlooked that there are two stoves unlike the first vessel. Therefore, s/he should understand that there is a 2Q temperature here. The student should calculate that this IIIrd vessel with 50 g is 80˚C with the stated formula of Δt temperature change. The student should then think that the initial temperature in this vessel is -20˚C</td></tr>
</table>

and should interpret that the final temperature of this vessel will be 60˚C to obtain the expressed Δt temperature change. How all expressed calculations should be done is presented below. However, when the answer of the student is examined, it is revealed that a temperature ratio is made between the vessels by considering only the amount of the substances, especially the time is not taken into account, and this causes serious errors. When the answer of the student in Q5 is examined, the student misunderstands that if there is a 40 °C change in a vessel with 50 g, a temperature change of 80 °C will occur in a vessel with 100 g, and the student takes into account the first temperature of this vessel and misinterprets that its final temperature will also be 60˚C. In addition, the student also evaluates the final temperature of the IIIrd vessel by taking into account the Ird vessel. Based on the fact that the masses of Ird and IIInd vessels are the same, the student thinks that the heat is given twice as much as the IIIrd vessel, which will indicate twice as much as the final temperature of the Ird container, ie 40 °C. The student misunderstands it here again. However, the student does not think that the heat given here is directly proportional to Δt.

For Ird vessel:
Q = m.c.Δt
Q = 50.c.[20-(-20)]
Q = 50.c.40
Δt =Q/50.c = 40˚C
T_{pre}= -20˚C
T_{final}= 20˚C
For IIrd vessel:
Q = m.c.Δt
2Q = 100.c.Δt
Δt = 2Q/100.c
For Δt = Q/50.c, again
It is Δt = 40˚C.
In this vessel since T_{pre}= -20˚C in order to obtain the temperature change of Δt,
It is theT_{final} = 20˚C.
For IIIrd vessel:
Q = m.c.Δt
2Q = 50.c.Δt
For Δt = 2Q/50.c because for Δt = Q/50.c, Δt = 40˚C.
So here is Δt = 80˚C for the IIrd vessel.
Since T_{pre}= -20˚C is in this vessel, this vessel is
T_{final} = 60˚C to obtain the temperature change expressed Δt.

In Table 8, it is seen that the PST173 coded pre-service teacher's level of interpretation of student understanding in the question "*Student Comprehension Knowledge Test*" Q5 corresponds to the "Acceptable" level. In the interpretation of the pre-service teacher with PST89 code, it is seen that the student correctly diagnosed the mistakes in his answers by looking at the amount of material in the containers and the heating times. Again, the pre-service teacher, the student's based on the same mass of the containers Ird and IIIrd. It appears that the container III[rd] was given twice as much heat as container I[rd], effectively detecting her false answer that this would indicate twice the final temperature (40˚C) of container I[rd].

The Findings on the pre-service teachers 'level of knowledge regarding difficulties and limitations of students in terms of learning "Heat and Temperature"

The findings obtained from the descriptive analysis made in order to determine the knowledge level of the pre-service science teachers regarding the difficulties and limitations of the students in learning "Heat and Temperature" subjects are presented in the graphic in Figure 3.

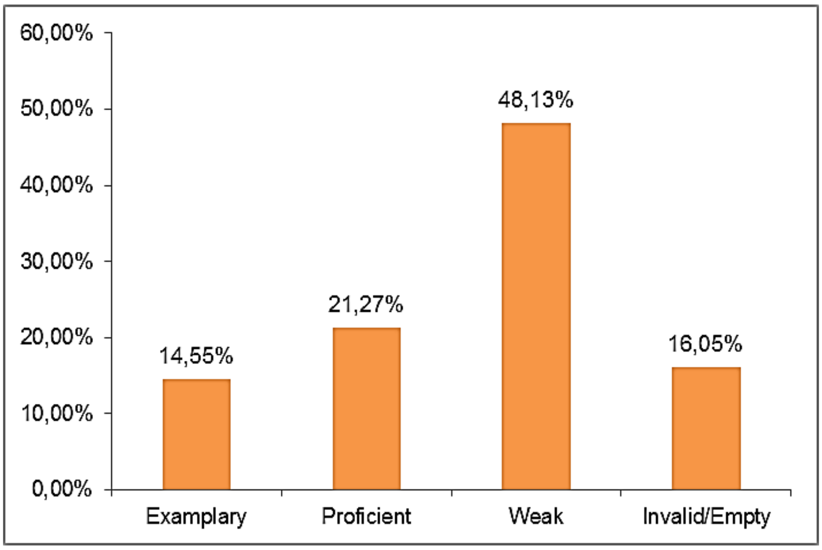


Figure 3. The Distribution of Knowledge Levels of Pre-Service Science Teachers on the Difficulties and Limitations of Students Learning About Heat and Temperature Subjects

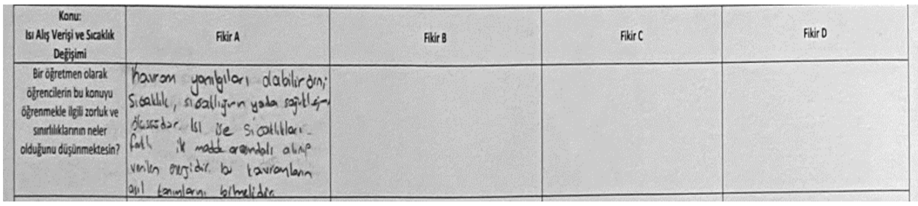
The graphic in Figure 3 shows the distribution of pre-service science teachers' knowledge levels regarding the difficulties and limitations of students while learning "Heat and Temperature" subjects. When the graph is examined, it is seen that the vast majority of the pre-service science teachers remain *Weak* (48.13%) in terms of student cognition on *"Heat and Temperature"* subjects. In addition, it is understood that 16.05% of pre-service teachers are at the *Invalid / Empty* level. However, 14.55% of pre-service teachers are at the *Exemplary* level and 21.27% of them are at the *Proficient* level. Considering especially the lack of professional experience, the rate of pre-service teachers (35.82%) reaching the *Exemplary* and *Proficient* level can be considered as a positive result. On the other hand, it is seen that the rate of pre-service teachers (64.18%) at both *Weak* and *Invalid / Empty* levels is quite worrying. These findings show that the majority of pre-service science teachers have poor knowledge on the difficulties and limitations of the students in terms of learning "Heat and Temperature" subjects.

The examples showing the level of the pre-service teachers' knowledge about the difficulties and limitations of students in learning heat and heat subjects are shown in Table 9.

Table 9. The Examples of the Knowledge Level of Pre-Service Science Teachers Regarding the Difficulties and Limitations of Students in Learning "Heat and Temperature" Subjects

The pre-service teacher's knowledge level related to the student's learning difficulties and limitations	The example about the pre-service teacher's knowledge level related to the student's learning difficulties and limitations. (What are the Difficulties / Limitations in teaching this idea? What do you know about the student thoughts that influenced teaching this idea?)
Weak	see below
Acceptable	see below

Weak

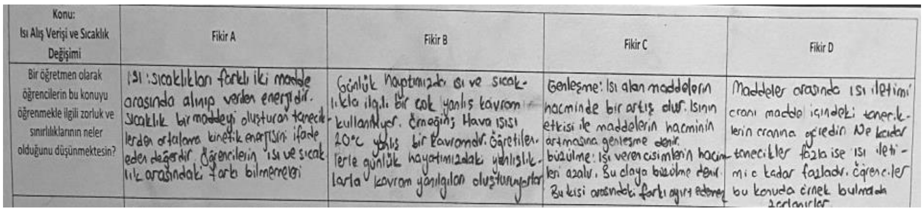


Konu: Isı Alış Verişi ve Sıcaklık Değişimi	Fikir A	Fikir B	Fikir C	Fikir D
Bir öğretmen olarak öğrencilerin bu konuyu öğrenmekle ilgili zorluk ve sınırlılıklarının neler olduğunu düşünmektesin?	kavram yanılgıları olabilir örn; Sıcaklık, sıcaklığın yada soğukluğun ölçüsüdür. Isı ise sıcaklıkları farklı iki madde arasında alınıp verilen enerjidir. bu kavramların asıl tanımları bilinmelidir.			

"There may be misconceptions. For example, temperature is a measure of warmth or coldness. Heat is the energy exchanged between two substances with different temperatures. The main definitions of these concepts should be well known."

(PST17's knowledge)

Acceptable



Konu: Isı Alış Verişi ve Sıcaklık Değişimi	Fikir A	Fikir B	Fikir C	Fikir D
Bir öğretmen olarak öğrencilerin bu konuyu öğrenmekle ilgili zorluk ve sınırlılıklarının neler olduğunu düşünmektesin?	Isı: sıcaklıkları farklı iki madde arasında alınıp verilen enerjidir. Sıcaklık bir maddeyi oluşturan taneciklerden ortalama kinetik enerjisini ifade eden değerdir. Öğrencilerin ısı ve sıcaklık arasındaki farkı bilmemeleri	Günlük hayatımızda ısı ve sıcaklıkla ilgili bir çok yanlış kavram kullanılıyor. Örneğin; Hava ısısı 20°C yanlış bir kavramdır. Öğretilenlerle günlük hayatımızdaki yanlışlıklarla kavram yanılgıları oluşturuyorlar	Genleşme: Isı alan maddelerin hacminde bir artış olur. Isının etkisi ile maddelerin hacminin artmasına genleşme denir. büzülme: Isı veren cisimlerin hacimleri azalır. Bu olaya büzülme denir. Bu kişi arasındaki farkı ayırt edemez	Maddeler arasında ısı iletimi oranı madde içindeki taneciklerin oranına göredir. Ne kadar tanecikler fazla ise ısı iletimi o kadar fazladır. Öğrenciler bu konuda örnek bulmada zorlanırlar

"Students do not know the difference between the concepts of heat and temperature. Inaccuracies arising from some expressions used in daily life (For example, the air temperature is 20^0C.) Misconceptions about the physical changes of heat transmitting and receiving materials. Learning difficulties in understanding heat conduction between substances."

(PST213's knowledge)

Table 9 contains sample quotations showing the level of knowledge of students' difficulties and limitations in learning the "Heat and Temperature" subjects of PST213 and PST17. When the answer written by the pre-service teacher coded PST17 on the interview form is examined, the students can come up with a single idea about the learning difficulty in this subject, however, the students have many difficulties in learning this subject. It is seen that the PST213 coded teacher candidate is more detailed and more aware of the student learning difficulties.

Discussion and Conclusion

Pre-service science teachers' understanding of the students on the subject of "Heat and Temperature" is examined in this study. The results show that the vast majority of pre-service science teachers remain very weak in the structures of KSU on this subject. The results of the study reveal that most of the pre-service teachers cannot effectively diagnose students' misconceptions about "Heat and Temperature" and do not make scientific explanations on the basis of teacher professional knowledge regarding these misleadings.

The obtained results coincide with the results of previous studies reporting that pre-service science teachers usually have insufficient KSU (Benedict-Chambers & Aram, 2017; Frederik et al., 1999; Metioui, 2019). The related literature shows the reason why science teachers are not aware of possible misunderstandings of students is largely related to their "Content Knowledge (CK)" structure (Berry, Depaepe & van Driel, 2016; Chan & Yung, 2018; Gullberg et al., 2008; Mantyla & Nousiainen, 2014; Ozden, 2008; Rasul, Shahzad & Iqbal, 2019). The results of Van Zee, Roberts-Harris and Grobart’s researches (2016) show that pre-service science teachers are not aware of students' misunderstandings about “Heat and Temperature”, which is closely related to the weakness of CK structures. Garcia-Carmona (2020) also reveals the relationship between CK and KSU, which science teachers have on "Heat and Temperature" in their research. Therefore, it can be said that the primary step to improve the KSU structures of pre-service science teachers is the evaluation and development of the pre-service teachers' CK structures in the prevocational period. However, pre-service science teachers cause the students to misunderstand while teaching subjects they do not specialize when they start the profession according to the study carried out by Tanahoung et al. (2009). Therefore, it can be said that pre-service science teachers cannot reach the sufficient KSU level in science subjects that they have structured weakly during their undergraduate period. Moreover, this may lead pre-service teachers to start the profession and not to be aware of their students' misunderstanding in various science subjects and not to know how to provide them with useful explanations. In addition, it is revealed that most of the pre-service science teachers cannot predict the potential learning difficulties of the students and are weak in considering them as a result of the research. This situation reveals that pre-service teachers concentrate only on a professional knowledge structure based on CK. Therefore, this situation shows that many of the teacher preparation programs are weak to build professional knowledge on the basis of possible student misunderstanding regarding science subjects.

Furthermore, many studies show that the construction of KSU-based professional knowledge in science strengthens teachers' PCK development (Nurmatin & Rustaman, 2016). Therefore, it can be said that strengthening the KSU structures of pre-service teachers in the context of student learning difficulties that stand out in the literature will make significant contributions to the construction of their PCK structures.

Recommendations

The results of this study provide some important clues about the quality of science teacher training in the context of Turkey. Based on these results, it is thought that the development of the KSU on "Heat and Temperature" of pre-service science teachers in the prevocational period will be useful in reducing students' misconceptions in these subjects in the future. In addition, course contents focusing on CK and KSU should be created in science teacher preparatory programs. It should be ensured that both the CK and KSU structures of pre-service teachers on subjects, which the secondary school students have difficulty in learning, should be developed through these programs. Moreover, pre-service teachers should be given the opportunity to correct their own mislearning and develop strategies to eliminate student learning mistakes. Moreover, pre-service teachers should be encouraged to form a critical approach on their professional knowledge. In addition, it is necessary to investigate whether they have CK and KSU professional knowledge deficiencies in other science subjects before the pre-service teachers graduate from teacher training programs.

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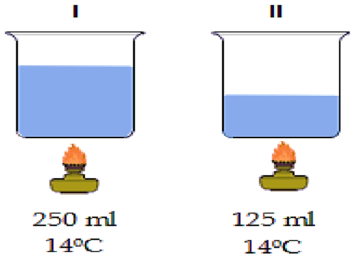
Appendix A.

Student Thinking Comprehension Test

The science teacher takes an exam to determine his students' cognition on the "Heat and Temperature" subject. The questions in this exam and the answers given by the students are listed below. Considering that you act in place of this teacher, make your assessments of the answers given by the students to the section reserved for you below.

Q1. The water in the Ist and IInd identical vessels is heated in the same amount of time in the figure on the right. What is the temperature of the water in the IInd vessel when the temperature of the water reaches 30^{0}C in the Ist vessel? Explain the reason.

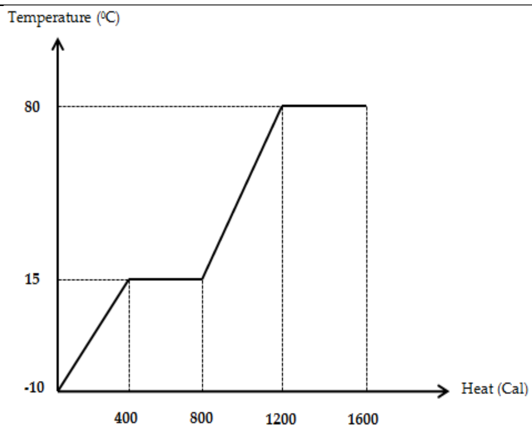


Student response: ***"I think the final temperature of the water in the IInd vessel will be 30˚C. This is because, when the water with the same initial temperature is heated in the same amount time, the increase in temperature will be the same. If we put it this way: The temperature change after heating 250 ml of water in the Ist vessel is 16˚C. 4000J is required for the 16˚C temperature increase of the water in the vessel. Likewise, since a temperature of 4000J is required in the IInd vessel in the same amount of time, there is a temperature increase of 16˚C again, which means that the final temperature of the IInd vessel will be the same as in the Ist vessel. "***

By examining the student's answer, make your assessment related to the quality of this answer.

Preservice teacher evaluation;

Q2. A Heat-Temperature graph of substance A is given on the right. When you look at this chart, what do you think about the change of state and mass of Substance A? Explain your answers by taking into account the values in the chart. (Heat of fusion of substance A 200 cal/g)

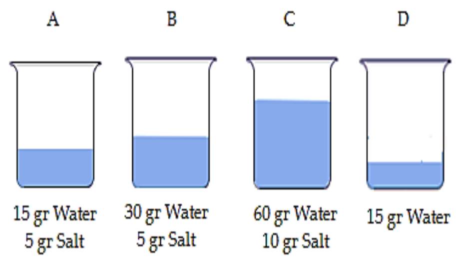


Student response: *"According to this graph, substance A begins to melt at -10 ° C and boil at 80°C. In addition, substance A is solid between 15°C and -10°C, and liquid between 15°C and 80°C. When we examine the graph, the top horizontal line above for substance A indicates that this substance has reached the boiling point and after reaching this point, it will continue to boil at this temperature for a while. The lowest value is -10°C, which refers to the melting point of substance in such graphs. If this chart has lower values, those values will indicate freezing point. The substance amount of A can be found by using 800 cal, which is the heat given in the melting state in the graphic above. Since the melting temperature of this substance is 200 cal/g, a total temperature of 800 cal is given here to melt 4 g substance."*

By examining the student's answer, make your assessment related to the quality of this answer.

Preservice teacher evaluation;

Q3. The identical vessels contain water and salt whose amount are specified below them. Let's imagine that we put the water in these vessels in front of our window on a cold winter day. What do you think about the freezing order of the water in these vessels? Explain the reason.

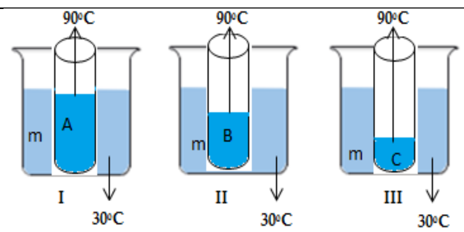


Student response: *"When we observe these vessels with water and salt, the water in vessel D will freeze first. Then the water in vessels A and B will freeze at the same time. The water will freeze in vessel C at the latest. This is because salt lowers the freezing temperature of water. Therefore, when we look at the amount of salt in the vessels, there is no salt in the D vessel, so the water in this vessel will start to freeze first. Then the water in the A and B vessels, which have an equal amount of salt as 5g, will start to freeze at the same temperature. Finally, the water in vessel C where maximum salt is added as 10 grams will freeze."*

By examining the student's answer, make your assessment related to the quality of this answer.

Preservice teacher evaluation;

Q4. The identical Tubes A, B, C have 90°C with a mass of 400g, 300g and 200g, respectively. These tubes are submerged in vessels I, II and III with a temperature of 30°C and equal amount of water. What do you think about the temperatures of the water in vessels I, II and III when heat exchange between tubes and containers is completed? Explain the reason.

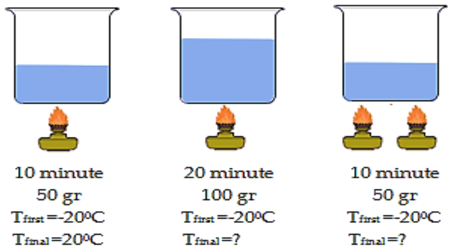


Student response: *"Here, the temperature of each tube is equal and 90°C. It is also known that the masses of containers I, II and III are equal. Since the mass of the liquid in tube A is 400 g and the maximum, the maximum temperature change will be in the Ist vessel, then a little less change will be in the IInd vessel where* *the tube B is submerged, and the least temperature change will be in the III^rd^ vessel in which the tube C with the smallest mass is submerged."*

By examining the student's answer, make your assessment related to the quality of this answer.

Preservice teacher evaluation;

Q5. What do you think about the final temperature of vessels II and III compared to vessel I? Explain the reason.



Student response: *"When we start examining the first vessel, it is seen that there is a change of 40°C between the first temperature and the last temperature. If there is a 40 °C change in a vessel with a mass of 50 g, a temperature change of 80 °C occurs in a vessel with a mass of 100 g. Therefore, the final temperature of the IInd vessel is 60°C. Furthermore, considering the final temperature of the third container by taking into account the Ist container, the mass is the same, but twice as much as the heat of the first vessel is given, which means that twice as much as Ist vessel will be the final temperature of the vessel, ie 40 °C.*

By examining the student's answer, make your assessment related to the quality of this answer.

Preservice teacher evaluation;