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EXAMINATION OF PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDING LEVELS OF KEPLER'S LAWS WITH RANKING TASK QUESTIONS

Abstract. *The purpose of this study was to investigate pre-service science teachers' understanding levels of Kepler's second and third laws. The participants of the study were 38 pre-service science teachers who attended introductory astronomy class in their teacher education program. The participants' understandings of Kepler's laws were examined by their answers to ranking tasks, which required participants to rank the situations given in the question, and then to explain the reasons behind their answers. The findings showed that the participants' understanding levels ranged from partial understanding with alternative conceptions to sound understanding. Moreover the number of the participants with partial understanding with alternative conceptions exceeded the participants with sound understanding. The participants' explanations to ranking tasks also indicated that although participants knew the classic statements of Kepler's laws, they had also alternative conceptions. Five different alternative conceptions were identified from the participants' explanations. Two of them have not been reported in previous studies.*
Key words: *Kepler's laws, pre-service science teachers, ranking tasks, understanding levels.*

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Introduction

Celestial objects and their movements have always drawn attention of human beings for millenniums. Consequently, as one of the oldest sciences, astronomy has shown great progress and still continues to develop since prehistoric times. On the other hand research on astronomy education has started to develop in the last three decades and it is a relatively new research area compared to astronomy (Bailey & Slater, 2003; Lelliott & Rollnick, 2010). Research on astronomy education inquires about the best ways to teach extensive knowledge that astronomy has produced through the history. In this respect, teachers play a central role in the implementation of the research results in classrooms. Research on education shows that one of the important factors affecting the quality of education is teachers' content knowledge (Greenwald, Hedges, & Laine, 1996; Gess-Newsome, 2001). In order to teach astronomy well, teachers need to have a deep understanding of the astronomical topics. For this reason, the investigation of the teachers' knowledge and understanding of the astronomical topics is important.

In research on astronomy education, students' understanding levels, misconceptions, and difficulties about basic astronomy topics have been investigated in various studies (e.g. Mali & Howe, 1979; Nussbaum, 1979; Sneider & Pulos, 1983; Baxter, 1989; Sadler, 1992; Vosniadou & Brewer, 1992; Zeilik, Schau, & Mattern, 1998; Zeilik, Bisard, & Lee, 2001; Vosniadou, Skopeliti, & Ikospentaki, 2004; Ogan-Bekiroglu, 2007). In these studies, students' understanding of basic astronomy concepts and students' alternative understandings were explored at all levels namely primary, secondary and university levels (e.g. Jones, Lynch, & Reesink, 1987; Baxter, 1989; Sahin, 2001; Ekiz & Akbas, 2005). Mostly investigated subjects were basic astronomy topics such as causes of the seasons, solar system, phases of the moon and stars (e.g. Bisard, Aron, Francek, & Nelson, 1994; Trumper, 2000; Zeilik & Bisard, 2000; Iyibil & Saglam Arslan, 2010).

Findings of these studies indicate that students at all levels including pre-service teachers showed similar alternative understandings about astronomy concepts (Trundle, Atwood, & Christopher, 2002). According to research and theories on students' conceptual understanding, students do not overcome their misconceptions or alternative understandings unless they are addressed appropriately. Therefore, to help students to develop scientific understanding of science and astronomy concepts, it is important to design learning environments that supports conceptual understanding (Fosnot, 1996; Duit & Treagust, 2003). Moreover, research results showed that one of the sources of students' alternative understandings is teachers (e.g. Osborne & Cosgrove, 1983; Barrass, 1984; Soyibo, 1995; Altinkaynak Yaylaci, Yamak, & Kavak, 2011). Teachers who have their own alternative understandings or less competent in subject matter knowledge, may transmit their flawed views to their students. In this respect, as a part and creator of a learning environment, teachers play an important role in the development of their students' understanding. Thus, for pre-service science teachers it is more important to develop scientific understanding of concepts that they will teach. In order to have scientifically literate society, pre-service science teachers must first overcome their own alternative understandings and become knowledgeable about students' potential alternative conceptions (Trundle, Atwood, & Christopher, 2007). For all these reasons, it is important to investigate pre-service science teachers' understanding levels of astronomy.

Pre-service teachers' understanding of astronomy concepts has been investigated for various topics. For instance, Atwood and Atwood (1997) explored pre-service elementary teachers' conceptions of the causes of night and day and the seasons. Similarly Trumper (2006a, 2006b) investigated pre-service teachers' basic understanding of Sun-Earth-Moon relative movements and seasonal changes. Trundle, Atwood, and Christopher (2002, 2006, and 2007) and Ogan-Bekiroglu (2007) examined pre-service teachers' understanding of phases of the Moon. Iyibil and Saglam Arslan (2010) investigated pre-service physics teachers' models about the concept of star. Although movements of the Moon and the Earth have been investigated to explain phases of the moon and seasons in various studies, pre-service science teachers' understanding of these movements related to Kepler's laws has not been studied as much.

Kepler is one of the important historical figures with the laws that he introduced to astronomy and science. With his laws, Kepler correctly modeled the movements of the objects in the Solar system based on Brache's observational data. He also developed Copernicus' circular solar system model to the elliptical model. Moreover his second and third laws provided a base for Newton's universal law of gravitation. In this respect Kepler and his laws play an important role in introduction and explanation of the development process of astronomy to students.

Despite this fact, the number of studies on students' understanding of Kepler's laws is scarce. One of the exceptions of this is the study of Yu, Sahami, and Denn (2010). In their study, they examined university students' understanding of Kepler's laws before the instruction. In the study, students were asked questions about the shape of the planets' orbits and details of the velocities of the planets. According to their results, 75% of these students thought that planets' orbits are highly elliptical. This means that most of the participants do not know Kepler's first law correctly. Although Kepler's first law states that the planets' orbits are elliptical, they are not highly elliptical. In addition, Yu et al. (2010) observed that 60% of the participants did not have any idea about the speeds of the planets, and some (20% of the participants) thought that planets move at constant speed. In addition, participants, who thought planets move at different speeds, stated that inner planets move faster than that of the outer ones. These results indicated that some of the participants were aware of Kepler's second and third laws. Eight of their participants believed that speed of the planets is dependent on the mass of the planets. Only one participant explicitly stated that the smaller planets move faster. In their study, the researchers mostly focused on and explained the reasons behind the misconception about the Kepler's first law. However, the authors did not elaborate on their research results of Kepler's second and third law in detail as much as the first law. In their conclusions, the authors recommended using virtual simulations to help students visualize and understand Kepler's' laws.

Another study on Kepler's law was done by Bostan-Sarioglan and Kucukozer (2013). They investigated 133 tenth grade students' understanding of Kepler's second law. In this study, the participants were asked the speed of the Earth at points A (aphelion) and B (perihelion). The authors found that none of the participants showed sound understanding of the law. Thirty participants knew that the Earth moves faster at point B than point A, but they did not give any explanation. Therefore, they were considered at partial understanding level. On the other hand, 14 participants had knowledge of Kepler's second law, but they also had alternative conceptions. Most of their participants' (65%) understanding was at alternative conceptions level. The alternative conceptions

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that were identified in their study were: the speed of the Earth is higher at point A (aphelion), because the Earth is farther away from the Sun at point A, and the speed of the Earth is faster at point A, because the Earth has traveled longer distance at point A. Nevertheless, the authors did not provide any explanations for the reasons of these alternative conceptions.

In their study, Bostan-Sarioglan and Kucukozer (2013) used open ended questions and Yu et al. (2010) used also students' drawings in addition to open ended questions to assess their participant's understanding of Kepler's laws. On the other hand, in science and astronomy education, various methods are used to assess students' conceptual understanding. Among those methods multiple-choice concept tests, two-tier concept tests take their places among others (Treagust, 1988). Concept tests usually focus on identifying students' misconceptions or alternative conceptions. In addition to choices, two-tier questions include explanation level as a second tier. After choosing an answer, students provide or choose an explanation for their answers in two-tier questions. The purpose of this dimension is to eliminate chance factor in multiple-choice questions and determine the students' justifications for their answers. Ranking task method is a kind of two-tier tests. In these tasks, students are asked to rank given situations instead of multiple choice questions, and then they explain the reasons behind their ranking. In this way, these tasks allow researchers to better understand reasoning behind students' thoughts (Maloney, 1987). In this study to assess pre-service science teachers' understanding levels of Kepler's second and third laws ranking tasks were used.

The Purpose of the Study

As stated previously, it is important for pre-service teachers to develop scientific understanding of the topics that they are going to teach and be informed about students' common misconceptions in their subject area. Although there are many studies investigating students' understanding of basic astronomy concepts, Kepler's laws have not been investigated for pre-service science teachers. The previous research about Kepler's laws only focused on freshmen and high school students' pre-conceptions. Our study, however, aims to fill the gap in this area. The purpose of this study is to investigate pre-service science teachers' understanding levels of Kepler's second and third laws.

Methodology of Research

General Background of Research

In order to achieve the purpose of the study, data collection and analysis methods of qualitative research design were used. By using this research method, it was possible to describe the participants' understanding levels thoroughly in the study. LeCompte and Preissle (1994) state that "Qualitative research is based on and grounded in descriptions of observations." (p.141). In this study, observations about the participants' understanding levels were made through their explanations and answers to ranking tasks about Kepler's laws. Those explanations for ranking tasks provided the opportunity to make detailed descriptions of their understanding levels. The obtained data were analyzed via content analysis.

Sample of Research

The study was performed with 38 pre-service science teachers who attended astronomy class in science and technology education program in 2013 Spring semester. The participants of this research were identified by convenience sampling method. Convenience sampling is defined as a sample in which research participants are selected based on their convenient accessibility and proximity to the researcher (Saumure & Given, 2008). Eleven of the participants were male and 27 were female pre-service science teachers. In this astronomy class, the participants were taught history of astronomy, Kepler's laws, universal law of gravitation, solar system, phases of the moon, planets and their satellites, galaxies, formation of stars, red giants, and black holes. The data has been collected after Kepler's laws have been discussed in the class.

Instrument and Procedures

Four ranking tasks (RTs) about Kepler's second and third laws were used to investigate the participants' understanding levels. RTs are paper and pencil based questions that ask students to rank several slightly different variations of a specific situation or concept. RTs type questions were formerly introduced by Maloney (1987) based on Siegler's (1976) rule assessment technique. RTs usually consist of four parts. The first part describes the situation and provides context for ranking. The second part presents the situations with figures. The third part provides a space for students to write down their response sequence. The last part asks students explain the reason behind their rankings. The most important characteristic of RTs is to elicit students' comparative judgments and the reasons for those judgments. In this respect, RTs are two-tier tasks that require students to give and explain their answers.

The four RTs[1] used in this study were developed by Hudgins, Prather, Grayson, and Smits (2007). The RT 1 and 2 provided information about the participants' understanding levels of Kepler's second law. On the other hand, RTs 3 and 4 helped us to assess the participants' understanding of Kepler's third law. Moreover, the first RT included three sub tasks: RT 1a, 1b, and 1c. The details of the RT questions are provided below.

Kepler's second law states that a planet's radius vector sweeps out equal areas over equal times. To address this law, the RT 1a asked the participants to rank the *time* for a comet to travel four different segments (with same area) of its orbit around the Sun as seen in figure 1. In the RT 1b students ranked the *distances* that the comet travelled in each segment of its orbit. In the RT 1c, the *speed* of the comet was ranked for four different segments of its orbit. The RT 2 also asked the speed of an asteroid at four different points of its elliptical orbit around the Sun.

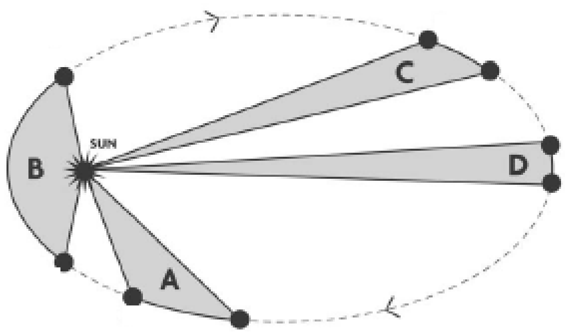

Figure 1: Elliptical orbit of a comet traveling around the Sun. The shaded areas are equal.

The RTs 3 and 4 addressed the third law. According to Kepler's third law, the square of the orbital period of a planet is proportional to the cube of its semi-major axes. $P^2 \sim a^3$ where "a" is semi-major axis and "P" is period with units of years and in units of Astronomical Units. In simple words, this law implies that an outer planet have longer period than an inner planet orbiting the Sun and an outer one also travels at slower speeds than an inner planet. To address this law, the RT 3 asked the students to rank the orbital periods of five planets with different orbits (3 circular and 2 elliptical). Finally, the RT4 asked students to rank the orbital periods of four planets, orbiting the same star, with different radiuses and masses.

Data Analysis

The participants' answers to RTs provided two-level data. The first level was the rankings and the second level was reasons for the rankings. These levels were evaluated together. If the student's ranking was incorrect, but following explanation was correct then the student's answer was considered as correct. In other words, in determining correctness of the answers, students' explanations played the major role.

The obtained data were analyzed according the understanding levels suggested by Abraham, Williamson, and Westbrook (1994). In this analysis method, students' answers are categorized into five different understanding levels. These levels are: no understanding (NU), alternative conception (AC), partial understanding with specific

1 The RTs were obtained from http://astro.unl.edu/interactives/ web site

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alternative conception (PU/AC), partial understanding (PU), and sound understanding (SU) levels. The details of these levels are provided in the following list. At the first step of the analysis, correctness of students' answers and typical explanations were identified for each question. In the second step, these answers were coded with understanding levels for Kepler's second and third laws. While doing this, coherency of students' related answers were checked as suggested by Aktan (2013). In other words, the students' answers to RTs 1a, 1b, 1c, and 2 were coded together to determine their understanding levels about the Kepler's second law and RTs 3 and 4 were coded together to determine students' understanding levels of the Kepler's third law. The following part shows the students' typical answers to each question and the percentages of these answers.

No Understanding (NU): Blank, repeats question; irrelevant or unclear response,
Alternative Conception (AC): Scientifically incorrect responses containing illogical or incorrect information,
Partial Understanding with Specific Alternative Conception (PU/AC): Responses showing that the concept is understood but also containing alternative conception,
Partial Understanding (PU): Responses containing some components of the scientifically accepted response,
Sound Understanding (SU): Responses containing all components of the scientifically accepted response.

Results of Research

Results about Participant's Understanding of Kepler's Second Law

In their answers to the RT 1a, 25 participants (66%) ranked the times correctly. As an explanation 15 of these participants (40%) only stated Kepler's second law correctly, which is comet sweeps out equal areas over equal times. On the other hand, in addition to providing the classic statement of Kepler's second law, 10 participants (26%) also explained that the comet travels at different speeds at each segment of its orbit. However, 13 participants (34%) gave incorrect answer. Eight of them (21%) stated that it takes less time to travel the segments closer to the Sun, because the comet moves faster when closer to the Sun. Although these participants knew that the speed of the comet varies on its orbit, they failed to consider arc length of each segment. Moreover, 5 of the participants (13%), who gave incorrect answer, reported that comet moves at constant speed, and it takes more time to travel the longer distances.

RT 1b asked the arc length of each segment. Thirty participants (53%) ranked the arc lengths correctly. Twenty of them (53%) explained that according to the figure in the question, the comet travels longer distances when it is closer to the Sun and shorter distances when it is farther away. On the other hand, as their explanation, 10 students (26%) stated that to sweep out equal areas in each segment, the comet travels longer distances and moves faster when it is closer to the Sun. Nevertheless, 8 students (21%) gave unclear answers to the RT 1b.

RT 1c posed a question about the speed of a comet at each segment of its elliptical orbit. As an explanation to their correct rankings, 15 participants (39%) just stated that the comet moves faster when it is closer to the Sun. In addition to this answer, 13 participants (34%) also explained that the comet moves faster to sweep out equal areas, when it is closer to the Sun. Contrary to these correct answers, 2 students (5%) thought that the comet moves slower when it is closer to the Sun and 4 participants (11%) stated that the comet moves at constant speed at its orbit. Moreover, 4 participants (11%) gave no explanation to their answers.

RT 2 asked the speed of an asteroid at different points of an elliptical orbit. Along by their correct rankings, 14 participants (37%) stated that the asteroid moves faster when it is closer to the Sun. Eleven participants (29%) also explained that the speed of the asteroid is reversely proportional to the distance between the Sun and the asteroid. However, 6 participants (15%) thought that the asteroid moves slower when it is closer to the Sun. Akin to the RT 1c answers, there were also three participants (8%) who thought that the asteroid moves at constant speed. Four participants (11%) gave no explanation in their answers. The participants' typical answers to RT 1a, 1b, 1c, and 2 and the frequencies of the answers are presented in the Table 1.

Table 1. The participants' typical answers to RT 1a, 1b, 1c, and 2 and the number and frequencies of these answers.

Questions	Responses	N	%
Kepler's Second Law			
RT1a-Rank the time for a comet to travel equal areas in elliptical orbits	Comet sweeps out equal areas over equal times	15	40
	Comet sweeps out equal areas over equal times because it travels with different speeds at each segment	10	26
	Comet moves faster when closer to the Sun, therefore it takes less time to travel the segments closer to the Sun	8	21
	Comet moves at constant speed and it takes more time to travel the longer distances	5	13
RT1b- Rank the distance for a comet to travel equal areas in elliptical orbits	According to the figure in the question, comet travels longer distances when it is closer to the Sun and shorter distances when it is farther away	20	53
	To sweep out equal areas in each segment, the comet travels longer distances and moves faster when it is closer to the Sun	10	26
	Confused understanding	8	21
RT1c- Rank the speed of a comet at each segment of its elliptical orbit with equal areas	The comet moves faster when it is closer to the Sun	15	39
	The comet moves slower when it is closer to the Sun	2	5
	Because the comet sweeps out equal areas over equal times, it moves faster when its closer to the Sun	13	34
	The comet moves at constant speed	4	11
	No explanation	4	11
RT2- Rank the speed of an asteroid at different points of its elliptical orbit	The asteroid moves slower when it is closer to the Sun	6	15
	The asteroid moves faster when it is closer to the Sun	14	37
	The speed of the asteroid is reversely proportional to the distance between the Sun and the asteroid	11	29
	The asteroid moves at constant speed	3	8
	No explanation	4	11

Each participants' answers to RT 1a, 1b, 1c, and RT 2 were evaluated together to determine their understanding levels of Kepler's second law. Table 2 summarizes the results of the participants' understanding levels of Kepler's 2nd law.

Table 2. The participants' understanding levels of Kepler's second law.

Levels	Frequencies	Percentages
No Understanding-NU	0	0
Alternative Conception-AC	13	34
Partial Understanding with Specific Alternative Conception-PU/AC	9	24
Partial Understanding -PU	0	0
Sound Understanding-SU	16	42

According to their answers, 13 participants (34%) did not know the classic statement of Kepler's second law and gave incorrect answers to the RT1a. These participants' answers were categorized as alternative conceptions.

ISSN 1648–3898

As seen in Table 1, 5 participants (13%) thought that comet moves at constant speed and it takes longer time to travel the longer distances. In this typical answer, "constant speed" idea was considered as alternative conception. An example of constant speed alternative understanding comes from the participant number 35.

> I thought x= V. t formula. The speed of this comet is constant. The distances that the comet took are different. Under this circumstance, the times will be different. So the times are directly proportional to the covered distances.
>
> (Participant 35 - RT1a)

> Speeds of all planets, stars, and satellites are always constant.
>
> (Participant 35 - RT1c)

Second kind of alternative conception appeared also at participants' incorrect answers to RT 1a. Eight participants (21%) incorrectly answered RT 1a and reported that it takes less time for a comet to travel the segments closer to the Sun, because the comet moves faster when closer to the Sun. Although these participants knew that the speed of the comet varies in its elliptical orbit, they could not apply it to the question. The following answer of the participant number one to RT 1a illustrates this case.

> The speed of the comet increases, when it gets closer to the Sun. Therefore, at the closest segment, the comet spends less time because it is faster.
>
> (Participant 1 - RT1a)

This answer demonstrates that since the participant one failed to consider the arc length of each segment, the participant confused "speed" concept with "time" concept. At this point, the participants who gave similar answers were considered as having alternative conception about the "speed- time" confusion.

Contrary to the participants who had only alternative conceptions about Kepler's second law in the study, some participants knew the statement of Kepler's second law, but at the same time they also had alternative conceptions. These participants were considered at partial understanding with alternative conceptions (PU/AC) level. According to table 2, 9 participants' answers (24%) were at partial understanding with specific alternative conception level. Although these participants knew the statement of Kepler's second law, they did not understand this law and had alternative conceptions about it. The following excerpts exemplify the responses of the students at partial understanding with alternative understanding level.

> It (*the comet)* sweeps out equal areas at equal times.
>
> (Participant 4 - RT1a)

> The comet travels slower when it is closer to the Sun, and faster when it is far from the Sun.
>
> (Participant 4 - RT1c)

The first excerpt shows that the participant knew Kepler's second law, but at the same time the second excerpt demonstrates that she also had an alternative conception which is the comet moves slower when it is closer to the Sun. Among others, the participants 15 and 17 also had a similar alternative conception. In her answer, the participant 15 further explained that

> The speed of the comet decreases when it gets closer to gravitational field, because the comet enters to gravitational field.
> (Participant 15 - RT1c)

In addition, according to the participant 17;

> The Sun has a gravitational force. D is the closest point on the orbit. Therefore, the asteroid is exposed to the strongest attraction at D. Thus it will get slower at this point. On the contrary, because the point B is the farthest, the asteroid will move the fastest at this point.
>
> (Participant 17 - RT1c)

The participants who had this alternative conception did not understand forces that keep the comet in its orbit. They thought that gravitational force slows down the comet. Five (14%) of the participants at partial understanding with specific alternative understanding level supposed that the comet travels slower when it is closer to the Sun. On the other hand, 2 participants (5%) at partial understanding with specific alternative understanding level stated that the speed of the comet is constant. Although the participants at PU/AC level knew Kepler's second law, they answered the other related questions incorrectly. According to the findings there were no participants at partial understanding level.

The participants at sound understanding level correctly stated Kepler's second law in their answers to RT1a. In addition, these participants' correct answers and consistent explanations to the RTs 1a, 1b, 1c and 2 provided evidences for their sound understanding. In their explanations, these participants pointed out that the speed of the comet varies according to its position on its orbit. The participants stated that comet travels faster when it gets closer to the Sun and slower when it gets further. Few students also related the change of speed with gravitational force. In RT 1b, the participants also noticed the connection between the distance that the comet travelled in each segment and the speed of the comet. Thus, they concluded that the time to travel the each part for the comet stays constant. The following answers of the participant 12 illustrate the evidences for her knowledge and understanding of Kepler's second law.

> According to Kepler's second law, the radius vector connecting the comet to the Sun sweeps equal areas in equal times.
>
> (Participant 12 - RT1a)

> According to Kepler's second law, in order to sweep equal areas in equal times, the comet should cover more distance when it is closest to the Sun than it is farthest to the Sun.
>
> (Participant 12 - RT1b)

> According to Kepler's second law, the comet should travel the fastest when it is closest to the Sun and the slowest when it is farthest. When universal gravitational force is equated to the centripetal force, radius will be inversely proportional to speed. So, it will travel fastest when the comet is the closest to the Sun and slowest when it is farthest to the Sun.
>
> (Participant 12 - RT1c)

According to analysis results, it was observed that 16 participants (42%) showed evidences that they understood the second law at sound understanding level. The similar analyses were done also for the Kepler's third law. In the following section students' typical answers for Kepler's third law and their percentages are provided in detail.

Results about Participant's Understanding of Kepler's Third Law

The participants' answers to RT 3 provided information about their knowledge of Kepler's third law. In this specific question, the participants ranked the orbital periods of the planets given in the question. Twenty-six participants (68%) knew that the orbital period of a planet is proportional to its semi-major axis. In addition to this knowledge, to answer the question correctly the participants must also know the concept of semi-major axis of an ellipse. Twenty six students knew Kepler's third law, but only 19 of them answered the RT 3 correctly and six participants gave an incorrect answer because they could not figure out the semi-major axis of an ellipse. Moreover 6 participants (16%) explained that planets that are closer to the Sun move faster, therefore they have shorter orbital periods. However one participant (3%) thought that all the planets orbiting the Sun have the same orbital periods. Unfortunately 5 participants (13%) did not provide any explanation. Of those, three participants correctly ranked the periods of the planets, but two of them did not.

Kepler's third law deals with dependence of planets' periods to planets' orbital distances from the Sun. In addition to distance from the Sun, the RT 4 also added mass variable into the question and asked orbital periods of the planets orbiting the same star with different radiuses and masses. Only 8 participants (21%) knew that the orbital period of a planet is proportional to its radius, but it is independent of its mass. These participants correctly answered the RT 4. On the other hand, 19 participants (50%) stated that the orbital period of a planet is proportional to its radius, and it is dependent of its mass. These 19 participants ranked the orbital periods of the planets

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incorrectly. Unfortunately, 11 participants (29%), whom rankings are incorrect, did not write any explanations to their answers.

Table 3. The participants' typical answers to RT 3 and 4 and the number and frequencies of these answers.

Kepler's Third Law		N	%
RT3- Rank orbital periods of the planets with different radiuses and semi-major axis	The orbital period of a planet is proportional to its semi-major axis (students know semi-major axis of an ellipse)	19	50
	The orbital period of a planet is proportional to its semi-major axis (students do not know semi-major axis of an ellipse)	7	18
	Planets that are closer to the Sun move faster, therefore they have shorter orbital periods	6	16
	All the planets orbiting the Sun have the same orbital periods	1	3
	No explanation	5	13
RT4- Rank orbital periods of the planets, orbiting the same star, with different radiuses and masses	The orbital period of a planet is proportional to its radius and independent of its mass	8	21
	The orbital period of a planet is proportional to its radius and dependent of its mass	19	50
	No explanation	11	29

According to the results (table 4) only one student did not show any evidence that he/she neither knew nor understood Kepler's third law. This participant incorrectly answered both RT 3 and 4, did not provide any explanation. Nevertheless, 21 participants (55%) correctly answered RT3, but gave incorrect answers and explanations to RT 4. As seen in table 4, these participants' understanding levels were assessed as PU/AC level. These participants knew Kepler's third law and answered the RT 3 correctly. However, they thought that period is dependent on the planet's mass and consequently answered the RT 4 incorrectly. The dependence of the planet's period to its mass is considered as alternative conception. The participants showed two kinds of alternative conceptions about mass period relation. The first alternative conception was that the mass of the rotating object is inversely proportional to its period. The following excerpt exemplifies the responses of the participants with this kind of alternative conception.

According to $\frac{T^2}{r^3} = \left(\frac{4\pi}{Gm}\right)$ formula, T^2 is directly proportional to r^3 and inversely proportional to m.
(Participant 14 - RT 4)

As it is observed in this excerpt, some participants plugged the mass of the planets into $(T^2/r^3) = (4\pi/Gm_{Sun})$ equation instead of the mass of the Sun. As a result of their calculations, they reported that the periods of the heavier planets are shorter than that of the lighter planets. They thought that as the mass of the planet increases the planet's period decreases. On the other hand, as a second alternative conception, some participants stated that the heavier planets' periods are longer than that of the lighter planets. In other words, as the mass of the planet increases the planet's period also increases. The following answer of the participant 33 illustrates this alternative understanding.

> When we compare C and D, their diameters are equal but C is 3 times heavier, therefore its period will be longer. The periods of C and D is longer than A and B because radiuses of C and D are bigger than that of the A and B, and as the r (radius) increases T (period) increases.
> (Participant 33 - RT 4)

Table 4. The participants' understanding levels of Kepler's 3rd law.

Levels	Frequencies	Percentages
No Understanding-NU	1	3
Partial Understanding with specific Alternative Conception-PU/AC (RT3 correct and RT4 incorrect)	21	55
Partial Understanding with specific Alternative Conception-PU/AC2 (RT3 and RT4 incorrect)	8	21
Sound Understanding -SU	8	21

Understanding levels of the participants (21%, 8 students) who incorrectly answered the question RT 3 and RT 4 were assessed as PU/AC2. Although these students knew Kepler's third law, they could not give correct answer to RT 3, since they miscalculated the semi-major axis. Furthermore, as observed at PU/ AC level, the students at PU/ AC2 level also had alternative conception, which is the planet's period is dependent to its mass.

The participants who correctly answered the RT 3 and 4 were considered at sound understanding level. These participants knew both the orbital period of a planet is proportional to its semi-major axis or its radius, and it is also independent of its mass. According to table 4, 8 participants' (21%) answers were at sound understanding level. The following answer of the participant 38 demonstrates this case and provides evidence for his sound understanding.

> Period of a rotating object does not depend on its own mass. A planet which is closer to the Sun has smaller period, because it is exposed to a larger gravitational force and this increases its velocity. Two planets with same mass and radius have equal periods. Planets with greater radius have longer periods.
>
> (Participant 38 - RT 4)

Discussion

In this study, 38 pre-service science teachers' understanding levels of Kepler's second and third laws were investigated by using ranking tasks and understanding levels suggested by Abraham et al. (1994). These levels helped us to see differences among the participants' understandings between no understanding and sound understanding.

According to the results, 13 students (34%) did not know the classic statement of Kepler's second law. Instead they answered the related question with their own alternative conceptions. Three alternative conceptions were observed about Kepler's second law. These were:

1. Celestial objects travelling in an elliptical orbit travel constant speed along their orbit.
2. Celestial objects, travelling in an elliptical orbit around the Sun, move slower when they get closer to the Sun than when they are far away from the Sun
3. Confusion of "speed" concept with "time" concept.

The participants who have the alternative conception number one simply thought that celestial objects travel at constant speed in their orbits. This alternative conception can stem from some students' misunderstanding of the instruction. While Kepler's laws have been discussed in the class, the participants have been informed that orbits of the some planets in solar system are nearly circular. It can be inferred that few of the participants overgeneralized this knowledge to all planets and to other celestial objects. Some participants with alternative conception number two explicitly stated that speed of the comet decreases when it is closer to the Sun, because it gets closer to gravitational field. From those answers, we can infer that these participants did not understand the forces that keep the comet in its orbit. The participants with alternative conception number three knew that the speed of the comet varies in its elliptical orbit, but they confused the concept of speed with time. They failed to consider the arc length of the each segment of the elliptical orbit. In Yu et al. (2010) study, some of the participants also thought planets move at constant speed akin to alternative conception number one in our study. However they did not report any alternative conceptions similar to alternative conception number two and three. On the other hand, Bostan-Sarioglan and Kucukozer (2013) reported alternative conception similar to number two. Their participants also thought that the speed of the Earth is higher at the farthest point from the Sun than that of the closest point.

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We also found that, some participants (24%) knew the statement of Kepler's second law, but at the same time they also had alternative conceptions. These participants were considered at partial understanding with alternative conceptions (PU/AC) level. Although these participants knew that objects in elliptical orbits travel equal areas over equal times, they did not understand this law and explained their answers with alternative conceptions presented above. Only 42 % (16 participants) showed evidence that they understood Kepler's second law at sound understanding level. These participants both knew Kepler's second law, and provided explanations indicating that they understood the reasons behind the law.

In terms of Kepler's third law, 55% of the participants' (21 students') understanding was at partial understanding with alternative conceptions (PU/AC) level. Although these participants knew that a planet's orbital period is proportional to its semi-major axis, they also thought that period is dependent on the planet's mass. These students had two different alternative conceptions about mass period relation. These were:

1- Heavier planets have shorter orbital periods than lighter planets, because period of the rotating object is inversely proportional to its mass.

2- Heavier planets have longer orbital periods than lighter planets.

Participants with alternative conception number one incorrectly plugged the mass of the planet instead of the mass of the Sun into Kepler's third law equation. Instead of thinking conceptually, these students were using the formulas algebraically. Participants with alternative conception number two did not provide any explicit reasons for their thinking. However, we can infer that these participants may be thinking that heavier objects are hard to move than smaller objects, therefore they have longer periods. Similarly few students in the study of Yu et al. (2010) believed that speed of planet and its orbit is dependent on the size or the mass of the planet. One student in their study explicitly explained that smaller planets move faster. In our study, only 8 participants' (21%) understanding levels were at sound understanding level. These students knew both the orbital period of a planet is proportional to its semi-major axis or its radius, and it is also independent of its mass.

Conclusion

Based on the results of our study, we observed that some of the participants of the study did not overcome their alternative conceptions about Kepler's laws after the instruction. More importantly, even though some of the participants knew the classic statements of Kepler's laws, they also had alternative conceptions. Thus, the participants' understanding levels ranged from partial understanding with alternative conceptions to sound understanding. In the study, we identified five different alternative conceptions. Two of those alternative conceptions have not been reported in previous studies. At this point, this study contributes to the literature on Kepler's laws by identifying two new alternative conceptions. In addition, previous research on Kepler's laws was carried out with freshmen and high school students. This study adds new perspective to studies related to Kepler's law by carrying the investigation with the pre-service science teachers. In this respect, by shedding light on pre-service science teachers' understanding levels of Kepler's laws, and their alternative conceptions, the results of this study can be useful in the design of a lesson on Kepler's laws both for university students and students at other levels. Nonetheless, the results of this study cannot be generalized for all pre-service science teachers. Therefore, further research is required to be able to make more general statements and to understand the reasons behind the alternative conceptions that pre-service science teachers have.

References

Abraham, M. R., Williamson, V. M., & Westbrook, S. L. (1994). A cross-age study of the understanding of 5 chemistry concepts. *Journal of Research in Science Teaching, 31* (2), 147-165.

Aktan, D. C. (2013). Investigation of students' intermediate conceptual understanding levels: the case of direct current electricity concepts. *European Journal of Physics, 34* (1), 33-43.

Altinkaynak Yaylaci, Ö., Yamak, H. & Kavak, N. (2011). Examining pre-service science teachers' opinions about holistic approach in science: Electrical energy example. *Procedia Social and Behavioral Sciences*, *15*, 2764–2770.

Atwood, R. K., & Atwood, V. A. (1997). Effects of instruction on pre service elementary teachers' conceptions of the causes of night and day and the seasons. *Journal of Science Teacher Education*, *8* (1), 1-13.

Bailey, J. M., & Slater, T. F. (2003). A review of astronomy education research. *Astronomy Education Review, 2*, 20.

Barrass, R. (1984). Some misconceptions and misunderstandings perpetuated by teachers and textbooks of biology. *Journal of Biological Education, 18* (3), 201-206. doi 10.1080/00219266.1984.9654636.

Baxter, J. (1989). Childrens` understanding of familiar astronomical events. *International Journal of Science Education, 11* (5), 502-513, doi: 10.1080/0950069890110503.

Bisard, W., Aron, R., Francek, M., & Nelson, B. (1994). Assessing selected physical science and earth science misconceptions of middle school through university pre-service teachers. *Journal of College Science Education*, *24* (4), 38- 42.

Bostan Sarioglan, A., & Kucukozer, H. (2013). Determination of conceptions of secondary 10th grade students about torque, angular momentum and Kepler's 2nd law, *NEF-EFMED*, *7* (1), 121-141.

Duit, R., & Treagust, D. F. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *International Journal of Science Education, 25* (6), 671-688.

Ekiz, D., & Akbas, Y. (2005). Ilkogretim 6. sinif ogrencilerinin astronomi ile ilgili kavramları anlama duzeyi ve kavram yanılgıları. [Primary school 6th grade students' understanding level of conceptions related to astronomy and misconceptions] *Milli Egitim Dergisi, 165*, 61-78.

Fosnot, C. T. (1996). *Constructivism: theory, perspectives, and practice*. New York: Teachers College Press.

Gess-Newsome, J. (2001). The professional development of science teachers for science education reform: A review of research, In *Professional Development Planning and Design*, J. Rhoton & P. Bowers (Editors). Arlington, VA: NSTA Press.

Greenwald, R., Hedges, L. V., & Laine, R. D. (1996). The effect of school resources on student achievement. *Review of educational research, 66* (3), 361-396.

Hudgins, D. W., Prather, E. E., Grayson, D. J., & Smits, D. P. (2007). Effectiveness of collaborative ranking tasks on student understanding of key astronomy concepts. *Astronomy Education Review, 5* (1), 1–2.

Iyibil, U., & Saglam Arslan, A. (2010). Fizik ogretmen adaylarinin yildiz kavramina dair zihinsel modelleri [Pre-Service physics teachers' mental models about stars]. *NEF-EFMED*, 28.

Jones, B. L., Lynch, P. P., & Reesink, C. (1987). Children's conceptions of the earth, sun and moon. *International Journal of Science Education, 9* (1), 43-53.

LeCompte, M. D., & Preissle-Goetz, J. (1994) Qualitative research: what it is, what it isn't, and how it's done. In Bruce Thompson (Ed) *Advances in Social Science Methodology*, Vol. 3, New York: Jai Press.

Lelliott, A., & Rollnick, M. (2010). Big ideas: A review of astronomy education research 1974–2008. *International Journal of Science Education, 32* (13), 1771-1799.

Mali, G. B., & Howe, A. (1979). Development of earth and gravity concepts among Nepali children. *Science Education, 63* (5), 685-691.

Maloney, D. (1987). Ranking tasks: A new type of test item. *Journal of College Science Teaching, 16* (6), 510.

Nussbaum, J. (1979). Children's conceptions of the earth as a cosmic body: A cross age study. *Science Education, 63* (1), 83-93.

Ogan-Bekiroglu, F. (2007). Effects of model-based teaching on pre-service physics teachers' conceptions of the moon, moon phases, and other lunar phenomena. *International Journal of Science Education, 29* (5), 555-593, doi: 10.1080/09500690600718104.

Osborne, R. J., & Cosgrove, M. M. (1983). Children's conceptions of the changes of state of water. *Journal of Research in Science Teaching, 20* (9), 825-838.

Sadler, P. M. (1992). *The initial knowledge state of high school astronomy students*. Ed.D., Harvard University, Ann Arbor.

Sahin, F. (2001). Ilkogretim 2. sinif ogrencilerinin uzay hakkindaki bilgilerinin degerlendirilmesi. *Burdur Egitim Fakultesi Dergisi, 2* (2), 156-169. [Assessment of 2nd grade elementary school students' knowledge about space]

Saumure, K., & Given, L. (2008). Convenience sample. In L. Given (Ed.), *The SAGE encyclopedia of qualitative research methods.* (pp. 125-126). Thousand Oaks, CA: SAGE Publications

Siegler, R. S. (1976). Three aspects of cognitive development. *Cognitive Psychology, 8* (4), 481-520.

Sneider, G., & Pulos, S. (1983). Children's cosmographies: Understanding the earth's shape and gravity. *Science Education, 67* (2), 205-221.

Soyibo, K. (1995). A review of some sources of students' misconceptions in biology. *Singapore Journal of Education*, 15, 2, 1-11.

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education, 10* (2), 159-169.

Trumper, R. (2000). University students' conceptions of basic astronomy concepts. *Physics Education, 35* (1), 9-15.

Trumper, R. (2006a). Teaching future teachers basic astronomy concepts–Sun-Earth-Moon relative movements–at a time of reform in science education. *Research in Science & Technological Education, 24* (1), 85-109.

Trumper, R. (2006b). Teaching future teachers basic astronomy concepts—seasonal changes—at a time of reform in science education. *Journal of Research in Science Teaching, 43* (9), 879-906.

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2002). Pre-service elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching, 39* (7), 633-658.

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2006). Pre-service elementary teachers' knowledge of observable moon phases and pattern of change in phases. *Journal of Science Teacher Education, 17* (2), 87-101.

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2007). A longitudinal study of conceptual change: Preservice elementary teachers' conceptions of moon phases. *Journal of Research in Science Teaching, 44* (2), 303-326.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology, 24* (4), 535-585.

ISSN 1648–3898

Vosniadou, S., Skopeliti, I., & Ikospentaki, K. (2004). Modes of knowing and ways of reasoning in elementary astronomy. *Cognitive Development, 19* (2), 203-222.

Yu, K. C., Sahami, K., & Denn, G. (2010). Student ideas about Kepler's laws and planetary orbital motions. *Astronomy Education Review, 9*, 010108. http://dx.doi.org/10.3847/AER2009069

Zeilik, M., & Bisard, W. (2000). Conceptual change in introductory-level astronomy courses. *Journal of College Science Teaching, 29* (4), 229-232.

Zeilik, M., Bisard, W., & Lee, C. (2001). Research-based reformed astronomy: Will it travel? *Astronomy Education Review, 1*, 33.

Zeilik, M., Schau, C., & Mattern, N. (1998). Misconceptions and their change in university-level astronomy courses. *The Physics Teacher, 36*, 104.

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