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# IMPROVEMENTS IN TEACHERS' KNOWLEDGE AND UNDERSTANDING OF BASIC ASTRONOMY CONCEPTS THROUGH DIDACTIC GAMES

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**Abstract.** *Literature review shows that many primary school teachers have poor understanding of basic astronomy contents. Therefore, the aim of the study was to introduce specific astronomical content to in-service primary school teachers through two didactic games, to evaluate the didactic games and the teachers' knowledge and understanding before and after the implementation of the didactic games. The research included 24 in-service primary school teachers. The data were collected through the knowledge test (pre-post design) and questionnaires for each didactic game. The results showed that the teachers evaluated the didactic games as suitable for use in the classroom as they emphasized that they are educational, explicit and interesting. The implementation was identified as effective because the median for fractional gains was 0.54 and showed the medium gain in teachers' knowledge and understanding of selected astronomy contents. It was recognized that in-service primary school teachers do not feel competent for introducing complex astronomical contents to their students. However, the presented approach could encourage in-service primary school teachers to deepen their knowledge and to teach astronomy contents with a method that is closer to their students. University teachers could point out the advantages and disadvantages of didactic games in astronomy content and discuss them with pre-service primary school teachers.*
**Keywords:** *astronomy education, didactic games, in-service primary school teachers, Moon phases*

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## Introduction

Astronomy is an attractive science topic also because of the ongoing research, new "revolutionary" discoveries and results that students can follow in the various media. In recent years, the media reported on the first observation of gravitational waves, all three rocket boosters successfully landed on Earth for the first time after launch, the first photo of a black hole, etc. All this revolutionary news increases curiosity and interest in astronomy. In the history of mankind, however, there are always a lot of "secrets" behind topics that are abstract and difficult for non-scientists to understand. Despite all the research and knowledge gained, there are still a lot of undiscovered and unrevealed issues that give room to people's imagination. Probably for the same reason, many popular stories and movies are placed in the Space, to deepen the effect of the mysterious and arouse peoples' interest. In order for students to make the "great leap" from the mystery of understanding the science concepts, correct "small steps" must also be taken in the educational process.

Learning is a process that needs to be considered from many perspectives. Environment, genetic predispositions, experience, socio-cultural status, age. Sensorimotor skills have influence on cognition (Barrouillet, 2015; Bjorklund, 2018; Geršak et al., 2020; Goldin-Meadow, 2015; Lozada & Carro, 2016). Learning outcomes depend on motivation, teaching strategies, learning abilities, classroom climate and stage of cognitive development. The amount of findings and theories of development have so dramatically increased in the last decades that there is no unified account of developmental changes in cognitive processes that deemed as the ultimate aspiration of any theory of development (Barrouillet, 2015). However, many mechanisms hypothesized by Piaget are still present in one form or another (Barrouillet, 2015; Bjorklund, 2018; Glodin-Meadow, 2015). Several studies have empha-



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sized the importance of embodied action in cognitive processing in both children and adults (Goldin-Meadow, 2015; Smith, 2005). Cognition results from sensory-motor experience, where action influences perception and vice versa. The embodied cognition approach considers perception, action and cognition as tightly linked, and that previous sensorimotor experiences are seen as the basis of knowledge (Lozada & Carro, 2016). Piaget was the precursor of this theory, suggesting that knowledge and experience are interrelated. He attributed a crucial role to recurrent sensorimotor activity in developmental cognitive processes. Piaget's contribution to child development showed that cognition is grounded in concrete activity (Piaget, 1964). Piaget identified four stages of cognitive development: sensorimotor stage (infancy), the pre-operational stage (infancy and early childhood), the concrete operational stage (elementary and early adolescence) and the formal operational stage (adolescence and adulthood) (Feldman, 2004; Piaget, 1964). When students enter primary school, they are in the concrete operational stage and reach the formal operational stage from the age of 12 onwards. The age period of transition between one cognitive stage and the other can be quite blurred, and younger individuals can already reach higher levels of cognitive thinking and vice versa. It should be stressed that the intellectual development and abilities of some students never reach the formal operational stage (Labinowicz, 1989).

Many astronomical concepts and theories are abstract and involve significant spatial reasoning (Cole et al., 2015; Demir et al., 2017; Grubelnik et al., 2018, Plummer et al., 2013; Plummer, 2014; Plummer, et al., 2016). In order to adequately understand astronomical concepts and phenomena, higher cognitive levels need to be accomplished. To help students understand the abstract relative positions of the objects in the Universe that result in phenomena observed from the Earth, teachers must provide additional educational approaches (Parker & Heywood, 1998; Martinez Pena & Gil Quilez, 2001; Ogan-Bekiroglu, 2007). The use of models brings abstract concepts relating to the positions of the Sun, Earth, and Moon to the concrete level.

In Slovenia, learning contents from astronomy are implemented from kindergarten onwards. The teaching of astronomy in kindergartens and in the lower grades of primary school is based on an experiential approach. In the curricula for kindergarten the observation of the Moon, Sun, stars, shadows etc. is recommended (Bahovec et al., 1999; Kolar et al., 2011). The aim for the first-grade students (age 6 years) is to describe the difference between day and night, which derives from observations. In the third grade (age 8 years), the elective learning objective from the curriculum anticipates that students describe the movement of the Moon and Moon phases. Students' understanding of Moon phases mostly comes from their own observations of the Moon. In the fourth grade of primary school (age 9 years), describing reasons for Moon phases and demonstrating Sun and Moon eclipses on models is a part of the curriculum. It is evident that the learning objectives are based on the understanding of concepts derived from the positions and relative positions of objects in the Solar system (Balon et al., 2011; Ogan-Bekiroglu, 2007; Pine et al., 2001). The research studies summarize that it is appropriate to observe and describe the Moon phases with fourth-graders (age 9 years), while the understanding of the causes is rather demanding and most students do not assimilate it, although in Slovenia this is suggested in the curricula for Natural Science and Technology subject. On the other hand, it is interesting that the students who had enough time for observations and worked with models and discussions achieved the learning objectives. Moreover, the research shows that the achievement of the set objectives depends strongly on instructions, teaching forms, and methods (Hermann & Lewis, 2003; Trumper, 2003; Trumper, 2006; Trundle et al., 2007).

Abstract thinking is essential to understand the change in the illumination of the Earth during the day and night, the connection between day and night and the rotation of the Earth around its axis, the seasons, Moon phases, etc. Many authors point out that the complexity of these contents is difficult to comprehend not only for the fourth graders but also for older students and teachers (Bisard et al., 1994; Kavanagh et al., 2005; Şahin et al., 2017; Sarıoğlan & Küçüközer, 2014; Trumper, 2001; Trumper, 2003). Lelliott and Rollnick (2010) reported that the conceptions of the Earth and the day-night cycle are relatively well understood, especially by older students, while the Moon phases, the seasons and gravity are concepts that are difficult for most people to understand and explain. The adequacy of the content from the perspective of students' cognitive level has been discussed in numerus research studies. Trundle et al. (2007) has summarized research studies of many authors on basic astronomical concepts showing that the content on Moon phases is too complex to be introduced into lower grades of primary school, because students are not developmentally on the level to be able assimilate complex phenomena. Similarly, Stahly et al. (1999) reported that the topic may be too complex for the third graders, and they question whether these students are cognitively developed enough to understand lunar phenomena.

Literature review articles have shown that the link between performed research studies and its impact on classroom teaching is largely absent (Bailey & Slater, 2003; Lelliott & Rollnick, 2010). Moreover, the researchers


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stress that most adults are not able to explain why we observe different phases of the Moon. The connection between Earth-based observations of the Sun and the movements of the Earth in space is one of the major challenges that limit student progress in this topic (Martínez-Torregrosa et al., 2018). Understanding frames of reference is essential for comprehension of Moon phases. In their research, Shen and Confrey (2010) presented that teachers have difficulties in switching between heliocentric and geocentric systems. If teachers have difficulties with these topics, this must be treated as a major problem. How can they properly introduce topics from astronomy to the students? Pre-service and in–service teacher education needs to play important role in the improvement of teachers' knowledge.

*Research Problem*

Primary school teachers should prepare astronomy lessons carefully and accurately to provide an environment where students can consolidate their knowledge and take advantage of opportunities for self-discovery and upgrading purposes. Teachers need to understand the concepts and have to be able to switch between Earth-based and Space-based frames of reference.

One of the teaching methods that can be used for teaching astronomy is a didactic game. It promotes the cognitive, social, emotional, and kinaesthetic development of students (Geršak, 2020; Hyvoven, 2011; Kangas et al., 2016). Learning through play lies in embodiment, using the whole body in the play and learning process (Hyvonen, 2011; Price & Rogers, 2004).

Didactic games have the convenient property that they can be introduced in any grade and part of the lesson, regardless of the school level, i.e. from kindergarten to faculty level (Hyvonen, 2011) and in in-service teacher training. Mastering the real situation and giving meaning to different roles and behaviours are fundamental teaching objectives of didactic games. The research about the teacher's pedagogical activities in game-based learning settings is essential to understand how and why didactic games can be integrated into teaching and the curriculum framework (Kangas et al., 2016). A well prepared and knowledgeable teacher plays an important role in implementing the didactic game as an effective method in the teaching and learning process (Bognar, 1987; Tomić, 2002).

In teaching astronomy concepts, didactic games can help in comprehension of celestial movements through embodiment. Playing different roles of celestial objects and imitating their rotational and orbital movements from the Space-based frame of reference can serve as a valuable experience for enhancing spatial knowledge. As Plummer (2014) noted, if spatial thinking is improved, progress in astronomy learning could be expected. It is worthwhile to examine teachers' knowledge on Moon phases and to develop games to support progress in their astronomy learning process. Only a competent teacher is able to introduce a topic that is at the limit of the cognitive level of the students in the third and fourth grade.

Through curricula review, an important fact was found in the educational vertical. It is interesting that after the fourth grade of primary school, when the majority of students reach the formal operational stage, the content of Moon phases is not included in the curricula of science subjects in Slovenia. Spatial perceptions and connections between the Moon phases and the eclipses and relative positions of objects in the universe are not upgraded in upper grades (Planinšič et al., 2015; Skvarč et al., 2011). Astronomy related content is found again in the eighth grade physics curriculum, where the focus is entirely on other phenomena, such as describing the trajectories of objects in the Solar system, the properties of planets, the historical overview of astronomy, and in the use of star charts. This content is taught independently from those presented in the fourth grade (Verovnik et al., 2011). The overview of the curricula shows that the knowledge assimilated in the fourth grade is not updated and upgraded within the framework of formal primary education, but that it is entirely up to the individual work of the students to acquire this knowledge in the form of non-formal education. Some students meet this content in their later education in the third year of the secondary school program, whereas others gain their unique experience only in the fourth grade of primary school.

Therefore, the importance of astronomy topics in the fourth grade is indisputable. The main role, however, is played by the self-confidence and professional knowledge of the teachers in order to bring these topics closer to the third and fourth grade students. The research has focused on identifying in-service teachers' knowledge of basic astronomy topics and on evaluating the teaching approach of didactic games. Due to the teachers' interest in improving science knowledge and science teaching approaches, 24 in-service teachers who had applied for teacher training on didactic games in science were selected for the sample. The teachers played and


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evaluated two didactic games that had been developed on the basis of learning objectives for primary school students. The games deal with the basic astronomy concepts that are included in science curricula worldwide (Adams & Slater, 2000; Trumper 2006).

Selected teachers have acquired their knowledge and understanding of astronomy concept during their formal and informal education. The formal education for pre-service primary school teachers and teacher trainings for in-service teachers takes place at the Faculty of Education of the University of Ljubljana. One part of the study program for prospective primary school teachers is the subject Science – Physics in the first year of their studies. At this time, pre-service teachers encounter astronomy concepts that are consistent with the astronomy learning objectives of the curricula for the subject Natural Science and Technology in primary school. In the subject Science – Physics contents the pre-service teachers deepen their knowledge on the reasons for the day-night cycle, Moon phases, eclipses and tides. From the oral and written exams, it is evident that students have difficulties in reasoning based on spatial representation of celestial objects, cause – consequence descriptions of the phenomena and the integration of prior knowledge. The problems in conceptual understanding arise from weak prior knowledge or from the fact that in the fourth grade they have not acquired long-term knowledge and basic concepts about the motion and interposition of the celestial objects and correlated phenomena such as Moon phases and eclipses (Pavlin & Susman, 2016).

### *Research Focus*

The aim of the present study was to identify the main difficulties faced by in-service teachers in terms of their knowledge and understanding of astronomy contents in the fourth grade of the primary school in which they teach. In this context, two didactic games have been developed to assimilate and deepen the knowledge about Moon phases. The influence of the didactic games on the improvement of the knowledge and understanding of the in-service primary school teachers was followed. The research results might reflect in the preparation of in-service teacher training, the content of lectures and laboratory work for pre-service primary school teachers and consequently the transfer of knowledge to primary school students.

The following research questions were set:

RQ1: What is the overall progress of teachers in terms of the number of correct answers after the implementation of two didactic games?

RQ2: What are the teachers' reactions to didactic games in use and where do they notice the educational values of the presented didactic games?

## Research Methodology

### *General Background*

The research was developed in spring 2017 at the Faculty of Education of the University of Ljubljana. It was a mixed-method research in which both quantitative and qualitative data were collected, analysed, and integrated. In-service teacher training included astronomy topics prepared for refreshing and deepening teachers' knowledge of basic astronomy concepts and introducing the teaching approach through two didactic games. Teachers' knowledge and understanding of basic astronomical concepts was tested before and after the implementation of thematic didactic games. The didactic games were played and tested in their full scope as described in the subsection "Instrument and Procedures". After the didactic games were tested, opinions on the didactic games were collected.

### *Sample*

The sampling method was purposive, 24 in-service primary school teachers (age median *Mdn* = 36.0, interquartile range *IQR* = 9.00 years) voluntarily participated in a teacher-training seminar for Didactic Games in Science at the Faculty of Education of the University of Ljubljana. All participants were female, which reflects the current state of gender distribution of teachers in Slovenian primary schools. Teachers agreed to participate in the research. The research was done in accordance with the judgment of the Ethics Committee for Pedagogy Research of the Faculty of Education, University of Ljubljana. To ensure anonymity, each teacher was assigned a code.


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*Instrument and Procedures*

The data were collected by means of a paper-pencil questionnaire on two didactic games with the aim of evaluating the presented didactic games and by means of a paper-pencil knowledge and understanding test to identify the knowledge about astronomy among in-service primary school teachers.

A paper-pencil knowledge and understanding test (including general data and four tasks) was developed for the purpose of this research. The questions covered learning objectives from the curricula for the subject Natural Science and Technology where in-service primary school teachers teach the astronomy contents. The content units of the knowledge and understanding test are shown in Table 1. The validity and reliability of the paper-pencil test was achieved by preparing the questions in a group of three university teachers and coherent with the Barnett and Morran (2002) test. The questions were also tested in previous physics exams for pre-service primary school teachers as well.

Two didactic games were introduced in a group of 24 volunteer in-service primary school teachers who participated in the teacher-training seminar of didactic games in science. They solved four tasks on the pre-test, and they had the same tasks on the post-test. After each didactic game, they filled in the questionnaire with an open question to evaluate the game. The questionnaire contains open questions in which in-service primary school teachers expressed their responses, advantages and disadvantages and educational values of the presented didactic games.

**Table 1**
*Content Units of Four Tasks on Astronomy Knowledge and Understanding Test and Their Descriptions*

| Task | Content unit | Description |
|---|---|---|
| 1 | 1 Earth | Sketching the orbit of the Earth around the Sun and the Earth's rotation around its axis. Marking the directions of rotation and circulation. |
| | 2 Moon | Sketching the orbit of the Moon around the Earth and the rotation of the Moon around its axis. Marking of the rotation and circulation directions of the Moon. |
| 2 | 1 First quarter | A sketch of the Sun, Earth, and the Moon in space. |
| 3 | 1 Summer | The sketch of the positions of the Earth and its axis in relation to the Sun when there is summer in the northern hemisphere. |
| | 2 Moon eclipse | The sketch of the positions of the Sun, Earth, and Moon during moon eclipse. |
| | 3 Moon phase – moon eclipse | The name of the moon phase during a moon eclipse. |
| 4 | 1 Autumn | The sketch of the positions of the Earth and its axis in relation to the Sun when it is autumn in the northern hemisphere. |
| | 2 Solar eclipse | The sketch of the positions of the Sun, Earth, and Moon during a solar eclipse. |
| | 3 Moon phase – solar eclipse | The name of the moon phase during a solar eclipse. |

The research included two didactic games on astronomy in the fourth grade of primary school. The didactic games deal with the content of moon phases, eclipses, the movement of bodies in the solar system and the position of the Moon, the Earth and the Sun in space during various phenomena.

A didactic game that introduces the celestial positions of objects in the Universe is called Astrotheatre (Mati & Ferbar, 1992). It is a role-play including the embodiment. The teacher leads the game, suggests and organizes the students into 13 groups arranged in a large circle with the role of stars (zodiacal constellations). Each group receives a small poster with a name and a sketch of one zodiacal constellation (Figure 1). The arrangement of the constellations in a circle simulates the arrangement of the constellations around the ecliptic. Then the roles of the Sun, the Earth and the Moon are given to three volunteers who are invited to come to the centre of the circle. The player with the role of the Sun stands in the centre of the circle and holds the lamp to illuminate the Earth and the Moon. Therefore, this game is even more effective when the room or space is dark. The teacher organizes the


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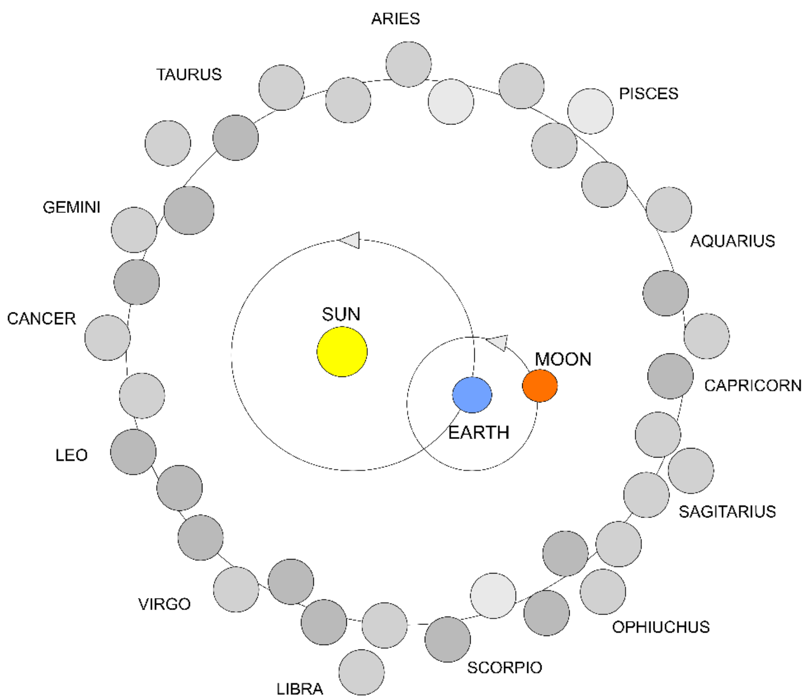
movement of the Earth around the Sun, discusses the seasons of the year and the change of day and night with the students. The representation of the movement of the Earth around the Sun reveals the reason for the different constellations that can be seen in the night sky throughout the year. At this point the teachers have the opportunity for an in-depth discussion on this topic.

Afterwards, the motion of the Moon is included in the didactic game. The movement of the Moon is presented in such a way that all participants can see the direction of rotation of the Moon, considering that from the Earth, we always observe the same half of its surface. The players with the roles of the Earth and the Moon move their bodies to show interrelated positions of the Moon, the Earth, and the Sun at different moon phases. The players discuss and play the time intervals at which the respective moon phase is visible to the observer from the Earth. Special positions and terms for Moon and Solar eclipses are discussed. The final part of this role-play is the discussion of tides and their relation to the positions of the Earth, the Moon and the Sun. The players show the situation at high and low tide and at tide changes within one day and in one month. Astrotheatre as a role-play is conceptually demanding and should therefore be introduced step by step and in parts.

**Figure 1**
*Astrotheatre: Placement of the Players in the Room*




Since the first game is based on embodiment and actively involves the entire classroom, the second game, Triplets, is a board game for one or two players enhancing the idea of playing during breaks and extended stays. In contrast to the first game, the players could play Triplets without the intervention of the teacher. This game serves to deepen the knowledge of moon phases, the change of day and night, solar and lunar eclipses. The students connect the relative positions of the Moon, the Sun, and the Earth with a certain phenomenon and its description.

The aim of the Triplets is to find three matching cards. The cards contain images, descriptions, and names of the phenomena (moon phases, solar and lunar eclipses). The game consists of a playing board and 16 cards. The player arranges the cards on the game board in such a way that context-relevant triplets are created. One card of the triplet is already on the board (Figure 2). When the player has finished the game, the correct positions of the cards can be checked independently. The solutions are hidden under the board and only have to be pulled out and compared with the arrangement of the cards.


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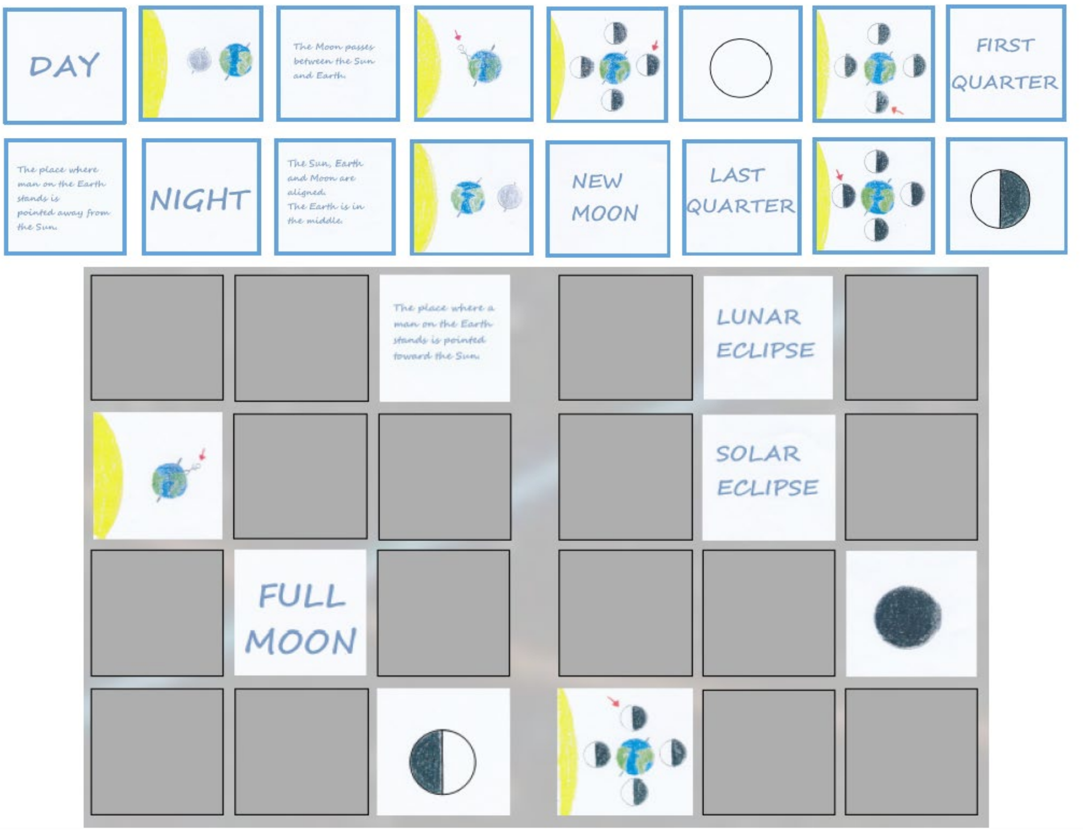
**Figure 2**

*Board Game Triplets: Board, and Cards that a Player Locate on the Board and Form Meaningful Triplets*




*Data Analysis*

The data from the knowledge and understanding pre- and post-tests were evaluated according to the preliminary model answer (correct, incorrect), exported and statistically processed in SPSS (Statistical Package for the Social Sciences). Basic descriptive statistics (median *Mdn* and an interquartile range *IQR*) of the numerical variables were determined. To find the effectiveness of the approach per question, a fractional gain was calculated from the number of correct answers before and after implementation, *g* = (<correct answers after the implementation> - <correct answers before the implementation>) / (number of teachers - <correct answers before the implementation>). Benchmarks for defining low gain (0-.3), medium gain (.3-.7) and high gain (.7-1.0) are given by Hake (1998). However, "*g*" might be negative if the number of correct answers after implementation is lower.

Data from questionnaires were analysed qualitatively. The coding units were determined taking into account the search of those parts of the text that contained essential data for the presented research. The central process was open coding, i.e. we read out the codes from the documents (Vogrinc, 2008). The teachers' statements about didactic games were analysed and coded by three independent researchers. The steps mentioned above were carried out separately for each document. After the analysis of all codes and the merging of the content-related codes into categories, the research questions were answered.

**Research Results**

The results of the in-service teachers on pre-test and post-test are presented as a percentage of correct, incorrect, and unanswered questions. In order to identify progress, their achievements were scored, and the results are shown in Figure 3, which shows the results of teachers. The shift towards a higher number of points achieved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on a post-test is evident. It was identified that the intervention of the didactic games had a positive influence on the knowledge of the teachers.

**Figure 3**

*The Percentage of Teachers with a Certain Number of Achieved Points of 9*

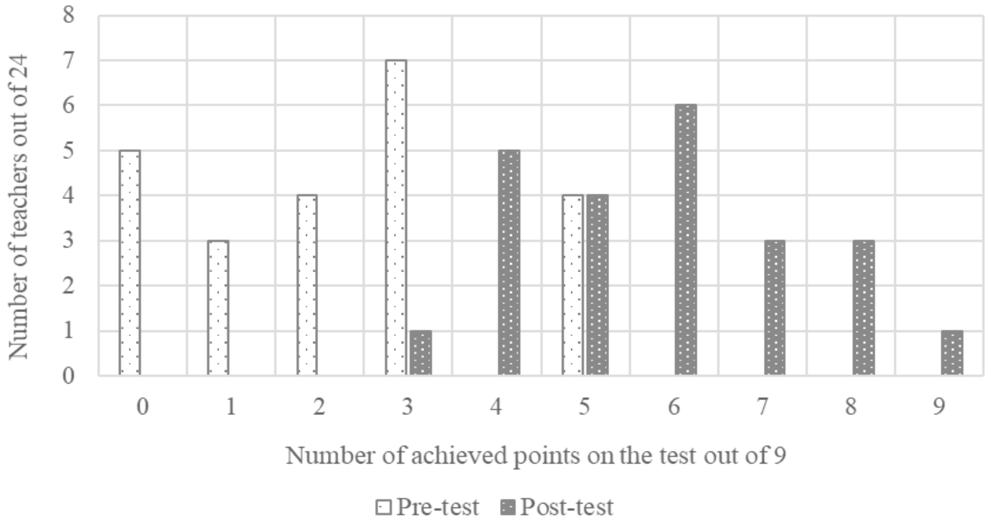


Table 2 shows the number of correct answers in relation to each content unit. To be more precise, the following list of the names of the content units with their meanings was compiled in Table 1. Table 2 shows that 20 and 17 of the teachers appropriately sketched the movement of the Earth and the movement of the Moon on post-test, respectively. In all cases an improvement in the level of knowledge compared to the pre-test was obvious. Only 5 participants sketched the positions of the Sun, the Earth and the Moon correctly on the pre-test when the first quarter was visible in the northern hemisphere. This task is particularly challenging because two different points of view (from the Earth and from space) have to be considered. The results of the post-test show an improvement, as 10 more teachers correctly sketched it. The best results in the pre- and post-test were observed in the sketches of moon- and solar- eclipses. In the pre-test, 17 and 16 of the teachers drew an appropriate sketch of celestial objects at moon- and solar eclipse, respectively. In the post-test, all teachers wrote down the correct positions of the Moon, the Earth, and the Sun for both phenomena. There were two surprising results regarding the name of the moon phase during these phenomena. In the pre-test there was no correct answer on the moon phase during moon eclipse, while 20 of the teachers wrote the correct moon phase during solar eclipse. On the post-test, more than half of the participants (13) wrote the correct moon phase for moon eclipse, so that an improvement was noted. However, there was a large decrease in the correct answers in the moon phase at solar eclipse in the post-test. This could be due to the 50:50 chance of guessing the correct answer, since the participants knew that the post-test had either a full moon or a new moon on it. The other reason could be the Slovenian names of the moon phases. There are two different expressions for each phase, which can easily be confused. Another explanation for the results is that during the pre-test the teachers might have given the answers they knew by heart, while during the post-test they used the reasoning presented with didactic games. Since the change of view from Space to the view from Earth is often a demanding task, many wrong answers were found. Teachers often had difficulty distinguishing between the first and the last quarter and between the full moon and the new moon.

Drawing the sketch of the Earth on its orbit around the Sun at the position where it is autumn on the northern hemisphere was the most demanding task. The identified improvement in the teachers' knowledge and understanding was small, as this topic was not given enough attention in the games. The translation of spatial awareness into a two-dimensional sketch was obviously very demanding; especially drawing the Earth's axis, which was also noticed in the task related to the position of the Earth in summer. During the post-test, more teachers correctly sketched the inclination of the Earth's axis in summer than in autumn.



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The implementation of didactic games was effective because the average normalized gain for all content units except one varied from .09 to 1.00. The average fractional gain was medium, .54.

**Table 2**
*The Number of Correct Answers on Each Content Unit Given By Teachers on Pre- and Post-Test and Fractional Gains (G) Per Content Question*

| Task | Content unit | Number of teachers out of 24 | | *g* |
|---|---|---|---|---|
| | | Pre-test | Post-test | |
| 1 | 1 Earth | 7 | 20 | .76 |
| | 2 Moon | 8 | 17 | .56 |
| 2 | 1 First quarter | 5 | 15 | .53 |
| 3 | 1 Summer | 2 | 11 | .41 |
| | 2 Moon eclipse | 17 | 24 | 1.00 |
| | 3 Moon phase – Moon eclipse | 0 | 13 | .54 |
| 4 | 1 Autumn | 1 | 3 | .09 |
| | 2 Solar eclipse | 16 | 24 | 1.00 |
| | 3 Moon phase – solar eclipse | 20 | 15 | -1.25 |
| | | *Mdn = 8.00; IQR = 15.00* | *Mdn = 15.00; IQR = 10.00* | *Mdn=0.54; IQR = 0.63* |

The implementation of the didactic games was effective because the average normalized gain was in average medium (.54) (Table 2). However, high-normalized gains were found:

- in task 1, content unit Earth (sketch of the Earth's orbit around the Sun and rotation of the Earth's around the axis);
- task 3, content unit Moon eclipse (the sketch of positions of the Sun, the Earth, and the Moon at moon eclipse);
- and task 4, content unit Solar eclipse (the sketch of the positions of the Sun, the Earth, and the Moon during a solar eclipse).
- Low normalized gain was identified in task 4, content unit 1, and negative normalized gain in task 4, content unit 3 (name of the moon phase during a solar eclipse). For other tasks, the average normalized gains were medium, from .41 to .56.

The teachers evaluated the proposed didactic games directly after the game. The teachers' opinions and reflections on the games were generally positive (Table 3). From the teachers' responses to the didactic games we perceive many statements that prove that these games are educational. The teachers used the word "educational" or they used expressions related to active learning, group work, the role of the teacher, etc. For the didactic game Triplets, the teachers appreciated the performance of the game, which included feedback for the players. Each player could check whether his or her distribution of playing cards was appropriate or not.

The teachers considered the order of play to be reasonable, and they also strongly believed that the Astro-theatre had to be performed before the introduction of the Triplets. Many believed that the Triplets would be too demanding without the Astrotheatre. There were some comments on the games which are not included in Table 3 but are still relevant. The Astrotheatre requires a good teacher - a leader with good professional skills. A teacher can lead this game properly only if he knows phenomena well and has a good knowledge of the inter-locations and movement of the objects in the Universe. Both didactic games can be performed in an ordinary classroom. It has been pointed out that the consolidation of knowledge can be achieved by playing the game Triplets, because it is a game that is suitable for exercise even during breaks and students' extended stays and where the teachers do not have to supervise the game.


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**Table 3**
*Categorized Common Statements about the Astrotheatre and Triplets Game Given by Teachers*

| Astrotheatre | | Triplets | |
|---|---|---|---|
| **Category** | **Number of teachers out of 24** | **Category** | **Number of teachers out of 24** |
| Educational | 3 | Educational | 3 |
| Explicit | 16 | Explicit | 4 |
| Demanding | 6 | Demanding | 4 |
| Interesting | 9 | Interesting | 15 |
| Active learning in a group | 11 | Good for exercise | 6 |
| A lot of info (gradual implementation) | 8 | Necessary connection with Astrotheatre | 20 |
| | | Good feedback | 18 |

## Discussion

*Interpretation of the results is given through the answers on research questions.*

*RQ1: What is the overall progress of teachers in terms of the number of correct answers after the implementation of two didactic games?*

Kallery (2001) has reported that the knowledge and understanding of basic concepts and phenomena in science by Greek teachers of early science is quite limited. This is related to current research results, as only one third of the in-service teachers answered pre-test questions correctly. The results indicate that teachers do not have a strong foundation of their pre-knowledge and professional knowledge on basic astronomy topics.

By means of two didactic games, Astrotheatre and Triplets, in-service primary school teachers were guided to develop knowledge and understanding of the movement of the Moon and the Earth in the Solar system, Moon phases, eclipses, the change of day and night, and the change of seasons. The results of the current research showed the progress in knowledge and understanding of the moon phases of in-service teachers. The teachers' progress was medium. Results are similar with the findings of the report by Lelliot and Rollnick (2010), according to which the concepts of the Earth and the day-night cycle are relatively well-understood, while the Moon phases, the seasons, and gravity are concepts that most people find difficult to understand and explain. Current research shows that in-service teachers have some difficulty in representing concepts on the paper to illustrate the Moon phases and the seasons. These findings are in agreement with Kıroğlu (2015), who made a research on primary school teachers about basic astronomy concepts. One third of the teachers answered the questions incorrectly, which is similar to the results of the current research, where 15 out of 24 in-service teachers answered correctly on each content unit after teacher training (*Mdn*=15.00). However, there is quite large *IQR* that shows wide range in the individuals' knowledge and understanding of basic astronomy concepts.

In the teacher training as a part of current research, the embodiment was intertwined with the models to help in-service teachers to improve the spatial perceptions of celestial bodies' positions. The results show the improvement in the teachers' knowledge on all content units, except on moon phases and on solar eclipses. The results are consistent with Ucar, (2014), who has reported that the use of simulations and models in the teaching of astronomy concepts improves students' achievements.

In addition, during the teacher training for in-service teachers, it was expounded by in-service teachers that they do not feel comfortable teaching astronomy topics, although the teachers work on models of the solar system, models for moon phases and eclipses, and they even have a role-play for seasons, tides and moon phases during pre-service teachers' study program. Many of them have remembered that they have accomplished something in lectures, laboratory work, and field work, but they have never assimilated and consolidated this knowledge. Slater, Safko and Carpenter (1999) report on similar foundlings.


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*- RQ2: What are the teachers' reactions to didactic games in use and where do they notice the educational values of the presented didactic games?*

The second group of research findings relates to the responses of in-service teachers to didactic games and noticed educational values of the presented didactic games. The teachers evaluate the didactic games positively, as they have improved their knowledge through the didactic games they played in the seminar. The teachers who participated in the research are more likely to transfer and include the presented games in their lessons; some of them have already done so. However, when searching on the internet, many interactive games on astronomy can be found. In the literature review the computer games and other augment reality systems are presented and tested (Barringer et al., 2018, Patrício et al., 2019). The games presented in the current research have some advantages since the teachers do not need to acquire special ITC knowledge and do not have to spend money to buy the board games, tablets etc. In-service teachers are able to perform and make the presented didactic games by their own according to the rules and templates. The results of the current research show, that teachers liked the games especially their interconnection, their universality for using the games in different stages of education, the covered learning objectives and the possibilities to play them indoor and outdoor.

**Conclusions**

The aim of this work was to determine the progress of in-service primary school teachers in terms of knowledge and understanding of the moon phases and to evaluate the didactic games used through the eyes of the teachers who teach the content in primary school. The current research demonstrates that a well-planned and well-established teaching process of astronomy topics is essential for proper understanding of these topics. One of the possible activities could be an activity with didactic games, which are presented and are suitable for students from primary school students to the pre-service primary school teachers and in-service primary school teachers around the world.

Based on our experience with pre–service teachers, they are often not aware of the importance of the science topics they are presented to and of consolidation of their knowledge during their study on the faculty. From the exams carried out, it is evident that pre-service primary school teachers have difficulty in recognizing moon phases from random positions of the Moon, the Sun, and the Earth when these random positions differ from those presented in lectures and laboratory work. If the positions of the object were different from the positions they draw in their notes, the number of wrong answers was greater, which shows that they are learning by heart and do not understand the background of the phenomena. They are good at reproducing knowledge, but whenever the use of knowledge is required in a new situation, the results were poor. Since the pre-service primary school teachers are future teachers who will teach these topics, special attention is needed during their studies at the faculty level. Learning, comprehension, conceptual understanding and the acquisition of knowledge should take a lot of time, therefore a reflection on changes in teaching methods and timescales regarding the teaching astronomical content is necessary. However, when pre-service teachers become in-service teachers, they realize that the teacher trainings are very welcome for their professional development.

The in-service teachers included in the current research show medium improvement in their knowledge and understanding of basic astronomy concepts during teacher training. There might be many reasons for this. One is the fact, that teacher trainings took place on Fridays after their job obligations. Many teachers are exhausted and tired at the end of the week. The other might be in the amount of the concepts and phenomena described and presented in short time. The Astrotheatre game is recommended to be played in concept parts not as a whole game at a time. Due to the busy schedule of teacher training, both games were introduced at once, one after another. However, the situation of addressing a large amount of learning contents is more problematic in teaching astronomy contents on all stages of education. As reported, many researchers suggest that more school hours should be prescribed to astronomy contents in curricula. The lack of time to enable students the consolidation of their knowledge is a great drawback in the school system beside the inappropriateness of the content from the perspective of students' cognitive level as it has been discussed in numerus research studies. Content about Moon phases is too complex to be introduced to the lower grades of primary school because students are not developmentally on the level to be able to assimilate complex phenomena. Within the current research, it could be shown that some knowledge issues are also recognized in the group of teachers and partially minimized through activities including the presented didactic games.


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The presented research raises guidelines for further research, a larger sample size and teachers who do not attach great importance to science should be included so that a more concrete picture of the knowledge and understanding of the moon phases and the impact of the presented didactic games and their evaluation can be obtained.

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