KNOWLEDGE IN SHADOW – MISCONCEPTIONS RELATED TO LIGHT PHENOMENA THAT ARE RETAINED IN SPITE OF EDUCATION[1]

Gordana MIŠČEVIĆ
Teacher Education Faculty, University of Belgrade, Belgrade, Serbia

Sanja BLAGDANIĆ
Teacher Education Faculty, University of Belgrade, Belgrade, Serbia

Marija BOŠNJAK STEPANOVIĆ
Faculty of Education, University of Novi Sad, Sombor, Serbia

INTRODUCTION

Misconceptions in knowledge related to various segments of life are more or less present not only in children but also in adults, and often remain even after formal education. There are numerous sources of these non-scientifically based interpretations of reality, one of them being the teachers themselves. As certain studies point to an analogy between misconceptions of students and teachers (Kruger, 1990; Metioui & Trudel, 2012), the present paper addresses this issue pertaining to the topic of light phenomena and the formation of shadows.

1 This research is part of the project “Concepts and strategies for ensuring the quality of basic education“ — Faculty of Teacher Education in Belgrade (Contract No. 451-03-2842 / 2019-14).

THEORETICAL FOUNDATION

The construct of scientific literacy

The term *scientific literacy* has been present in a large number of studies since the end of the 1950s. Scientific literacy is a complex, multidimensional construct and represents a set of competencies (Antić & Pešikan, 2015). It relates not only to acquiring a specific content in the area of physics, biology, chemistry or some other discipline, but also to a specific way of thinking, a system of values, and practice. There are two basic approaches to determining scientific literacy and these are a behaviorist and a constructivist approach. While the former implies that there are some measurable behaviors that an individual should possess in order to be scientifically literate, the latter emphasizes the construction of one's own interpretations, irrespective of the way in which scientific content has been presented, implying that everyone learns in their own way (Marušić Jablanović & Blagdanić, 2019).

The notion of misconceptions

Within the school context, spontaneous notions formed by the students' everyday experiences interact with organized and interrelated scientific notions, creating dynamic constructive relationships. A child does not learn scientific notions by heart, but creates them with the greatest effort of their own thoughts (Vigotski, 1996). Learning is a dynamic process in which students construct their knowledge and structures by interacting with the environment and people (Pijaže, 2002). Knowledge is, therefore, constructed by an individual and this is the reason why the teacher-centered approach has often been criticized. Students constantly reconstruct their understanding of phenomena in the social and physical environment by actively thinking about entities and processes. The assimilation process represents a change of existing concepts, leading to their integration into existing structures, while the process of adaptation of an organism to outer conditions represents accommodation (Ilić, 2013). Misconceptions pertain to the ideas created by wrong assimilation and they are contrary to scientifically accepted conceptions (Stein, Larrabee & Barman, 2008). A number of other terms can be found in literature: *preconceptions, naive beliefs, naive knowledge, naive theories*, *and mixed conceptions* (according to Antić, 2007). Misconceptions may remain in the student's cognitive structure or even reappear a few weeks after the instructional process is over and during which the student showed initial understanding of the scientific notion. Once scientific concepts are misunderstood, the student's progress in a particular subject is impaired. Misconceptions are therefore recognized as a serious educational problem and their overcoming is necessary for effective and long-lasting learning (Metioui & Trudel, 2012; Muratović, 2015).

There has been a growing interest among researchers in the reasons for misconception appearance, various types of misconceptions, and adequate pedagogical interventions. Various classifications of misconceptions have been given so far, and the ones that, according to the authors' opinion, appear as the most adequate are the following: overgeneralized knowledge (ideas that are correct in some, but not in all situations), misconceptions (incorrect in all situations), or linguistic and semantic errors (resulting from linguistic confusion, particularly in case of polysemous words as their understanding is mainly associated with the most common or the first meaning of the word, i.e. the meaning that the student is familiar with (Pine, Messer & John, 2001).

Research on misconceptions related to light phenomena

A considerable number of studies have focused on misconceptions of students, pre-service, and in-service teachers about light phenomena – the nature of light, light sources, shadows etc. A study on the model of the rectilinear propagation of light and the variation of a shadow size conducted with pre-service teachers reports that misconceptions are created due to the fact that lighting is often generated by large sources generating blurred shadows (Metioui & Trudel, 2012). Certain studies have focused on the semantic and pedagogical improvement of prospective physics teachers' understanding of light concepts by drawing concept maps (Taşkın & Kandil İngeç, 2019), or by textual explanations of ready-made concept maps (Usta, Ültay & Ültay, 2020). A recommendation for providing a better-quality understanding is to incorporate educational technology, i.e. 2D models, 3D visualisations, animations and films (Türkmen, 2015). Children's explanations are based on their own experiences, information obtained from adults or perceived through media. More and more researchers point to the importance of initiating science education at an early age and offer various modes of involving little children in scientific activities (Akerson, 2019), while there are those who point out the necessity of conducting additional research into the development of students' scientific reasoning skills (Yilmaz & Bulunuz, 2019). A survey on alternative ideas about shadow formation focused on drawings by preschool children aged 4-6 (Delserieys, Impedovo, Fragkiadaki, & Kampeza, 2016). The indicators for analyzing drawings fell within the four categories: presence of the three entities needed to represent the phenomenon of shadow formation, shadow characteristics, alignment, and nature of light. The results highlighted the diversity of categories that emerged, i.e. alternative ideas. Castro and Rodriguez (2014) studied mental representations of light in students aged 8-9 years and concluded that the subjects used different categories of representations for the light and rarely recognized the light as a separate entity in the area, independent sources that produce it and the effects it causes during its spread. A similar study with students aged 11-12 years showed almost identical findings (Grigorovitch, 2015). A study in which children used their own bodies as obstacles to the light and in that way explored the direction of the light and changes of the relative positions of the light source and the obstacle, showed positive effects on learning about shadow formation while employing the body-based activity. The activity explicitly incorporates the rectilinear movement of light into the process of shadow formation and at the same time provides learning through direct experience. Numerous research works on detected misconceptions related to the nature of light, light sources, propagation of light and material transparency have examined the effectiveness of certain teaching strategies (constructivist approach, project-based learning, learning through play, problem-oriented learning by computer games) on the process of conceptual change (Boyes & Stanisstreet, 1991; Grigorovitch, 2014; Hsu, Tsai, & Liang, 2011; Lindstrand, Hansson, Olsson, & Ljung-Djarf, 2016; Şahin, Ipek, & Ayas, 2008). All these studies report that in spite of the applied teaching strategy, children of various ages (from preschool to high school age) still show certain misconceptions, such as the ideas that the shadow is always behind an object, the shadow has to be on the same side as the Sun, the Moon is a source of light and the firefly is not, etc.

Light phenomena in the primary and secondary school syllabi in Serbia

Since the present study included fourth grade students and class teachers in primary education, this section focuses on the contents included in the primary school syllabi, both in the first (1^{st}- 4^{th} grade) and second cycle (5th-8th grade) of primary education. Further analysis of the fourth grade content includes only topics covered by the subject Nature and Society. As teachers were also the study participants, the contents taught in higher grades have also been included in the analysis. Although the teachers had completed primary education (and further education) at different times, the contents presented here have been part of the syllabi for years and even decades. Secondary education contents are not included in the analysis since the teachers had completed various secondary schools and therefore the contents related to light phenomena also vary. The primary school contents were the basis for creating the task used in the study.

The students participating in the research had lessons of the subject Nature and Society according to previously used syllabi (introduced in the period 2006-2010). Therefore, the subsequent analysis refers to these past school syllabi. Light phenomena were introduced in the first grade of the primary school, predominantly relating to sunlight (and heat) as the source of all life on earth. Considering light as a physical phenomenon, the notions of day and night, as well as the notion of shadow, i.e. the relation of the shape and size of the shadow with the shape and size of the object that produces it, were already present in the first grade syllabus (Curriculum for Primary school – World around us, 2010). In the second grade contents, the Sun was more clearly identified as the source of light (but without further analysis of other, natural and artificial sources of light) and its position as an indicator of the specific time of day (Curriculum for Primary school – World around us, 2010). It was only the fourth grade syllabus that offered a deeper analysis of the above contents by considering the consequences of varying factors that influenced the size of a shadow, as well as by exploring light penetration of different materials (Curriculum for Primary school – Nature and Society, 2006).

Physics subject lessons scarcely covered light phenomena, focusing mostly on learning and teaching the rectilinear propagation of light in order to make students understand the following:

- Difference between the nature of light as a wave and the nature of sound as a mechanical wave;
- Difference between light sources and the difference between a shadow and a half-shadow;
- An eclipse of the Sun and the Moon.

METHOD

The subject of the research. In both children and adults, knowledge related to natural phenomena is created through the interaction with the environment and through social interaction (with adults and peers), as well as through formal and informal learning situations. Along with scientifically accepted understanding of a natural phenomenon, there is very often a certain number of misconceptions, erroneous or non-universal understanding of the phenomenon held in the cognitive structure. One of the main roles of the educational system is to identify these misconceptions and help students overcome them. This enables the creation of a coherent system of scientific notions, both in a specific field and the world in general. In order to achieve this, it is necessary that teachers hold correct scientific ideas (not misconceptions) about the contents they teach. Earlier research has shown that some misconceptions are common to both students and teachers (Kaltakci & Erylmaz, 2007; Kruger, 1990; Metioui & Trudel, 2012).

The aim of the research is to identify the frequency of various misconceptions related to light phenomena in fourth-grade students and primary school class teachers.

The research questions addressed in the survey are the following:

Which scientific facts related to light and shadow are best and worst understood, i.e. cause misconceptions in participants;

To what extent does the presence of misconceptions about light and shadow decrease with the age;

Are the most frequent misconceptions on light phenomena common to both groups of participants?

Our starting hypothesis is that misconceptions pertaining to light phenomena are present in both groups of participants, but are more common among students. We expect that students show difficulties in understanding certain aspects about light and shadow that are common for their age, as reported in prevous research (Castro & Rodriguez, 2014; Pine, Messer, & John, 2001). We also expect that those aspects of light phenomena that cause most difficulties to the students are problematic to the teachers to some extent.

The instrument description. The data on the students' misconceptions related to light phenomena were gathered through their responses to an illustrative task created in such a way as to indicate the students' understanding of light and shadow, i.e. misconceptions related to them.

The task is an adapted version of a simpler task *Being Shadowed* published in *Learn Science! for grades K-2 by © Dorling Kindersley Limited* (Figure 1). The students are expected to draw a shadow of the girl. The adapted version of the task includes the cardinal directions (E-East, W-West) and some additional information and instructions that make this task more complex than its original version.

Figure 1. Original illustrative task about shadows
(Learn Science! for grades K-2 by © Dorling Kindersley Limited)

The textual part of the task is the following: It is 3.00 pm. Draw the girl's shadow using a solid line. Then using a dashed line draw the position of the Sun and the girl's shadow two hours later (at 5.00 pm).

The first part of the task checks if the participants understand that:

1) the shadow is rectilinear;
2) the shadow is a non-lighted space on the opposite side of the opaque object in relation to the light source. As the object is opaque, the shadow has no colour and the details on the object are not visible on it. The shadow becomes visible only when it falls on the surface;
3) the shadow shape depends on the object shape;
4) the shadow is formed from the very object (it is bound to it);

5) the shadow position depends on the position of the light source.

In this task the students could use the tree shadow as an orientation to determine the shadow position (and not the position of the light source, i.e. the Sun. The second part of the task is therefore very important (Figure 2), as it asks the students to mark the new shadow position (and the Sun) two hours later, i.e. after the Sun moves to the west. Drawing of the second position of the shadow indicates:

1) Whether the participants understand how the position of the Sun changes during the day (from the east to the west in a semicircular path, reaching the highest position at noon and the lowest when it rises and sets);
2) Whether the participants understand how the length of a shadow depends on the position of the light source (how far the object is from the light source and/or at what angle it falls on the object).

Figure 2. Example of correctly completed adapted task on shadows

The third, fourth and fifth items referring to the first part of the task, as well as both of the two items relating to the second part of the task, are integrated in the syllabi of the subjects World around us and Nature and Society. The first item is part of Physics syllabus, while the second one (the shadow has no colour and the details observable on the object are not visible on it, as the shadow becomes visible only when it falls on the surface) is considered to be experiential knowledge. We therefore expect that both students and teachers do well in this part, although research on misconceptions related to light and shadows suggests that they are present in participants of all ages – from preschool children to adult professionals working as teachers.

Research methods, techniques and instruments. Considering the aim and the subject of the present study, this research can be categorized as descriptive research as it focuses on analyzing and understanding the current state in educational practice. The technique of testing is applied in order to detect the presence of alternative conceptions in students finishing the first cycle of primary education and in class teachers who work with students of that age.

Although there are many tests on students' misconceptions related to natural phenomena, including light (Metioui & Trudel, 2012), there is no standardized test for this age that assesses misconceptions on the light phenomena taught within the subjects World around us/Nature and Society. For this reason, the task described above was created. The task is based on the content of the syllabi of the subjects World around us/Nature and Society, and at the same time includes typical misconceptions on the light phenomena discussed above (Pine, Messer, & John, 2001; Smolleck & Hershberger, 2011). The task, therefore, belongs to the category of criterion-referenced tests.

The sample includes 817 participants – 662 fourth-graders and 155 class teachers.

Data processing. Qualitative data analysis was applied and it was additionally supported by simple statistical analyses (frequency and percentages of the participants' responses) that indicate the presence of alternative understanding of light phenomena.

RESULTS

The data analysis is presented in two sections. The first section refers to the shape of the shadow and the second one presents the results of its position and size in relation to the light source. The analysis of the participants' drawings included three categories of responses – correct, incorrect, and the task is incomplete or does not clearly show what the drawing represents. In all segments of the task there was a large number of responses that fell within the third category, and this was particularly observable in the teachers' responses. As we could not know whether a participant did not complete the task because they did not know how to do it or had a lack of motivation, we could not classify these responses as incorrect. An unclear drawing could also be a parameter for both understanding and non-understanding of the task. Considering this, the quantitative analysis was applied only to correct responses, as we wanted to determine the number of participants who clearly showed good understanding of a certain aspect of light (and shadow).

The analysis of the shadow shape is firstly presented, as we consider it to be simpler for understanding than understanding the shadow position and size. The simplicity of this task is also reflected in the fact that the relation between the shape of an object and its shadow is taught in the first grade of primary school. The other two aspects (the shadow does not include details observable on the object, in our example these may refer to the eyes, mouth or some details on the clothes, and there is a relationship between the shadow and the object on a specific surface) are not explicitly taught in school, but are experientially confirmed in every-day situations. The analyzed data suggest that the shadow shape does not represent a problem to approximately two thirds of fourth-graders (from 60.42% to 68.58%) (Table 1).

Table 1. Object shape and shadow shape

	Shadow corresponds to the object shape *f* (%)	Shadow has no details *f* (%)	There is a relation between the shadow and the object *f* (%)
Students	409 (61.78%)	400 (60.42%)	454 (68.58%)
Teachers	75 (48.39%)	39 (25.16%)	86 (55.48%)

Although at first look it seems surprising that there is a lower number of teachers who correctly drew the shadow shape, the analysis of incorrectly completed drawings actually shows that none of the teachers drew a shadow that did not correspond to the object shape nor added details to it (eyes, mouth, buttons etc.), and only four teachers (2.58%) drew a shadow separated from the object. A large number of drawings could not be assessed, as the teachers mostly marked only the shadow position with a line, making it impossible to assess the segments of the shadow shape. Although the results of the teachers' responses are weaker than the students' results, we can still assume that the teachers generally have no dilemmas considering the issue of the shadow shape, as most of their students do not show any dilemmas considering this issue.

As for the shadow position, there are also three aspects included in its analysis – determining the Sun position two hours later, the shadow position in relation to the light source and the change in the shadow size and position two hours later. The collected data are presented in Table 2.

Table 2. The Sun position and the shadow position and size

	Adequate Sun position *f* **(%)**	**Adequate shadow position in relation to light source** *f* **(%)**	**Adequate shadow position in relation to light source two hours later** *f* **(%)**	**Adequate shadow size two hours later** *f* **(%)**
Students	190 (28.70%)	372 (56.19%)	81 (12.23%)	99 (14.59%)
Teachers	53 (34.19%)	100 (64.52%)	60 (38.71%)	60 (38.71%)

Although the Sun movement during the daytime is taught in the subject Nature and Society (parts of daytime, orientation by cardinal directions and in nature), less than a third of the students show that they understand the Sun's path from the east to the west and that it lowers on the horizon as it gets late. Almost the same number of students incorrectly marked the position of the Sun, and more than 40% of them did not even try to do this part of the task. When this number is compared to the previous segments of the shadow shape, it is noticed that a considerably higher number of students (approximately twice to four times larger) did not try to complete this part of the task. This most likely implies that more students hold misconceptions, i.e. non-understanding of the apparent change in the Sun position during the daylight. What seems to be more alarming, however, is that almost identical percentage of teachers (27.74%) hold the same misconception, i.e. uncertainty, and only slightly more than a third of the teachers could correctly mark the Sun's position two hours later. As in the case with students, it can be assumed that among the teachers who did not draw the new position of the Sun there were those who avoided it as they were not sure about the answer. The assumption is, therefore, that the real number of teachers with inccorect knowledge on the changing Sun position is greater than 27.74%.

The shadow position is a more complex task, as it implies thinking not only about the shadow, but also about the light source causing the shadow and its effect on the change of the shadow. It is, therefore, a dynamic set of changes that is quite demanding for understanding and drawing, but this represents part of the fourth-grade syllabus of the subject Nature and Society. Our findings indicate that more than half of the students (56.19%) and teachers (64.52%) understand that the shadow is created opposite to the opaque object and that its position depends on the position of the light source. The findings are in line with the views of British primary science teachers who consider this segment to be of above average difficulty (M=3.36, on the scale 1 to 5, with 1 denoting very easy and 5 denoting very difficult) in terms of difficulty for children of this age (Pine, Messer & John, 2001). As expected, there is a decline in the participants' responses when another factor is added in this task situation, and that is the change in the position of the light source. The number of students who correctly completed this part of the task is more than four times lower than in the previous case. A decline is also observable in the teachers' responses, but it is not as dramatic as in the case with the students (from 64.52% to 38.71%). The reason for these differences in participants' responses may be found in the very concept of the task, as in the first part of the task the participants could use the already given shadow of the tree as orientation for determining the position of the shadow (and not the position of the light source, i.e. the Sun). When the results of the shadow position two hours later are compared with the results referring to the shadow size after the same period of time, identical or almost identical findings are observed. Slightly more than a third of the teachers (38.71%) correctly completed the part of the task on the relation between the change in the shadow position and size and the change in the position of the light source. As almost two thirds of the teachers could not provide the correct answer here, it is not surprising that just above 10% of the students were able to do it (12.23%, i.e. 14.59%). This segment of the obtained results clearly demonstrates to what extent the teacher's (non)understanding of a scientific notion affects the students' understanding, in spite of the fact that the notion is explained in the coursebook.

Although, as was expected, the obtained results indicate that the teachers show a better understanding of light phenomena than the students, the present findings point to a number of the questions. The first of these is certainly how teachers can plan and create lessons on contents that they have dilemmas and/or misconceptions about. Does it mean that this situation (and teachers' awareness of the problem) imposes the use of the most ordinary and "most secure" way of teaching – receptive teaching, i.e. retelling the contents from the book, and consequently, asking students just to reproduce definitions when assessing their knowledge. Nevertheless, the responsibility for students' misconceptions should not be placed only on the teachers and their incomplete knowledge of the contents they teach. The reasons are numerous and apart from teachers, they include the students' personal experiences, coursebooks, and language used (Kaltakci & Erylmaz, 2007). As one of the reasons for widespread misconceptions about light phenomena, Metioui and Trudel (2012) point to inadequate personal experiences as a consequence of our life surroundings full of artificial lightning, often generating blurred shadows, which leaves us without an opportunity to clearly perceive the nature of light, its rectilinear propagation and various shadow manifestations.

CONCLUSION

As already stated, there has been growing interest among researchers in identifying the sources and various types of misconceptions, as well as creating adequate pedagogical approaches, and more and more educators point out the importance of initiating science education at an early age. A study expressing the key role of teachers on the formation of scientific notions about light (Rodriguez & Castro, 2016) highlights the importance of good preschool and primary school class teachers' education and their professional development in sciences. The issue of whether students' misconceptions and their treatment in educational practice should become part of formal education of teachers might be raised by the following findings of this survey:

- Teachers mostly show no dilemma regarding the shadow shape, and the same holds good for approximately two thirds of fourth-graders.

- The majority of students show a misconception related to the apparent change of the Sun position during the daylight, and surprisingly the same refers to 27.74% of teachers.
- More than half of students and teachers understand that the shadow is formed opposite to the opaque object, i.e. its position depends on the position of the light source.
- There is a decrease in the participants' performance when an additional factor – the change in the position of the light source – is introduced in the task.
- More than a third of the teachers correctly completed part of the task referring to the relation between the change in the shadow position and size and the change of the light source.

As concluded by Antić and Pešikan (2015), science education plays a developmental and formative role and therefore it is worth investing effort in raising the quality of science teaching and learning. Analyzing it *from the student's point of view*, these authors suggest that it is first necessary to assess the students' prior knowledge and then encourage the basic functional literacy and reading comprehension skills as part of it. It is necessary to encourage the students' thinking skills by developing metacognitive strategies and basic concepts in understanding science. If there is a lack of basic concepts in the curriculum, this may be an impediment for a deeper understanding of science. Finally, it is necesarry to include research practice within the school context and local community, i.e. within the social and cultural milieu of the students. It is important to build knowledge and not to aim at replacing one notion by another, using (verbalized) definitions and explanations, as it may happen that children hold scientific explanations while they are at school and maintain alternative views when out of school, i.e. in everyday situations. The awareness of one's own knowledge, ideas and concepts is a prerequisite for any concept change (Marušić Jablanović & Blagdanić, 2019). The change of a concept, i.e. the path from a misconception to scientific notion is context-dependent and unstable. Long-lasting and stable changes occur when the students recognize relevant common characteristics of a concept in various contexts, i.e. when the concept becomes generalized within various contexts (Gunstone & Mitchell, 1998). When it comes to teachers, the first step is to analyze their own knowledge and attempt to improve it (Miščević, 2006). It is particularly important that teachers are familiar with children's typical misconceptions related to natural phenomena. These misconceptions or half-truths containing knowledge acceptable in certain contexts but not universally correct, should not be perceived as a negative phenomenon, but as an important indicator in planning the teaching process (Marušić Jablanović & Blagdanić, 2019). In planning the teaching process aimed at correcting students' misconceptions, teachers should consider that students will accept new concept meanings only if they are not satisfied with the existing meanings, i.e. if they are unable to explain a certain problem by existing ideas. The new meaning needs to be "fruitful" in order to be accepted, in other words it has to serve as a solution to a current problem and some other problem in the future (Allen, 2011). Teachers should have an insight into the most frequent and typical misconceptions of students in order to identify them and adequately react to them. At the same time, they should possess a large repertoire of teaching methods that enable them to assess which of them is most suitable in a particular situation so that neither knowledge nor misconceptions remain "in shadow".

REFERENCES

- Akerson, V. (2019). Teaching and learning science in early childhood care and education. In P. Brown, B. McMullen, & N. File (Eds.), *The Wiley handbook of early childhood care and education* (pp. 355-375). New Jersey: John Wiley & Sons.
- Allen, M. (2010). *Misconceptions in Primary Science*. New York: Open University Press.
- Antić, S. (2007). Zablude u znanju koje ostaju uprkos školskom učenju [Misconceptions persistant despite school studying]. *Zbornik Instituta za pedagoška istraživanja*, *39*(1), 48–68.
- Antić, S., & Pešikan, A. (2015). Naučna pismenost i socio-konstruktivistička perspektiva. *Psihološka istraživanja*, *18*(1), 99-119.
- Boyes, E., & Stanisstreet, M. (1991). Development of Pupils' Ideas about Seeing and Hearing □ the path of light and sound. *Research in Science & Technological Education*, *9*(2), 223-244.
- Castro, D., & Rodriguez, J. (2014). 8-9 year old pupils' mental representations of light: teaching perspectives. *Journal of Advances in Natural Sciences*, *2*(1), 40-44.
- Curriculum for Primary school – World around us (2010). Official Gazette of the Republic of Serbia, Education Gazette, 7, 28-31.
- Curriculum for Primary school – Nature and Society (2006). Official Gazette of the Republic of Serbia, Education Gazette, 3, 43-47.
- Delserieys, A., Impedovo, M. A., Fragkiadaki, G., & Kampeza, M. (2016). Using drawings to explore preschool children's ideas about shadow formation. *Review of Science, Mathematics and ICT Education, 11*(1), 55-69
- Grigorovitch, A. (2014). Children's misconceptions and conceptual change in Physics Education: the concept of light. *Journal: Journal of advances in natural sciences*, *1*(1), 34-39.

- Grigorovitch, A. (2015). Teaching optics perspectives: 10-11 year old pupils' representations of light. *International Education & Research Journal*, *1*(3), 4-6.
- Gunstone, F. R., & Mitchell, J. I. (1998). Metacognition and Conceptual Change. In J. J. Mintzes, H. J. Wandersee & J. D. Novak (Eds.), *Teaching Science for Understanding* (pp.134-164). San Diego: Academic Press.
- Hsu, C. Y., Tsai, C. C., & Liang, J. C. (2011). Facilitating preschoolers' scientific knowledge construction via computer games regarding light and shadow: The effect of the prediction-observation-explanation (POE) strategy. *Journal of Science Education and Technology*, *20*(5), 482-493.
- Ilić, M. (2013). Pedagoške implikacije Pijažeove teorije intelektualnog razvoja za nastavu i učenje [Pedagogical implications of Piaget's theory of intellectual development for teaching and learning]. *Inovacije u nastavi - časopis za savremenu nastavu*, *26*(4), 100-113.
- Kaltakci, D., & Erylmaz, A. (2007). Identifying pre-service physics teachers' misconceptions with three-tier tests. AIP Conference Proceedings, Volume 899, Issue 1. Retreived from https://doi.org/10.1063/1.2733255.
- Kruger, C. (1990). Some primary teachers' ideas about energy. *Physics Education*, *25*(86), 86-91.
- Lindstrand, A. E., Hansson, L., Olsson, R., & Ljung-Djärf, A. (2016). Playful Learning about Light and Shadow: A Learning Study Project in Early Childhood Education. *Creative Education*, 7, 333-348.
- Marušić Jablanović, M., & Blagdanić, S. (2019). *Kada naučno postane naučeno: prirodno-naučno opismenjavanje u teoriji, istraživanjima i nastavnoj praksi [From science learning to science mastery – scientific literacy in theory, research and teaching practice]*. Beograd: Učiteljski fakultet: Institut za pedagoška istraživanja.
- Metioui, A., & Trudel, L. (2012). The Model of the Rectilinear Propagation of Light and the Study of the Variation of the Size of a Shadow. *US-China Education Review*, *B2*, 173-186.
- Miščević, G. (2006). Kvalitet znanja budućih učitelja o osnovnim astronomskim pojavama [The quality of knowledge of future teachers about basic astronomical phenomena]. *Nastava i vaspitanje*, *55*(3), 318-329.
- Muratović, M. (2015). Pristup konceptualne promene u nastavi fizike [Approach to conceptual change in physics teaching]. *Nastava i vaspitanje*, *64*(3), 573-583.
- Pijaže, Ž. (2002). Učenje i razvoj [Learning and development]. U Lj. Miočinović (prir.), *Pijažeova teorija intelektualnog razvoja* (171–184). Beograd: Institut za pedagoška istraživanja.
- Pine, K., Messer, D., & John, K. (2001). Children's Misconceptions in Primary Science: a survey of teachers' views. *Research in Science & Technological Education*, *19*(1), 79-96.
- Rodriguez, J., & Castro, D. (2016). Changing 8-9 year-old pupil's mental representations of light: a metaphor based teaching approach. *Asian Education Studies*, *1*(1), 41.
- Şahin, Ç., İpek, H., & Ayas, A. (2008, June). Students› understanding of light concepts primary school: A cross-age study. In Asia-Pacific Forum on Science learning and teaching, Vol. 9, No. 1 (pp. 1-19). The Education University of Hong Kong, Department of Science and Environmental Studies.
- Smolleck, L. & Hershberger, V. (2011). Playing with Science: An Investigation of Young Children's Science Conceptions and Misconceptions. *Current Issues in Education*, *14* (1), 1-32.
- Stein, M., Larrabee, T., & Barman, C. (2008). A study of common beliefs and mis-concpetions in physical science. *Journal of Elementary Science Education*, 1- 11.

- Taşkın, T., & Kandil İngeç, Ş. (2019). Prospective Physics Teachers' Understanding of the Speed of Light within the Scope of Special Relativity. *International Journal of Physics & Chemistry Education*, *11*(2), 45-53. Retrieved from http://www.ijpce.org/index.php/IJPCE/article/view/40
- Türkmen, H. (2015). After almost half-century landing on the moon and still countering basic astronomy conceptions. *European Journal of Physics Education*, *6*(2), 1.
- Usta, N. D., Ültay. E., & Ültay, N. (2020). Reading the concept map of physics teacher candidates: a case of light. *Science Education International*, *31*(1), 14–21.
- Vigotski. L. (1996). *Problemi opšte psihologije*. Beograd: Zavod za udžbenike i nastavna sredstva.
- Yilmaz, G., & Bulunuz, M. (2019). Evaluating the effect of formative assessment based learning on student's understanding regarding basic astronomical concepts. *European Journal of Education Studies*, *6*(5), 212-235