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The Effect of A Virtual Laboratory Application on Students' Conceptual Understanding of "Geometric Optics"*

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Abstract: The aim of this research is to examine the effect of a simulation-based virtual laboratory application on geometric optics on students' conceptual understanding. The research was carried out on 59 students from two different sections of the same grade who took the General Physics I course in the Department of Computer and Instructional Technologies. One of the sections was objectively determined as the experimental group and the other as the control group. The subject of Geometric Optics was taught in a simulation-based virtual laboratory environment with 29 students in the experimental group, and in a traditional laboratory environment with 30 students in the control group. After the experimental application, focus group interview technique, one of the qualitative data collection methods, was used to reveal the conceptual understanding of the students in detail. A total of 24 students, 12 from the experimental group and 12 from the control group participated in the focus group interview. Four focus groups were formed with these students and approximately 90 minutes of interviews were held with each focus group. In focus group discussions, students were asked about the law of reflection, image formation in plane mirror, properties of images created using concave mirror and convex mirror, and properties of images created using convergent and divergent lenses. The data obtained from the interviews were subjected to content analysis. The answers given by the students were classified according to their common opinions and presented in charts. According to the results of the focus group meeting, it was concluded that the conceptual meanings of the control group students about some geometric optics subjects such as image formation in plane mirrors, the law of reflection, image formation in spherical mirrors and thin lenses, compared to the students in the experimental group, were not at the desired level.

Keywords: Physics Educaiton, Virtual Laboratory, Simulation, Geometric Optics, Conceptual Understanding

1. Introduction

Physics is a science that helps us to understand the fundamental principles of nature. Physics gives us not only the opportunity to learn a lot about the world but also forms the basis of other sciences. However, students often encounter difficulties when learning physics subjects, which causes them to find the physics course difficult. Physics is a course that contains abstract concepts and mathematical operations are used frequently. Abstract concepts that are difficult to understand and the use of mathematical operations may cause students to find the physics course difficult (Bozkurt, 2008; Duit and von Rhöneck, 1998).

One of the most accepted ideas in physics education is that students need to understand physics. For this, it is necessary to create conceptual knowledge along with procedural knowledge. Procedural knowledge is concerned with mathematical calculations, formulas, and equations and is often used to solve problems. For instance, when a student needs to find the magnitude of the acceleration of an object, he must first know the formula for the magnitude of the average acceleration and then do the necessary mathematical operations to find the unknown variables in this formula. Conceptual knowledge is the core knowledge required to understand the principles and subjects of physics. By understanding fundamental concepts and relationships in physics, students can better understand the causes, consequences, and effects of physical phenomena. For example, when students understand the principle of conservation of energy, they can understand the relationship between the potential energy and kinetic energy of a system and how these energies are transformed. Conceptual knowledge is also important in terms of developing students' physical thinking powers.

Being able to teach in accordance with the structure of physics is directly related to students' understanding of physical concepts. For this, while learning a new concept correctly, students should know the concepts related to this concept in accordance with its scientific definition and structure the new concept accordingly. Teaching without conceptual

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understanding can lead to mistakes and perception of physics as difficult. In this case, there can be misconceptions, which is an undesirable situation. Misconceptions are incorrect meanings based on misunderstandings and misinterpretations. In other words, they are concepts that students have accepted as true for a long time and appear in more than one situation but do not change easily and contradict physical realities. Students often attribute different meanings to concepts that are far from being scientific, and in this case, misconceptions occur. In addition, since the new information that students are asked to gain is generally related to students' prior knowledge, if students have misconceptions in their prior knowledge, they can prevent accurate learning and lead to new misconceptions (Chi, 1992; Koray and Bal, 2002; Önen, 2005). Therefore, during the teaching processes, students should be provided with the accurate learning of the concepts and studies should be carried out to eliminate the misconceptions if any.

Another reason why students find the physics course difficult is the lack of experience in physics. Physics is a science that can be verified by experiments, and students' lack of physical experience can make it difficult to understand the subjects. Therefore, students need to be provided with more opportunities to conduct experiments and work with physical examples. In this sense, the use of laboratories for physics lessons is very essential (Çepni, Kaya, and Küçük, 2005; Ergin, Akgün, Küçüközer, and Yakal, 2000; Sönmez et al., 2005). Laboratory work allows students to understand concepts with concrete examples and apply them to real-world problems while reinforcing their learning. However, due to reasons such as the lack of consistency between the experimental activities carried out in laboratory environments and the questions asked in the university entrance exam in our country, the lack of tools and equipment in the laboratories, and the lack of experimental activities in the curriculum, it is seen that the necessary importance is not given to laboratory practices (Alkan, Çilenti, and Özdemir, 1991; Çepni, Akdeniz and Ayas, 1995; Ekici, 2015). Alternative teaching methods are needed in physics education to solve such problems.

Nowadays, developments in technology have greatly affected physics teaching as in every field. Computer-assisted learning, virtual experiments, audio-visual tools, robotics and automation, etc. can be an alternative to traditional teaching approaches in physics teaching. Technologies like these can help students to obtain a better understanding of complex physics issues by providing interactive experiences, and can offer more students the opportunity to experiment by reducing laboratory costs. Various studies have shown that students can better understand the subjects supported by animations, simulations, videos and visuals (Çiloğlu, et al., 2021; Tatlı and Ayas, 2011; Uğur, 2001).

Recently, there has been an increase in studies comparing real and virtual laboratory applications in physics teaching. It is a fact that the reasons such as the fact that learners can observe more clearly in real physics laboratories, their interaction with the teacher is higher and the communication is dynamic affect learning positively. However, factors such as the high cost of some experiments, the need for larger areas, safety problems and the inability to observe with the naked eye are also considered among the limitations of real laboratories (Cooper, 2009; Gröber et al., 2007). At this point, virtual laboratories are considered. It has been demonstrated by some studies that the use of virtual laboratories or simulation programs contributes positively to achieving the goals of learning and teaching processes by eliminating some of the problems encountered in the real laboratory environment and enabling students to develop positive attitudes towards physics (Bozkurt and Sarıkoç, 2008; Çinici et al., 2013; Karagöz and Özdener-Dönmez, 2007; Koç-Ünal and Şeker, 2020).

When the relevant literature is examined, it is seen that students have misconceptions and learning difficulties in geometric optics as in many other subjects of physics (Aydın and Öztekin, 2018; Galili and Hazan, 2000; Heywood, 2005; Kocakulah and Demirci, 2010; Taşlıdere, 2013; Yıldız, 2012). For example, whereas Aydın and Öztekin (2018) stated that students had misconceptions about the propagation, refraction and reflection of light, Kocakülah and Demirci (2010) stated that students had difficulty in drawing the image of an object placed in front of a plane mirror and determining its location, and stated that they could not determine whether the image was real or virtual. Galili and Lavrik (1998) mentioned that the reason why students have difficulty in learning optics is due to teaching methods and lack of materials. Akdeniz, Yıldız, and Yiğit (2001) also emphasized that science subjects should be studied in depth in the laboratory environment.

In this study carried out in this context, to indicate that virtual laboratory environments in which simulations are used can be an alternative to the traditional laboratory method in geometric optics course in physics, and at the same time for researchers, it is crucial to take virtual laboratory applications one step further in future studies. In addition, this study is important in order to see whether virtual laboratory applications in physics education are beneficial for students' conceptual understanding. The aim of this research is to examine the effect of teaching with a virtual laboratory application based on constructivist thinking and prepared by using simulations on the conceptual understanding of students compared to teaching with traditional laboratory method. In accordance with this purpose, the problem statement of the research is "How is the effect of teaching with a virtual laboratory application prepared on Geometric Optics on students' conceptual understanding compared to teaching with traditional laboratory method?"

2. Method

2.1. Research Model

In this research, which was designed as a case study from qualitative research approaches, it was aimed to examine the effect of a virtual laboratory application on geometric optics on students' conceptual understanding. Case study involves collecting and examining data about an event or situation through participant observations and in-depth interviews (Bogdan and Biklen, 1998).

2.2. Study Group

The study group of the research consists of 59 students studying in the 2nd grade of the Department of Computer Education and Instructional Technologies (CEIT). The research was carried out in the Physics II course taught in the spring term of 2013-2014, and a pre-test on Geometric Optics was applied to two different sections of the class at the same level. As a result of the independent sample t-test applied to the scores obtained from the pre-tests, it was seen that there was no significant difference between the sections. Accordingly, one of the sections was randomly determined as the experimental group and the other as control group. After the experimental application, focus groups were formed to examine the students' conceptual understanding of geometric optics. A total of 24 students, 12 from the experimental group and 12 from the control group, participated in the focus group interview. While the students were selected for the focus groups, it was considered that there were students with different levels of success who could represent each group. The structures of the focus formed from both groups are as in Table 1.

Table 1. The structure of the focus groups

Groups	Focus Groups	Female	Male	Total
Experimental Group	1st	2	4	6
	2nd	3	3	6
Control Group	3rd	2	4	6
	4th	4	2	6
Total		11	13	24

2.3. Data Instruments

After the experimental application, focus group interviews were conducted with the students in order to reveal the conceptual understanding of the students in detail. Before the interview, the students were informed about the purpose of the interview and they were asked to freely express their opinions and thoughts, and it was ensured that the interview recording would not be shared with anyone. An average of 90 minutes was interviewed with each focus group. No direction or pressure was made regarding the answers given by the students. The purpose of focus group interviews is to obtain in-depth, detailed and multidimensional qualitative information about the perspectives, lives, interests, experiences, tendencies, thoughts, perceptions, feelings, attitudes and habits of the participants about a determined subject. The answers given to the questions in the focus group interviews are formed as a result of the interaction of the individuals in the group with each other. Therefore, hearing the answer given by one member of the group to the question asked by other individuals gives them the opportunity to form their own thoughts.

In the focus group discussions, the following questions were asked to the students:

1. What is the law of reflection?
2. Explain briefly how image formation occurs in a plane mirror.
    - *It has been questioned how the image of a real object is formed according to where it is in front of the plane mirror and what the image properties will be.*
3. What are the characteristics of images created using concave mirrors?
    - *The special rays used for image formation in the concave mirror were questioned.*
    - *It has been questioned where and how the image of a real object will be formed according to where it is in front of the concave mirror.*
4. What are the characteristics of images created using convex mirrors?

- *The special rays used to find images in a convex mirror were questioned.*
- *The properties of the image of a real object in front of the convex mirror were questioned.*

5. What are the characteristics of images created using a converging lens?
   - *The special rays used to find images in the converging lens were questioned.*
   - *The properties of the image that will be formed according to the position of a real object in front of the converging lens have been questioned.*
6. What are the characteristics of images created using a diverging lens?
   - *The special rays used to find images in the diverging lens were questioned.*
   - *The properties of the image that will be formed according to the position of a real object in front of the diverging lens have been questioned.*

2.4. Data Analysis

Focus group interviews were recorded with a video camera to reveal students' conceptual understanding of geometric optics, and notes were taken about the interview. Then, the recording of the interview and the notes taken by the moderator were converted into written documents in the computer environment. The obtained data were subjected to content analysis, the data obtained as a result of the analysis were coded and the coded data were re-examined and the categorization of the related ones was made. While analyzing the data, the students were given representative codes such as "Student 1, 2, 3, …", and the findings were supported by quoting directly from the students' views.

2.5. Experimental Procedures

During the five-week practice, Geometric Optics subjects were covered in the experimental group in a simulation-based virtual laboratory environment. Basically, two different simulations were used in virtual laboratory applications. These simulations are compiled simulations based on Java, and both simulations have been translated into Turkish and rearranged in a way that students can understand. The first simulation, called "Tin Lens", was used to reinforce the student's attention with repetitions and at the beginning of the lesson, in order to attract the attention of the student quickly but not in depth, how the image formation occurs in mirrors and thin lenses. The second simulation called "Optics Applet" offers more opportunities to the user. This simulation was especially used in the activities carried out under the guidance of the teacher in the discovery step of the 5E model, which is suitable for the constructivist approach, in the stage of making the students comprehend the subject.

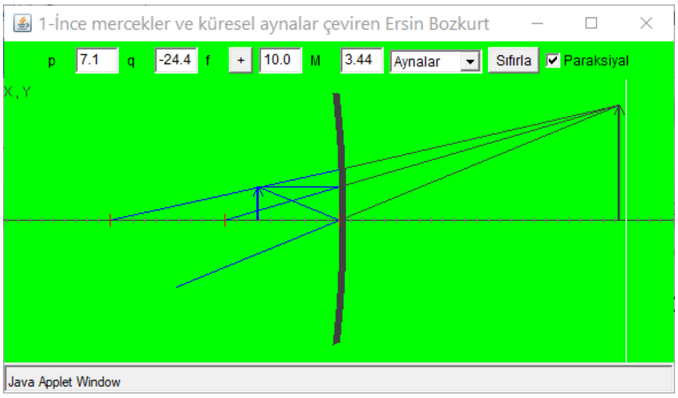

Figure 1. "Thin Lens" simulation (Hwang, 2004).

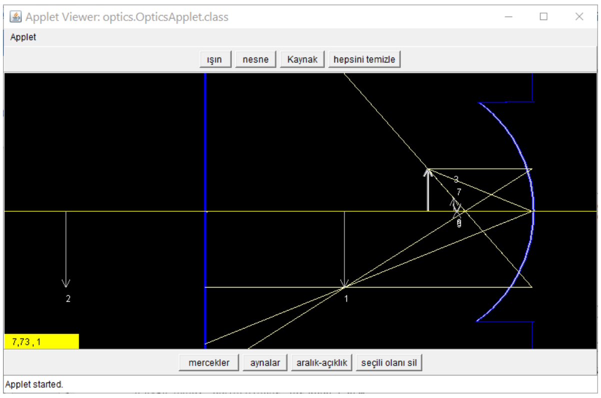

Figure 2. "Optics Applet" simulation (Christian and Lee, 2011).

On the other hand, the subjects in the control group were taught by the lecturer in the same teaching process with the lecture method and questions and answers, discussion, etc., and the participation of the students in the lesson was ensured with the help of these techniques.

3. Findings

The students' answers in focus group interviews were classified according to the common views and used in tables. Although their remarks were different in saying from different students' perspectives, their thoughts were gathered under the same roof. Some of their remarks were given under the classifications. In the interviews, it was emphasized that real objects were used in the image formation. The objects were linear on the optic axis and students answered the questions over the real objects.

3.1. Law of Reflection

Firstly, reflection law was asked to the students. Their answers about the reflection of the light were determined from their common attitude and views, and they were given in Table 2. In the table, the answers were lined from the highest repetitions to the lowest.

Table 2. The law of reflection

What is reflection law?	Experiment Group		Control Group	
	Female	Male	Female	Male
The angles of incident and reflection are equal.	5	5	4	3
The incident ray is on the same plane with the reflection ray.	4	3	3	3
For the incident angle and reflection angle to be equal, the plane should be flat.	1	2	2	3

Although most of the students gave correct answers to the questions posed for the law of reflection, it was observed that some students had a lack of knowledge. In reflection, some students stipulated in the sentence that the angles of incidence and reflection of the incident and reflected rays with the normal should be equal to each other. Accordingly, the students said that the reflection surface must be flat so that the angles of incidence and reflection are equal. This statement was expressed by 8 students in total, 3 in the experimental group and 5 in the control group. When these students were asked what kind of law would work if the surface was rough, there have been discussions in the groups that there should not be a different law of reflection and students were indecisive on this issue. The statements of one student from the experimental and control group on this subject are as follows:

Student 9: For the reflected ray and incident ray to be the same, the surface should be flat.

Student 17: …if the reflection surface is rough, incident ray and reflected ray cannot be the same. For this to happen, the surface should be flat.

3.2. Image Formation in Flat Mirror

In the focus group interviews, the students were asked how the image formation of a real object is in a flat mirror and about the characteristics of the image. The answers determined according to the common attitudes and thoughts of the students are given in Table 3. The answers given in the table are lined from the highest to the lowest according to the number of repetitions.

Table 3. Image formation in flat mirror

Image formation in flat mirror	Experiment		Control	
	Female	Male	Female	Male
The image formed in a flat mirror is flat and virtual in the same size as the object. The distance of the object and image to the mirror are the same.	5	7	6	6
In a flat mirror, the image is rotated symmetrically from right to left. There is a right-left reversal.	2	3	4	5
Flat mirror has front and rear reversal.	3	4	2	1
The resulting image is formed on the mirror surface.	-	-	-	2

One of the situations in which students are mistaken is when the image in a flat mirror is inverted to the right and left. There were different attitudes and discussions on this issue in focus groups. Students who generally make the mistake of perspective said that an object whose back is not visible in the mirror cannot undergo front-to-back reverse. It was observed that a total of 14 students, 5 from the experimental group and 9 from the control group, made mistakes in this regard. In addition, two students in the control group and in two different focus groups emphasized that the formed image was formed on the mirror surface even it is virtual. The statements of some students about these thoughts are as follows:

Student 18: The image, even it is virtual, is formed on the mirror surface. The image is on the mirror surface.

Student 21: How does the flat mirror reverse the back of the object? In my opinion, there is no such thing like front-back reverse.

3.3. Concave Mirror and Image Formation in the Concave Mirror

In this section, students' knowledge of where the real object's image will be according to the place of the object in front of the concave mirror. For this, the students were asked questions about how the image formation occurs and about the special rays used. It has been said that the spherical defects of the concave mirror used are neglected.

When the students were asked about the special rays used for image formation in the concave mirror, all of the experiment and control groups mentioned 4 special rays. These are given below respectively.

- *The ray coming to the concave mirror parallel to the optic axis is reflected to pass through the focus.*
- *The ray coming through the focus to the concave mirror is reflected parallel to the optic axis.*
- *The ray coming to the apex of the mirror is reflected in a way that is equiangular with the optic axis.*
- *The rays coming to the concave mirror passing through the center point return by reflecting on themselves.*

However, some issues were only expressed by 6 students in the second focus group in the experimental group. The statements of these students are as in the following.

> • *The rays coming to the concave mirror in a way that their extension passes through the center point in front of the concave mirror return by reflecting on themselves.*
>
> • *Rays coming to the concave mirror in a way that their extension passes through the focus in front of the concave mirror are reflected in such a way that they are parallel to the optic axis.*

Students in other focus groups emphasized that the light only comes through the focal point. They could not mention the other situations told by the students in the 2nd focus group above.

After these questions about special rays, the students were asked how many special rays they can use simultaneously for image formation. There were a variety of answers to this question. In this case, only the students in the 2nd focus group said that all of them could be used. However, they said that it cannot be used in some cases and the reason for this is that the object is on the focus or center points. Except for the 2nd focus group, which included students from the experimental group, 18 students in other groups emphasized that if the object is not located at the center point or at a point before the focal point, special rays cannot be sent from these points. Some of the answers given by the students to the question about how many special rays can be used simultaneously for image formation are as follows:

> *Student 6: If the object is between the focus and the center, we cannot draw the ray coming from the center.*
>
> *Student 19: Teacher, we can use all but one of them. We send as parallel, we send from the focus, and we send to the vertex. In order for us to send from the center, the object must be off-center. In order to send it from the focus, the object must be out of focus.*
>
> *Student 14: We can create images using all of them. But we cannot create images using all of them at the same time.*

The students were asked questions about the properties of the images formed in the concave mirror. The answers given by the students according to the location of the object are as in Table 4.

Table 4. Concave mirror and image formation on the concave mirror

Place of the Object	Properties and place of the image	Experiment		Control	
		Female	Male	Female	Male
∞-M	It is reverse between M-F, smaller than the object and real.	5	7	5	4
	It is reverse between M-F and smaller than the object. I am indecisive about whether it is real or virtual.	--	--	1	2
M	It is reverse at M, the same size with the object and real.	5	7	6	6
M-F	It is reverse between ∞-M, bigger than the object and real.	5	7	4	3
	It is reverse between ∞-M, the size is bigger. I am indecisive about whether it is real or virtual.	--	--	1	2
	It is reverse between M-F, the size is the same and real.	--	--	1	1
F	The image is on the infinity.	5	7	6	6
F-T	The image is virtual, bigger than the object and flat.	5	7	5	4
	It is reverse between ∞-M, bigger than the object and real.	--	--	1	2

According to the table created regarding the interviews, it is seen that especially the control group students has lack of knowledge and are in error. For cases where the object is between ∞-M on the optic axis of the concave mirror, 3 control group students were indecisive about whether the image was virtual or real.

Likewise, if the object was between M and F, 3 students from the control group were indecisive about whether the image was virtual or real. In addition, 2 students are mistaken about the location and size of the image. They argued that the size of the image would remain the same and the image would still be formed between M-F.

In the case where the object is between F and T, 3 students in the control groups are mistaken about the location of the image, its being reverse and virtual or real. The fact that the students said that the image should be off-center, reverse and real indicates that they are mistaken.

3.4. Convex Mirror and The Image Formation in the Convex Mirror

In this section, the students' knowledge about where the image of the real object will be formed according to its place in front of the convex mirror was questioned. The students were told that the spherical aberrations in the convex mirror are not considered. The students were asked questions about how the image is formed and about the special rays used.

First, the students were asked about the special rays used for image formation in the convex mirror. All of the experimental and control groups mentioned 4 special rays. These are given respectively below.

- *The ray that comes to the convex mirror parallel to the optic axis is reflected in such a way that its extension passes through the virtual focus.*
- *The ray coming to the convex mirror with its extension passing through the virtual focal point is reflected parallel to the optic axis.*
- *The ray arriving at the apex of the mirror is reflected in a way that is equiangular with the optic axis.*
- *The rays that come to the convex mirror so that their extension passes through the virtual center point return by reflecting on themselves.*

After these questions about special rays, the students were asked how many special rays can be used simultaneously for image formation. All groups said that all special rays in a convex mirror can be used in this question, unlike a concave mirror. Students who think that all special rays cannot be used in a concave mirror stated that they do not think that there is any obstacle in a convex mirror, since the rays do not have to cut a point on the optic axis.

> *Student 6: We do not send a ray from the focus or center point on the optic axis in this mirror. So we can use all of them.*

> *Student 19: If we send one of the rays emanating from an object on the optic axis to the vertex, one to its extension passing through the virtual focus, one from the virtual center point and the other parallel to the optic axis, there is no obstacle in front of them. Thus, we use all special rays.*

When the students were asked questions about the properties of the images formed in the convex mirror, the answers given by the students according to the position of the object are as in Table 5. It is shown as the virtual focal point (F_s) and the virtual center point (M_s) and the distance intervals and distances in front of the mirror are arranged according to the remarks of the students.

Table 5. Convex mirror and image formation in the convex mirror

Place of the Object	Place and Properties of the Image	Experiment		Control	
		Female	Male	Female	Male
∞-T	It is between T-F_s, smaller than the flat object and virtual.	5	7	4	1
∞-F	It is bigger than the flat object and virtual. (There is no information about the place of the image.)	--	--	2	4
F	The size of the image is the same with the object. It is flat and virtual. (There is no information about the place of the image.)	--	--	2	4
F-T	The image is virtual, smaller than the object and flat. (There is no information about the place of the image.)	--	--	2	4
∞-T	It is between T-F_s , bigger than the flat object and virtual.	--	--	--	1

The students were asked what they could say about the convex mirror image and properties of a real object on the optic axis without giving any space or distance. Although there were different opinions in the experimental groups, the students in the groups adopted a common attitude and agreed on a single answer. Except for one student in the 4th focus group in the control group, the other students showed a common attitude. 4. A student in the focus group said that unlike his groupmates, the size of the image would be large and he was undecided about the location of the image. In the third focus group, common decisions were made, but it was observed that there were lack of information and misconceptions in the answers given by the students. The students thought that the convex mirror has different image properties at different distances as in the concave mirror. Accordingly, they said that if the real object is ∞-F, the size of the image will be larger than the object. They were also undecided about the range in which the image would be located. They stated that when the object is at a distance of F, its image will be virtual, flat and the same size as the object. They did not express an opinion about the place where the image will be located. They said that the image of the object in the F-T interval will be virtual, flat and smaller than the object's size. They did not express an opinion about the place where the image will be located. Accordingly, the sentences of some students regarding these thoughts are as follows:

Student 23: In a convex mirror, the image gets larger as the object gets closer to the mirror. The size of the image cannot exceed the size of the object.

Student 15: In a convex mirror, the image gets larger as the object moves away from the mirror. The focus is its own size. It gets shorter as it gets closer. It gets bigger as it gets farther away.

Student 22: Teacher, in a convex mirror, the image of the object is formed between the apex of the mirror and the virtual focal point. It becomes larger and flatter than the object. The image is virtual.

3.5. Converging Lens and Image Formation in Converging Lens

The students were asked about the special rays used for image formation in the convergent lens. The side where the rays come from is considered as the front of the lens, and the side where the rays go by being refracted is accepted as the back of the lens. The situation we call the front and back of the lens was described by the students in the experimental and control groups. The aforementioned converging lenses are accepted as ideal thin lenses. Lens imperfections are not taken into account. The students were told that the rays used were monochromatic. All of the experimental and control groups mentioned 4 special rays. These are given below in order.

• *If we converge parallel to the optic axis, the ray coming into the lens is refracted so that it passes through the focus behind the lens.*

• *The ray coming to the converging lens through the focus is refracted to be parallel to the optic axis behind the lens.*

• *The ray that reaches the apex of the converging lens continues on its way without being refracted.*

• *If we converge through the center point, the ray coming into the lens is refracted to pass through the center point behind the lens.*

However, some issues were expressed by 6 students in the 2nd focus group (in the experimental group), as in the concave mirror. The statements of these students are as follows:

• *Rays coming into the lens converging so that its extension passes through the center point in front of the lens are refracted so that they pass through the center point behind the lens.*

• *If the extension passes through the focus in front of the lens, the rays coming to the lens are refracted parallel to the optic axis.*

Students in other focus groups emphasized that the light only comes through the focal point or the center point. The students in the 2nd focus group could not tell about the other situations expressed.

After these questions about special rays, the students were asked how many special rays can be used simultaneously for image formation. A variety of answers were given by the students. In this case, only the students in the 2nd focus group said that all of them could be used. However, they stated that it cannot be used in some cases and the reason for this is that the object is on the focus or center points. Except for the 2nd focus group, where the students from the experimental group were, 18 students in other groups emphasized that if the object is not located at the center point or at a point before the focal point, special rays cannot be sent from these points. Some of the answers given by the students to the question about how many special rays can be used simultaneously for image formation are as follows:

> *Student 6: We cannot draw the ray coming from the center if the object is between the focus and the center in a convergent lens as in a concave mirror.*

> *Student 17: Teacher, in order to find the image, I choose the easiest rays I can send at that moment. I don't think I can use them all. I send it from the focus, send it parallel and one to the vertex. I send from the center too, but if it's in front of the center, it's fine.*

> *Student 22: To send from the focus, it must be in front of the focus, to send from the center, it must be in front of the center. If the object is placed behind these points, we cannot send rays from these points. If it is above these points, we cannot send it.*

When the students are asked questions about the properties of the images formed in the convergent lens, the answers given by the students according to the position of the object are as in Table 6.

Table 6. Converging lens and image formation in converging lens

Place of the Object	The place and Properties of the Image	Experiment		Control	
		Female	Male	Female	Male
∞-M	It is between the lens and between M, reverse, smaller than the object and real.	5	7	6	6
M	It is behind M, the same size with the object and real.	5	7	6	6
M-F	It is behind the lens, between ∞-M, reverse, bigger than the object and real.	5	7	4	3
F	Image is on the infinity.	5	7	6	6
F-T	It is in front of the lens, the same side with the object, image is virtual, bigger than the object and flat.	5	7	4	4
	It is behind the lens, between ∞-M, reverse bigger than the object and real. The image cannot be virtual in the converging lens.	--	--	2	2

According to the table created regarding the interviews, the answers given by the students about the image formation in the convergent lens are generally more accurate than the other optical instruments. However, some statements of the control group students show that some situations are not fully understood. 3 students in the control group said that when the object is between F-T, its image should be real and larger than the object. Despite the fact that the same students' groupmates emphasized by drawing that the image should be virtual, these students repeated that the image should be real. When these students were asked why they thought differently from their groupmates, they replied as *"A virtual image cannot be formed in a convergent lens."*

Apart from these situations, some opinions regarding the convergent lens in the 3rd focus group may change with the shape of the lens. After the explanation given below by student number 16, another friend of his also gave his approval and thought that it should be so.

> *Student 16: Teacher, if we converge, if we look at the lens from the bump side, we can converge, if we look from the concave side, it can be divergent. So it can change depending on the direction we look at.*

3.6. Divergent Lens and Image Formation in Divergent Lens

In this section, the students' knowledge about where the image of the real object will be formed according to the situation in front of the divergent lens was questioned. The students were asked questions about how the image forms and about the special rays used. As in the convergent lens, the side where the rays come from is accepted as the front of the lens, and the side where they are refracted is accepted as the back of the lens. It is stated that the divergent lens used is an ideal thin lens, lens defects are neglected and the rays used are monochromatic.

First, the students were asked about the special rays used for image formation in the divergent lens. All of the experimental and control groups mentioned 4 special rays. These are given below respectively.

> • *The ray that comes to the divergent lens parallel to the optic axis is refracted and goes so that its extension passes through the focal point in front of the lens.*

• The ray coming into the lens so that its extension passes through the focal point behind the divergent lens is refracted so that it is parallel to the optic axis.

• The ray that reaches the apex of the divergent lens continues on its way without being broken.

• The rays coming to the lens, passing through the center point behind the divergent lens, are refracted so that their extension passes through the center point in front of the lens.

After these questions about special rays, the students were asked how many special rays can be used simultaneously for image formation. All groups said that all special rays in the divergent lens can be used, unlike the convergent lens, in this question. Students who think that all special rays cannot be used in the convergent lens stated that they do not think that there is any obstacle in the divergent lens, since the rays do not have to cut a point on the optic axis.

Student 6: We do not send a ray from the center point or focal point in front of the divergent lens, as in a convex mirror. So I think we can use them all.

Student 21: In the divergent lens, we do not have to pass the rays that we will send from the object through a special point on the optic axis. We have no barriers, so we can take advantage of all the special rays.

When the students are asked questions about the properties of the images formed in the divergent lens, the answers given by the students according to the position of the object are as in Table 7.

Table 7. Divergent lens and image formation in divergent lens

Place of the Object	The Place and Properties of Image	Experiment		Control	
		Female	Male	Female	Male
∞-T	It is the same side with the object, virtual and occurs in front of the lens between the focus and apex.	5	7	4	1
∞-F	In front of the lens, it is flat, larger than the object, and virtual (no information about image location).	--	--	2	4
F	It occurs in front of the lens. The image becomes the same size as the object, flat and virtual (no information about the location of the image).	--	--	2	4
F-T	In front of the lens, it is virtual, smaller than the object, and flat (no information about the location of the image).	--	--	2	4
∞-T	In front of the lens, it is between the focus and the apex, larger than the subject.	--	--	--	1

The students were asked what they could say about the image and properties of a real object on the optic axis in the divergent lens without giving any spacing or distance. Although there were different opinions similar to those in the convex mirror in the experimental groups, the students in the groups adopted a common attitude and agreed on a single answer. Attitudes in the convex mirror were similarly preserved in the control groups. Except for one student in the 4th focus group in the control groups, the other students showed a common attitude. A student in focus group 4 said that unlike his groupmates, the image would be larger. In the third focus group, common decision was reached, but it was observed that there were lack of information and misconceptions in the answers given by the students. The students made similar mistakes that they made in the convex mirror. They thought that there are different image properties at different distances, as in a converging lens. Accordingly, they said that if the real object is ∞-F, the size of the image will be larger than the object. They were also undecided about the range in which the image would be located. They stated that when the object is at a distance of F, its image will be virtual, flat and the same size as the object. They did not express an opinion about the place where the image will be located. They said that the image of the object in the F-T interval will be virtual, flat and smaller than the object's height. They did not express an opinion on where the image could be found. The sentences of some students regarding these discourses are as follows:

Student 14: In a divergent lens, if the object is at the focal length of the lens, its image will be on the same side as the object. Its size will be the same as the object, but it will be virtual.

Student 17: The image properties of the convex mirror and the divergent lens are similar. Therefore, the images formed on the convex must be similar.

4. Discussion and Conclusion

From the interviews on the law of reflection, it was seen that some of the experimental and control group students had a lack of knowledge. It is seen that this situation is more frequently seen in the control group than in the experimental group. The law of reflection operates independently of whether the surface is rough or flat. But some students in the experimental and control group said that the law would apply only if the reflection surface was flat. This is in line with the work of Yıldız (2012). In the related study, it was found that some prospective teachers made drawings in their answers that the light reflected from the rough surface was reflected from the surface in a curved way rather than in a linear way. Again, many studies have shown that students have difficulty in determining the behavior of light on different surfaces (Akdeniz, Yıldız and Yiğit, 2001; Saxena, 1991; Yıldırım-Benli, 2010). While the law of reflection was explained with figures and pictures in the control group, it was explained with animated and applied simulations in the experimental group. It is thought that the fact that this information described is more permanent in the experimental group students stems from this distinction. Accordingly, while 2 students from the experimental group had a lack of information, 5 students in the control group had lack of information.

In the interviews about the special rays in the concave mirror, all the students in the experimental and control groups gave completely correct answers. However, in the second focus group, students made other explanations by making different inferences other than memorization. These discourses are as follows:

- The rays coming to the concave mirror so that their extension passes through the center point in front of the concave mirror, and return by reflecting on themselves.
- Rays coming to the concave mirror with its extension passing through the focus in front of the concave mirror are reflected parallel to the optic axis.

The above deductions lead to the use of more specialized rays in drawings related to image formation. It is believed that students' ability to make these deductions stems from the use of this method in simulations. A drawing supporting students' statements about image formation is shown in Figure 3.

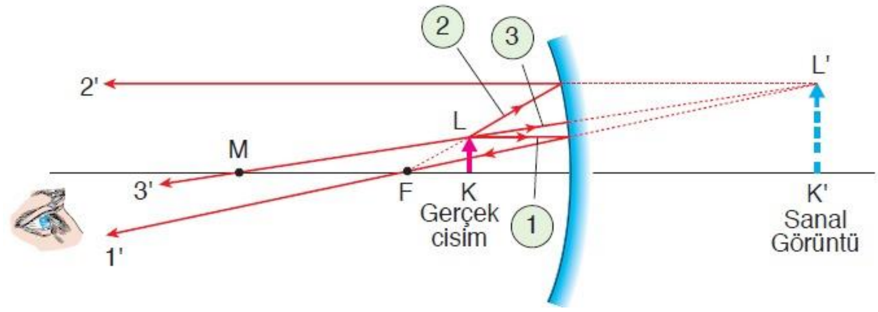

Figure 3. A diagram of image formation created by sending rays to a concave mirror that pass through the extension of its center and focus points.

In focal group discussions about the image of a real object in a concave mirror, the experimental group students provided accurate information about the position and characteristics of the image depending on the location of the object. However, differences were observed in the answers given in the control group, where some students provided incorrect or incomplete answers. These differences appeared in cases where the real object was located between infinity and the focus, between the center and focus, and between the focus and vertex. It is believed that the correct answers provided by the experimental group students regarding the image characteristics depending on the location of the real object were due to the simulations and applications they used. The experimental group students changed the location and size of the real object as they wished while observing the position, size, and type of the resulting image firsthand. It is believed that their ability to observe the changes in the image as they moved the object around increased the permanence of the information.

As for questions about the special rays in a convex mirror, all groups provided correct answers. They were also asked how many special rays can be used simultaneously in a drawing for image formation. Some students who thought that not all special rays would be used in a concave mirror said that all special rays could be used because they do not have to intersect the optic axis to reach the convex mirror. However, the answers of both the experimental and control groups did not differ regarding the special rays and their use in a convex mirror.

During discussions about the image of a real object in a convex mirror, the experimental group students explained the image characteristics correctly. However, in the control group, 6 students made different statements by determining the intervals in front of the convex mirror. Additionally, one student in the control group stated that an object in front of the convex mirror would be flat, virtual, and larger than the original between the vertex and the virtual focus of the mirror. Therefore, it was observed that 7 students in the control group were in error. It is thought that the difference between the experimental and control groups came from the simulations and applications they did. The experimental group students, through the simulations they have conducted, have observed that the image of an object in front of a convex mirror forms behind the mirror, between the virtual focus and the top point, as a small, virtual, and straight image, regardless of the location of the object. Similar findings have been reached in some studies on image formation in concave mirrors, and it has been observed that students have similar misconceptions about the subject in similar points (Aydın, 2007; Epik et al., 2002; Galili and Hazan, 2000; Kocakülah, 2006; Yıldırım-Benli, 2010; Yıldız, 2012; Yılmaz, 2010). In addition, it is observed that as the object is moved away from the lens, the image becomes smaller and approaches the focal point. The active participation of the experimental group students in the simulations is thought to have increased their retention of this knowledge.

In discussions about special rays in a converging lens, all groups correctly identified the special rays. Similar to the concave mirror question, the experimental group in the second focal point demonstrated more effective use of special rays with different statements. Thus, the students in the second focal point emphasized that it is not necessary for the object to be in front of these points to send a ray from the focus or center, as seen in Figure 4. It is believed that this inference was made by one of the focus groups due to the simulations used, where this method is applied.

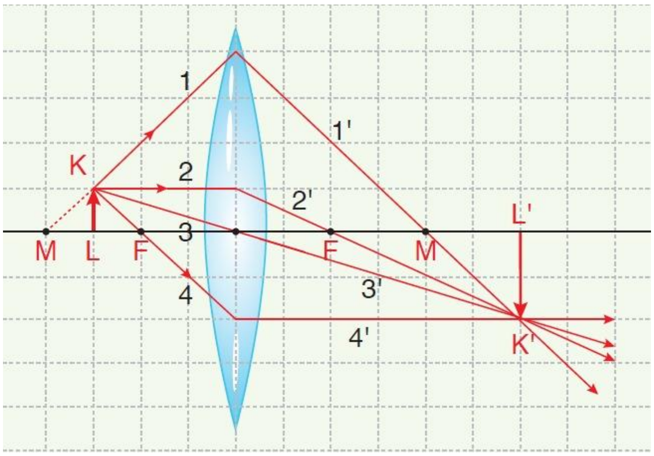

Figure 4. Image drawing in the lens whose extension is sent through the center with special rays.

When the formation and properties of an image for a real object in front of a converging lens were questioned, all of the experimental group students gave correct answers. However, in the control group, some students gave wrong answers about the image of an object located between the focus and lens of a converging lens. Specifically, 4 students in the control group gave wrong answers. The reason for this is thought to be the lack of examples in the textbooks on the location of the object between the focus and the vertex of a converging lens. It is believed that the use of simulations contributed to the experimental group students' better retention of this information.

When asked about the special rays in a diverging lens, all focus groups gave correct answers. When asked about the maximum number of special rays that can be used for the image formation drawings in a diverging lens, all focus groups stated that all special rays can be used. There was no differentiation between the groups.

In discussions about image formation through a diverging lens, the answers of the experimental and control groups differed. The focus groups composed of the experimental group provided correct answers about the properties of the image that would form in a diverging lens for a real object. However, it was observed that 7 students in the control group had misconceptions about the properties and location of the image.

It was observed that 6 students in the control group had the misconception that the image of a real object located at different positions and with different characteristics would form at the specified intervals in front of a diverging lens. Moreover, one student in the control group stated that the image of a real object located at any position in front of the lens would be larger than the object and would form between the focus and vertex of the lens. In studies conducted on image formation in lenses, it has been observed that students generally make mistakes regarding the position, size, and virtual-real nature of the images of objects placed at different points on the optic axis of the lens (Aydın, 2007; Kocakülah, 2006; Singh and Butter, 1990; Yıldız, 2012).

The experimental group students observed, through their simulations, that regardless of where they moved an object in front of a converging lens, its image formed on the same side of the lens as the object, between the lens' virtual focus and its vertex, was virtual, smaller than the object, and upright. During these observations, they also noted that as the object moved further away from the lens, its virtual image moved closer toward the lens' virtual focus and became more and more point-like. It is believed that these observations made through simulations resulted in more lasting knowledge for the experimental group students compared to the control group students.

5. References

Akdeniz, A. R., Yıldız, İ., & Yiğit, N. (2001). İlköğretim 6. sınıf öğrencilerinin ışık ünitesindeki kavram yanılgıları. *Çukurova Üniversitesi Eğitim Fakültesi Dergisi, 2*(20), 72-78.

Alkan, C., Çilenti, K., & Özçelik, D. (1991). *Kimya öğretimi*. Eskişehir: Anadolu Üniversitesi Yayınları.

Aydın, S. (2007). *Geometrik optik konusundaki kavram yanılgılarının kavamsal değişim metinleri ile giderilmesi.* (Yüksek Lisans Tezi), Atatürk Üniversitesi, Erzurum.

Aydın, S., & Öztekin, S. (2018). Üç aşamalı tanı testi ile fen lisesi öğrencilerinin geometrik optik konusundaki zihinsel modellerin belirlenmesi. *Uluslararası Eğitim Bilim ve Teknoloji Dergisi, 4*(3), 155-172.

Bogdan, R. C., & Biklen, S. K. (1992). *Qualitative Research for Education: An Introduction to Theory and Methods*. Boston: Allyn and Bacon.

Bozkurt, E. (2008). *Fizik eğitiminde hazırlanan bir sanal laboratuvar uygulamasının öğrenci başarısına etkisi.* (Doktora Tezi), Selçuk Üniversitesi, Konya.

Bozkurt, E., & Sarıkoç, A. (2008). Fizik eğitiminde sanal laboratuar, geleneksel laboratuarın yerini tutabilir mi? *Selçuk Üniversitesi Ahmet Keleşoğlu Eğitim Fakültesi Dergisi, 25*, 89-100.

Chi, M. T. H. (1992). Conceptual change within and across ontological categories Examples from learning and discovery in science. In R. Giere (Ed) *Cognitive Models of Science: Minnesota Studies in the philosophy of Science Minneapolis*, MN: University of Minnesota Press, 129-160.

Christian, W., & Lee, M. J. (2011). Optics Bench JS [Computer software]. Retrieved March 19, 2022, from https://www.compadre.org/Repository/document/ServeFile.cfm?ID=15324

Cooper, J. D. (2009). *Science contend reading: The role of reading in the seventh and eighth grade science classroom.* (Unpublished Doctoral Dissertation), Bowling Green State University.

Çepni, S., Akdeniz, A. R., & Ayas, A. (1995). Fen bilimlerinde laboratuvarın yeri ve önemi (III): Ülkemizde laboratuvar kullanımı ve bazı öneriler. *Çağdaş Eğitim Dergisi,* (206), 28-34.

Çepni, S., Kaya, A., & Küçük, M. (2005). Fizik öğretmenlerinin laboratuvarlara yönelik hizmet içi ihtiyaçlarının belirlenmesi. *Türk Eğitim Bilimleri Dergisi, 3*(2), 181-196.

Çiloğlu, T., Yılmaz Ö., Yılmaz, A., & Karaoğlan-Yılmaz, F.G. (2021). Eğitimde artırılmış gerçeklik konulu makalelerin incelenmesi. *Ahmet Keleşoğlu Eğitim Fakültesi dergisi, 3*(2), 147-158.

Çinici, A., Özden, M., Akgün, A., Ekici, M., & Yalçın, H. (2013). Sanal ve geleneksel laboratuvar uygulamalarının 5. sınıf öğrencilerinin ışık ve ses ünitesiyle ilgili başarıları üzerine etkisinin karşılaştırılması. *Bayburt Eğitim Fakültesi Dergisi, 8*(2), 92-106.

Duit, R. & von Rhöneck, C. (1998). Learning and understanding key concepts of electricity. In A. Tiberghien, E.L. Jossem & J. Barojas (Eds.) *Connecting research in physics education*. Boise, Ohio: International Commission on Physics Education-ICPE books. http://www.physics.Ohio-state.edu/~jossem/ICPE/TOC.html. Accessed 20 January 2012.

Ekici, M. (2015). *Fen bilimleri öğretmenlerinin sanal laboratuvar hakkındaki görüşleri ve bu yöntemden faydalanma düzeyleri.* (Yüksek Lisans Tezi), Adıyaman Üniversitesi, Adıyaman.

Epik, Ö., Kalem, R., Kavcar, N., & Çallıca, H. (2002). 'Işık', 'Görüntü Oluşumu' ve 'Görüntü Gözlenmesi' kavramları hakkında öğrenci görüşlerinin incelenmesi. *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi, 14*, 64-73.

Ergin, Ö., Akgün, D., Küçüközer, H., & Yakal, O. (2000). *Deney ağırlıklı fen bilgisi öğretimi*. Paper presented at the IV. Fen Bilimleri Eğitimi Kongresi 2000, Hacettepe Üniversitesi Eğitim Fakültesi, Ankara.

Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: Interpretation, structure and analysis. *International Journal of Science Education, 22*(1), 57-88.

Galili, İ., & Lavrik, V. (1998). Flux concept in learning about light: A critique of the present situtation. *Science Education, 82*(5), 591-613.

Gröber, S., Vetter, M., Eckert, B., & Jodl, H. J. (2007). Experimenting from a distance-Remotely controlled laboratory (RCL). *European Journal of Physics, 28*(3), 121-141.

Heywood, D. S. (2005). Primary trainee teachers' learning and teaching about light: Some pedagogic implications for initial teacher training. *International Journal of Science Education, 27*(12), 1447-1475.

Hwang F. K. (2004). Thin Lens (converging/diverging lens/mirrors) [Computer software]. Retrieved March 19, 2022, from: https://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=48.0

Karagöz, Ö., & Özdener-Dönmez, N. (2007). *Effect of virtual lab software used in physics courses on students' success in case of their use with different teaching methods.* Paper presented at the 7th International Education Technology Conference: Educational Technology for Innovation and Change in Education, Nicosia, North Cyprus.

Kocakülah, A. (2006). *Geleneksel öğretimin ilk, orta ve yükseköğretim öğrencilerinin görüntü oluşumu ve renklere ilişkin kavramsal anlamalarına etkisi*. (Doktora Tezi), Balıkesir Üniversitesi, Balıkesir.

Kocakülah, A., & Demirci, N. (2010). Secondary school students' conceptual understanding of image and image formation by a plane mirror. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 4*(1), 141-162.

Ünal, İ. K. & Şeker, R. (2020). Sanal laboratuvar uygulamalarının öğrenci akademik başarıları üzerine etkisinin incelenmesi: elektrik ünitesi. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 21*(1), 504-543.

Koray, Ö. & Bal, Ş. (2002). Fen öğretiminde kavram yanılgıları ve kavramsal değişim stratejisi. *G.Ü. Kastamonu Eğitim Fakültesi Dergisi,10(*1), 83-90.

Önen, F. (2005). *İlköğretimde basınç konusunda öğrencilerin sahip olduğu kavram yanılgılarının yapılandırmacı yaklaşım ile giderilmesi.* (Yüksek Lisans Tezi). Marmara Üniversitesi, Eğitim Bilimleri Enstitüsü, İstanbul.

Saxena, A.B. (1991). The understanding of the properties of light by students in India. *International Journal of Science Education, 13*(3), 283-289.

Singh, A. & Butter, H.B. (1990). Refraction: Conceptions and knowledge structure. *International Journal of Science Education, 12*(4), 429-442.

Sönmez, E., Dilber, R., Karaman, İ., & Şimşek, D. (2005). Fizik laboratuarında kullanılan deney malzemeleri üzerine bir çalışma. *Atatürk Üniversitesi Kazım Karabekir Eğitim Fakültesi Dergisi, 0*(11), 590-604.

Taşlıdere, E. (2013). The effect concept cartoon worksheets on students' conceptual understandings of geometrical optics. *Education and Science, 38*(167), 144-161.

Tatlı, Z., & Ayas, A. (2011). *Sanal kimya laboratuvarı geliştirme süreci*. Paper presented at the 5th International Computer & Instructional Technologies Symposium, Fırat University, Elazığ-Turkey.

Uğur, A. (2001). Eğitimde bilgisayar grafikleri ve grafik yazılımları. *Ege Eğitim Dergisi, 1*(1), 146-156.

Yıldırım-Benli, A. (2010). *Geometrik optik konularında soruşturma temelli öğrenim yaklaşımına uygun hazırlanmış etkinliklerin işbirlikli öğrenme ortamına uygulanmasının etkileri.* (Yüksek Lisans Tezi), Dokuz Eylül Üniversitesi, İzmir.

Yıldız, M. (2012). *Geometrik optik öğretiminde yapılandırmacı öğrenme kuramına dayalı olarak geliştirilen laboratuar materyallerinin etkililiğinin değerlendirilmesi.* (Yüksek Lisans Tezi), Karadeniz Teknik Üniversitesi, Trabzon.

Yılmaz, Z. A. (2010). *Kavramsal değişim metinlerinin üniversite öğrencilerinin geometrik optik konusundaki kavram yanılgılarının düzeltilmesi ve fizik dersine karşı tutumlarına etkisinin incelenmesi.* (Doktora Tezi), Atatürk Üniversitesi, Erzurum.

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Conflict of Interest

It has been reported by the authors that there is no conflict of interest.

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