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Cross-Grade Comparison of Students' Conceptual Understanding with Lenses in Geometric Optics

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ABSTRACT: Students commonly find the field of physics difficult. Therefore, they generally have learning problems. One of the subjects with which they have difficulties is optics within a physics discipline. This study aims to determine students' conceptual understanding levels at different education levels relating to lenses in geometric optics. A cross-sectional design is used in the study. Participants in the study include one hundred and seventy-seven students at three different education levels from primary and secondary schools, and higher education. Seven open-ended questions, examining participants' conceptual understanding levels in relation to lenses, act as the data collection instrument. It is determined that students hold misconceptions such as, "convex lenses diverge light rays", "concave lenses converge light rays", "a right-side-up image replaces the previously observed inverted image, when a convex lens is removed," "myopia is corrected via convex lens," and "hyperopia is corrected via concave lens." The results show that students from all groups (primary and secondary schools, and higher education) have a lack of knowledge and experience conceptual problems about lenses, although they learned this subject in school.

KEY WORDS: Physics education; optical lenses; image formation; conceptual understanding level

INTRODUCTION

The physics discipline requires learners to employ different representations together, such as graphs, laws and principles, formulas, and various abstract concepts. So, learning physics can be particularly difficult for many students. Being aware of students' conceptual difficulties in physics can provide valuable information for instructors, curriculum developers, and course textbooks authors.

Optics in physics is a rapidly developing industry and we often encounter its technological practices in our everyday lives. However teaching and learning the subject of optics is challenging for instructors and students (Galili & Hazan, 2000). Students generally begin to learn

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about geometric optics when they are at primary school. But can they fully understand the subject of geometric optics? What are their understanding difficulties or common misconceptions in this subject area continuing from primary school?

Prior research shows individuals have similar difficulties in understanding geometric optics from primary school through adulthood. Such studies from primary school (e.g. Andersson & Karrqvist, 1983; Koray & Bal, 2002; Osborne, Black, Meadows, & Smith, 1993; Selley, 1996), secondary school (e.g. Colin, Chauvet, & Viennot, 2002; Fetherstonhaugh & Treagust, 1992; Galili, Bendall, & Goldberg, 1993; Galili & Hazan, 2000; Galili & Lavrik, 1998; Langley, Ronen, & Eylon, 1997; Singh & Butler, 1990; Tao, 2004) and university level (e.g. Bendall, Goldberg, & Galili, 1993; Colin & Viennot, 2001; Goldberg & MacDermott, 1987; Kaya Şengören, 2010; Palacios, Cazorla, & Cervantes, 1989; Saxena, 1991) reveal that learners have several different concepts and difficulties in learning about light and its properties, vision, and image formation.

Prior knowledge of students about the subject is important to acquire the related new knowledge. Also possession of misconceptions hinders students' learning (Apostolides, 2008; Duit & Treagust, 2003). Therefore, it comes into prominence for science educators to determine their students' present understanding and misconceptions relation to this subject area. And it is essential to contribute to the development of science education programs.

The present study aims to determine conceptual understanding of students at different education levels such as primary school, secondary school and higher education, in relation to lenses in geometric optics as well as to investigate misconceptions students hold. The study endeavours to answer the following questions:

1. What are the conceptual understandings of students at different education levels (primary, secondary, and higher education) in relationship to lenses?
2. What are the misconceptions that the students at different levels hold in the subject of lenses?

LITERATURE REVIEW

In discussions about how an object is seen, students generally cannot demonstrate a link between the eye and viewed object or image (Bendall, Goldberg, & Galili, 1993; Galili, Bendall, & Goldberg, 1993; Galili & Hazan, 2000; Heywood, 2005; Langley, Ronen, & Eylon, 1997; Osborne, Black, Meadows, & Smith, 1993). Some students think that only looking at the object is sufficient to see it (Heywood, 2005; Langley, Ronen, &

Eylon, 1997; Şen, 2003). Students' diagrams or explanations on plane mirror image formation contain scientific mistakes or deficiencies (Galili & Hazan, 2000; Heywood, 2005; Langley, Ronen, & Eylon, 1997; Palacios, Cazorla, & Cervantes, 1989). For example, the study of Langley et al. (1997) examined 10th-grade students' conceptions and representations of optical systems, light propagation, illumination patterns, and visual patterns by using a questionnaire consisting of nine questions dealing with common situations involving light and sight. The most significant finding is that the majority of students do not represent light directed away from the light sources. Only a minority indicate direction toward the eye from both luminous and nonluminous objects and they rarely produce consistent explanatory diagrams for the phenomena of shadow formation, dazzling by a mirror, and plane mirror image formation and observation.

Galili and Hazan (2000) explored high school and teacher-training college students' knowledge of light, vision and related topics through a questionnaire comprised thirteen questions. Students were encouraged to draw diagrams or sketches to support their written answers. Before instruction, the majority of the students' written descriptions and sketches describing the vision process made no reference to a physical relationship between the observing eye and the observed objects. And some used expressions such as 'eyes can see', or 'I just open my eyes, and I see.' Also students thought that 'the image was always present in the mirror whether or not it was observed', 'images were first created by a special material comprising the mirror; subsequently we looked in the mirror and saw them', 'when a converging lens was removed, a right-side-up image replaced the previously observed inverted image.'

Heywood (2005) similarly explored conceptual area of light of primary undergraduate trainee teachers by using diagrammatic representations and interview. The study focused on two fundamental optical phenomena; how an object was seen and how an image was formed in a plane mirror. It was found that most students could select the correct scientific representation of how an object was seen and there was awareness of reflection in a plane mirror. However, students had difficulties to provide scientifically explanations and to apply reasoning in more complex contexts.

Goldberg and McDermott (1987) in their studies investigated undergraduates t when taking introductory physics, their understanding of the real images produced by convex (converging) lenses and concave mirrors. Their interviews, based on a simple demonstration, found that when an image was produced by a convex (converging) lens on a screen and then the lens was removed students thought an image would still form on the screen.

Other studies (e.g. Bendall, Goldberg, & Galili, 1993; Fetherstonhaugh & Treagust, 1992; Koray & Bal, 2002; Langley, Ronen, & Eylon, 1997; Osborne, Black, Meadows, & Smith, 1993; Saxena, 1991; Selley, 1996; Stead & Osborne, 1980; Uzun, Alev, & Karal, 2013) generally focus on students' understanding of geometric optics about light or sight concepts. Research related to students' understanding of lenses (Galili & Hazan, 2000; Colin, Chauvet, & Viennot, 2002; Goldberg & MacDermott, 1987; Singh & Butler, 1990; Tao, 2004) is very limited. Also a few studies on geometric optics (e.g. Kocakülah, 2006; Singh & Butler, 1990; Uzun, Alev, & Karal, 2013) are cross-sectional.

A cross-sectional study provides to opportunity to observe a sample, or cross-section, of a population or phenomenon that are made at a particular point in time as a snapshot (Babbie, 2009; Cohen, Manion, & Morrison, 2007; Jackson, 2009; Salkind, 2010). In education, cross-sectional studies imply indirect measures of the nature and rate of changes in the physical and intellectual development of samples of children drawn from representative age levels (Cohen, Manion, & Morrison, 2007). Cross-sectional studies enable the determining of misconceptions and conceptual development of students at different age levels (Morgil & Yörük, 2006).

Cross-Sectional Studies in Physics Education

Through cross-sectional research, it is possible to find answer to question of "which conceptual understanding or misconception at which grade/age" for education studies.

Trumper and Gorsky (1996) investigated physics students' conceptions of force in pre-service training for high school teachers. A cross-college age study was implemented with the participants in the present study were drawn from several colleges in Israel which conduct pre-service training programs for future high-school teachers. Total of the sample was 68 physics students (16 first year, 12 second year, 21 third year and 19 fourth year. The force conceptions held by the physics students were analysed by means of a two-part written questionnaire. According to findings there was a serious discrepancy between student teachers' understanding of force and the accepted scientific concept. For example, students' responses to the question of the 'book moving on a frictionless table' indicated that a great majority in the second and third years drew an arrow mostly showing a force in the direction of movement (impetus) or a force acting against the direction of motion. Some of students also did not recognize the existence of the normal force exerted by the table. Students in the first and fourth years performed better though there were still a considerable number of them drawing the 'impetus' force. Similarly, Trumper (2001) in his other study analysed senior high school students' astronomy conceptions through a written questionnaire presented to them during the beginning of the first semester. A cross-age study was implemented with the sample consisted of 153 tenth grade students (about 15 year-old), 116 eleventh grade students (about 16 years) and 109 twelfth grade students (about 17 years). According to findings the overall correct response rate was 43.6%, somewhat increasing through the 3 years, from 40.9% in grade 10 to 47.0% in grade 12. A statistically significant difference was found only when comparing the results of the 10th and 12th grade students. It was concluded that there was a serious discrepancy between senior high school students' conceptions of some basic astronomy concepts and the corresponding accepted scientific views. Most students underestimated distances in the Universe and overestimated the Earth's diameter. Also most students answered incorrectly the questions dealing with the following subjects: Sun overhead at noon, longitude time zones, and Moon's rotation.

Liu and Tang (2004) in their cross-grade study examined the progression of concepts of energy from grades 4, through grade 8, to grade 12 with modal ages of 9, 13, and 17, respectively and compared Canadian and Chinese students with respect to their conceptual progression. An open-ended questionnaire consisted of two open-ended questions, one asking students to make a list of terms that they thought were related to energy and the other asking them to write sentences clarifying the meaning of terms and relationships between the terms was applied to students. The findings of the study showed that, alternative conceptions and scientific conceptions co-existed. Alternative conceptions were stable from grade 4 to grade 12. Although a significantly higher percentage of Chinese grade 12 students made reference to understanding energy conservation than grades 4 and 8 students, the overall percentage for grade 12 students in both countries remained low (< 30%). There was no significant increase in percentage from grade 4 to grade 12, in either China or Canada. Another study on energy concept was conducted by Sağlam Arslan (2010). The researcher determined the level of understanding of energy concepts of students at different academic grades and the differences in understanding between these grades. Also conceptual development of these students was analysed. A cross-grade study was implemented with the sample consisted forty-three students at 3 different levels (high school, undergraduate, and postgraduate). The students' understandings of energy concepts were determined using a questionnaire that request answer as verbally and graphically. The findings showed that students from all three groups defined energy in similar ways and possess similar alternative conceptions. Also result showed that students at all levels experienced difficulties in visualisation. Students made no significant progress in graphical representation commensurate with their learning levels.

Gönen and Kocakaya (2010), investigated misconceptions that students had on the terms heat and temperature and how students' prior learning affected their misconceptions. Also they determined if students were able to make a connection between their own knowledge and physics in everyday life. A cross-age study was implemented with the sample consisted 342 students from different grades that ranged from sixth grade students aged 11-12 years to eighth students aged 14-15 years. A paper and pencil test composed of 14 multiple-chosen questions was developed but only five questions related to heat and temperature were used directly in the study. It was found that students' misunderstanding about the heat and temperature influenced their knowledge about these terms. Students' specific misconceptions in sixth and eighth grade were higher than seventh grade. It was concluded that most of students memorized these concepts and were not able to make a connection between their own knowledge and physics in everyday life. Also they concluded that depending on the instruction students received and over time, their conceptual understanding showed a steady increase from sixth grade to eighth grade, except in the case of item one.

Uzun, Alev, and Karal (2013) investigated students' understanding of light, sight and related concepts at different educational levels, from primary to higher education. Across-sectional approach was used since the participants were of different ages and at different educational levels. The participants consisted of 30 eighth grade primary school students, 26 eleventh grade secondary school students, and 42 student teachers. The data were obtained through open-ended, multiple choice questions, and drawing exercises. Findings of the study showed that the majority of participants, at all levels, had similar understanding of light, which meant that their conceptions or misconceptions about light remained similar from primary to university level. Some common misconceptions as "light goes out from the eyes to the object in the process of sight" and "light goes out from the eyes to a source in the process of sight" were indicated by participants at all levels.

For this study, a cross-sectional research design was chosen to determine conceptual understanding levels of students at different education levels such as primary school, secondary school and higher education in relationship to lenses. Although there have been several studies about optics generally focusing on light propagation and sight, studies on lenses in optics and using a cross-sectional ones have been very limited as mentioned. Hence, conducting such research increases the significance of this study.

METHODOLOGY

Cross-sectional research design was chosen for this research to determine the same conceptual understanding from primary school through higher education. Several researchers (e.g. Blanco & Prieto, 1997; Çalık & Ayas, 2005; Gönen & Kocakaya, 2010; Krnel, Glažar, & Watson, 2003; Sağlam Arslan, 2010; Westbrook & Marek, 1991) have utilized the cross-sectional research design to examine students' levels of understanding in the science area with satisfactory results (physics, chemistry, etc.).

Participants

The present study was conducted with 177 participants from three different levels of education primary, secondary, and higher education students in the Black Sea Region of Turkey during the 2013-2014 academic years. The first group consisted of 82 primary school students in the 8th grade (aged 13-14), the second group consisted of 50 secondary school students in the 12th grade (aged 17-18), and the third group consisted of 45 physics teacher candidates in 4th and 5th grades (aged 21 and up) enrolled in five year university physics teaching program. The primary school students in this study were taught about optical lenses in grade 7 (aged 12-13). The formal physics lessons began with secondary education in grade 9 (aged 14-15). The secondary school students of this study were taught about optical lenses in grade 12 (aged 17-18). Teacher candidates in physics teaching program first experienced geometric optics in Physics II course in the first year (grade 1). Also they took an "Optic and Waves" course in the second year (grade 2).

Data Collection Tool

In this study, seven open-ended questions relating to lenses, written and administered in Turkish, were designed by the researcher as the data collection instrument. These questions examined the participants' knowledge of lenses, in general. This type of instrument, frequently used in similar conceptual studies (e.g. Çalık & Ayas, 2005; Galili & Hazan, 2000; Tao, 2004; Trumper, 1993; Yuengyong, Jones, & Yutakom, 2008), instead of a rigid structure, multiple-choice test, aimed to increase the reliability of collected data. To determine content validity of the instrument, the measurement instrument was examined by one physics instructor from the university, one physics teacher from the secondary school, and one science and technology teacher from the primary school. It was necessary to reach a consensus among instructors on the primary school students' fourth and fifth questions, which was about image formation with optical lenses and whether it needed to differ from that for the secondary school and higher education (see Appendix). The condition of the object was taught in determining the shape and size of the image at secondary and higher education levels. However, after examination it was accepted as a measurement instrument that serves the purpose of the research by instructors. Questions on the measurement instrument and aims of the questions were as given in the Appendix.

The instrument was administered in the students' classroom environment. Students were told the questionnaire was intended purely for research purposes and would have no effect on their course grades. The participants were encouraged to answer all questions and given as much time as they needed. They completed their responses in a period of 20-30 minutes.

Analysis of Data

The data obtained from students' responses was analysed by using the approaches that determine full response (nomothetic) and classification of explanations into specific categories (ideographic). For the analysis, complete responses for all questions were first determined. Next, to analyse students' responses, the following criteria (Table 1), similar to a rubric developed by Abraham, Williamsom, and Wetsbrook (1994), were employed. Such criterion systems are generally used in similar studies (e.g. Çalık & Ayas, 2005; Kocakülah, 2006; Sağlam Arslan, 2010; Westbrook & Marek, 1991) to analyse data.

Table 1 Criteria Used in the Evaluation of the Open-Ended Questions

Understanding Level	Shortenings
Sound Understanding: Responses containing all components of the scientifically accepted response	SU
Partial Understanding: Responses that included at least one of the components of validated response, but not all the components	PU
Partial Understanding with Specific Misconception: Responses that included both correct and incorrect information	PUSM
Specific Misconceptions: Scientifically incorrect responses containing illogical or incorrect information	SM
No Understanding: Blank, repeats question; irrelevant or unclear response	NU

To prevent random errors or bias in coding that could arise from the researcher, another researcher re-coded about 50% of the answer sheets, randomly selected from each group (41 papers from primary school, 25 papers from secondary school, and 23 papers from higher education). The other researcher was requested to code answers according to the same categories previously used. An inter-coder reliability measure suggested by Miles and Huberman (1994), reliability = number of agreements / (total number of agreements + disagreements), was utilized to calculate the level of agreement between the two researchers. Inter-coder agreement results obtained from all groups were as indicated in Table 2.

Table 2 Inter-coder Agreement Results Obtained from All Groups

	Reliability according to questions			**Reliability for each group**			**Reliability obtained from all groups**
Questions	PS	SS	HE	PS	SS	HE	
1	.93	.84	.83				
2	.88	.96	.87				
3	.98	.88	.91				
4	.90	1	1	.93	.92	.90	.92
5	.98	.96	1				
6	.88	.84	.87				
7	.93	.96	.83				

PS: Primary School, SS: Secondary School, HE: Higher Education

Miles and Hubermann (1994) do not specify a particular inter-coder measure, but they suggested the inter-coder agreement should be in the 90% range, depending on the size and range of the coding scheme. The inter-coder agreement between researchers in this case was 91.67% and the coding was considered reliable.

RESULTS

The analysis of the collected data was completed question-by-question and findings were presented in Table 3 according to the levels of education. Students' wrong explanations for each question were given. To support students' explanations, examples from papers of students were presented from time to time.

Most student answers for Q1 about instruments using optical lenses, and functions of these lenses contain both correct and wrong explanations (PUSM) in all groups. The correct part for these answers is generally about names of the instruments. Students commonly write binoculars, telescope, camera, microscope, flashlight, and glasses for the instruments using optical lenses. But, they also give wrong responses about type of lenses or their functions in these instruments from primary school through higher education. Generally, they write a concave lens is used in the instrument instead of a convex lens. For example, PS students generally write a concave lens is used in binoculars.

As can be seen from Table 3, only 6% of the primary school (PS) students, 8% of secondary school (SS) students, and 29% of the physics teacher candidates (HE) answered at the "Sound Understanding" (SU) level for Q2, which dealt with discrimination of convex and concave lenses.

Table 3 Distribution of Students' Answers According to Level

Questions and their contents	UL	PS (N=82)	SS (N=50)	HE (N=45)
		f (%)	f (%)	f (%)
Q1 Instruments used optical lenses and the functions of these lenses	SU	3 (4)	12 (24)	6 (13)
	PU	14 (17)	8 (16)	9 (20)
	PUSM	61 (74)	30 (60)	30 (67)
	SM	4 (5)		
	NU			
Q2 Discrimination of convex and concave lenses	SU	5 (6)	4 (8)	13 (29)
	PU	23 (28)	27 (54)	13 (29)
	PUSM	5 (6)	4 (8)	3 (7)
	SM	33 (40)	9 (18)	15 (33)
	NU	16 (20)	6 (12)	1 (2)
Q3 Image formation on screen, when a convex lens is removed	SU	2 (2)	17 (34)	10 (22)
	PU	1 (1)		
	PUSM	2 (2)	2 (4)	2 (4)
	SM	58 (71)	20 (40)	32 (71)
	NU	19 (23)	11 (22)	1 (2)
Q4 Image formation with convex lenses	SU	3 (4)	12 (24)	6 (13)
	PU	10 (12)	5 (10)	2 (4)
	PUSM	16 (20)	15 (30)	18 (40)
	SM	42 (51)	7 (14)	14 (31)
	NU	11 (13)	11 (22)	5 (11)
Q5 Image formation with concave lenses	SU		16 (32)	8 (18)
	PU	8 (10)	7 (14)	2 (4)
	PUSM	9 (11)	10 (20)	18 (40)
	SM	56 (68)	10 (20)	15 (33)
	NU	9 (11)	7 (14)	2 (4)
Q6 Correction of myopia with optical lenses	SU		3 (6)	6 (13)
	PU	16 (20)	14 (28)	7 (16)
	PUSM	21 (26)	17 (34)	6 (13)
	SM	30 (37)	8 (16)	25 (56)
	NU	15 (18)	8 (16)	1 (2)

Q7 Correction of hyperopia with optical lenses	SU		3 (6)	6 (13)
	PU	14 (17)	16 (32)	8 (18)
	PUSM	19 (23)	16 (32)	6 (13)
	SM	31 (38)	5 (10)	24 (53)
	NU	18 (22)	10 (20)	1 (2)

UL: Understanding Level, SU: Sound Understanding, PUSM: Partial Understanding with Specific Misconception, SM: Specific Misconceptions, PU: Partial Understanding, NU: No Understanding
PS: Primary School, SS: Secondary School, HE: Higher Education

Answer percentages for students from SE and HE with correct explanations were higher than for PS students. Most PS students provided the following incorrect explanations about how they distinguish convex and concave lenses:

"convex lenses are thin, concave ones are thick,"

"the lens that diverges light rays is a convex lens, the lens that converges light rays is a concave lens,"

"the lens, if it magnifies the object, is a concave lens; if it doesn't magnify, is a convex lens."

Most student response rates from the different groups for Q3 were at the "Specific Misconceptions" (SM) level. Only 2% of PS students gave an answer at the SU level, indicating the image wasn't formed on the screen when the lens was removed. The common misconception was "a right-side-up image replaced the previously observed inverted image, when a convex lens was removed." In addition to this statement, some students' answers contained "the lens turned the image upside-down." Briefly, most students from all groups thought an image still formed on the screen when the converging lens was removed.

Students from the SS group gave scientifically correct responses for Q4 and Q5 about image formation with lenses, which were higher than the other groups. However, as shown in Table 4, more students' answers contained wrong, irrelevant, or no explanations, especially in the PS group. Many students from the PS group drew a concave lens figure instead of a convex lens for Q4 and drew the opposite for Q5 (Figure 1 and 2) for their explanations. Some students' common misconceptions in the PS group included

"convex lenses diverge light rays",

"concave lenses converge light rays",

"concave lenses turn the image upside-down and magnify it",

"convex lenses show the object away" (Figure 1),

"concave lenses show the object near" (Figure 2),

"convex lenses show the object smaller",

"concave lenses show the object bigger",

"convex lenses show the object thin and short" (Figure 3),

"concave lenses show the object thick and tall" (Figure 4).

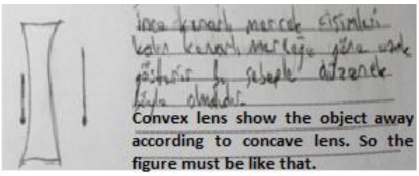

Figure 1 PS student's convex lens drawing and explanation

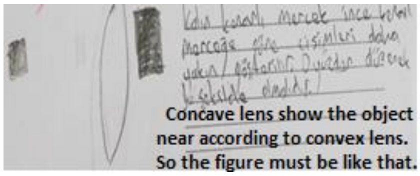

Figure 2 PS student's concave lens drawing and explanation

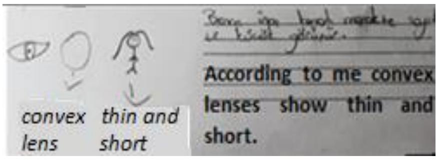

Figure 3 PS student's convex lens drawing and explanation

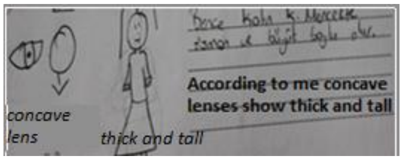

Figure 4 PS student's concave lens drawing and explanation

Students' misconceptions are shown in Table 4. Also, answers from SS and HE groups contain mistakes about shape and size of the image formed with lenses according to object positions.

Table 4 Students' Misconceptions Related to Lenses

Misconceptions	PS	SS	HE
Convex lenses are thin, the concave ones are thick	X	X	X
Convex lenses diverge light rays	X	X	X
Concave lenses converge light rays	X	X	X
A right-side-up image replaces the previously observed inverted image, when a convex lens is removed	X	X	X
Concave lenses turn the image upside-down and magnify it	X		
Convex lenses show the object away	X	X	X
Concave lenses show the object near	X	X	X
Convex lenses show the object smaller	X		X
Concave lenses show the object bigger	X		X
Convex lenses show the object thin and short	X		
Concave lenses show the object thick and tall	X		
Myopia is corrected via convex lens	X	X	X
Hyperopia is corrected via concave lens	X	X	X

To identify students' knowledge about correction of eye problems with lenses (Q6 and Q7), none of the PS students provided an answer at the SU level. For PS students and physics teacher candidates from HE, the highest percentage was at the SM level. An analysis of the responses for these questions given by a significant proportion of the students from all groups revealed students have common misconceptions that “myopia was corrected via a convex lens” (Figure 5) and “hyperopia was corrected via a concave lens” (Figure 6).

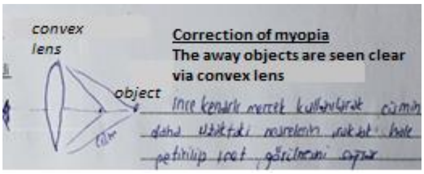

Figure 5 Drawing and explanation of a physics teacher candidate in 4th grade about correction of myopia

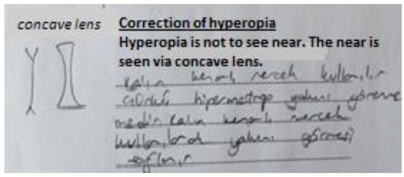

Figure 6 Drawing and explanation of a physics teacher candidate in 4th grade about correction of hyperopia

Also answers by some students from the HE group contained wrong drawings related to lenses. They drew concave lens figures for convex lens explanations (Figure 7) and the opposite, as in Figure 8.

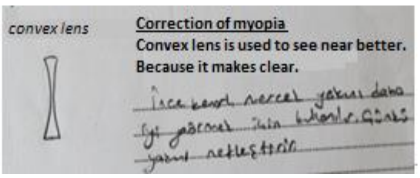

Figure 7 Drawing and explanation of a physics teacher candidate in 5th grade about correction of myopia

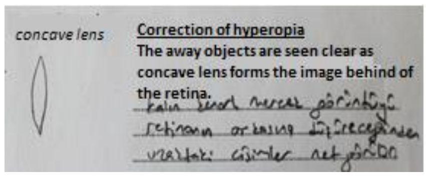

Figure 8 Drawing and explanation of a physics teacher candidate in 5th grade about correction of hyperopia

DISCUSSION AND CONCLUSION

This study investigated the conceptual understanding of students at different educational levels, in relationship to lenses in optics within the physics discipline. Students’ written responses for Q1 revealed that the majority of participants at all levels know instruments using lenses, but they have wrong explanations for the type of lenses instruments contained and in explaining the functions of these lenses. An important aim of science education is making science more relevant to students, more easily learned and remembered, and also more reflective of the actual practice of science (Arroio, 2010). But more often students believe the physics discipline is irrelevant to their lives (Efthimiou, 2006). By contrast with students’ opinions; physics can be seen in every area of our lives and to show this we need to represent applications of physics with life in our learning environments. Therefore, related to lenses in optics, we need to show students the structure of an eye, obtaining maybe a cow's eye. Also, functions of lenses can be explained based on instruments such as microscope, binoculars, camera, epidiascope, telescope etc. So, students can associate optics, and thereby physics, with life.

Explanations for Q2 indicated students, especially from PS, had difficulties discriminating convex and concave lenses from each other. These results show students have lack of knowledge about shapes and characteristics of lenses.

Findings from Q3, Q4 and Q5 revealed many students at all education levels had problems about image formation using lenses and functions of the lenses. Most students believed the image could occur on the screen without a lens. This result seemed consistent with that found in the literature (Goldberg & McDermott, 1987; Galili & Hazan, 2000; Kocakülah, 2006). Students actively engaged in hands-on experiments using convex and concave lens in learning environment could reinforce their understanding functions of lenses and their differences from each other.

Some students from the PS group think that convex lenses show the object thin and concave lenses, thick. This result may be derived from language problems as 'thin edge lens' expression instead of convex lens and 'thick edge lens' expression instead of concave lens are used more frequently by Turkish textbooks or teachers. This result is compatible with the research of Kocakülah (2006) who examined the forms of ideas about image formation and colours of the primary and secondary school students and prospective teachers who would be in a position to teach those in primary and physics classes.

One of the application areas for lenses in daily life is the treatment of eye problems. The present study results show participants have problems applying their knowledge of lenses to myopia and hyperopia eye problems. The poor results may be due to mixing of lens functions as understood by the previous questions.

Looking at the students' level of understanding for all questions by considering the sum of the percentages in 'Sound Understanding' and those at 'Partial Understanding' levels, there is an increase from grade 8 to grade 12. As the academic level advanced, the participants had more experiments and experiences in optics. So, scientifically correct explanations may be expected to increase as academic level advanced. However, there is a decrease from grade 12 to higher education about sum of the percentages in 'Sound Understanding' and 'Partial Understanding' levels perhaps resulting from the impact of the grades 12 external examination. The graph shows a 'Λ shaped' as considering PS to SS and to HE. Similarly, looking at the sum of the percentages of 'Specific

Misconception' of participants we see that it shows a 'V shaped' except in the case of item 1. Students' common misconceptions at all levels are indicated in table 4

Based on the results, it can be said students from PE, SE, and HE still lack knowledge or scientifically wrong explanations in functions of the convex and concave lenses, discrimination of these lenses, image formation with lenses and applying their knowledge of lenses to myopia and hyperopia eye problems. This is the case, although they learned this subject area in their schools. It shows that there are significant similarities between students' learning at different levels.

The results are valid for the study group who participated in present study, although the study doesn't intend to generalize the results to a larger universe. The HE group from the secondary physics education program are destined to become future physics teachers yet they still had conceptual problems with image formation and functions of convex and concave lenses. These problems need to be taken into account, especially as physics teacher candidates may transfer their non-scientific knowledge to their students. Future research need to examine reasons for such lack of knowledge and scientifically wrong responses of students in detail. This may arise because of several factors such as learning environments, teacher competencies, physics textbooks etc. And as the factor may differ for the education levels, there is a need to focus on the factor or factors related to education level to overcome these difficulties. For example, if the problem originated from traditional and teacher-centred learning environments, we can organize student-centred and active learning environments that students are engaged in optics activities such as experiments, discussing, writing, role-playing, simulations, demonstrations etc.

Study of Kapucu (2014) revealed that the majority of 267 pre-service primary school teachers did not like physics. Fundamental salient beliefs of them about why they disliked physics were their unsuccessfulness in solving physics problems and their previous teachers' teaching based on more memorization of physics formulas and rules. Also Rodrigues, Tavares, Ortega and De Mattos (2010) point out importance of a teacher's planning, organization and the dialogic interaction in the classroom for physics teaching. So, the problems may originated from teachers we can support them with in-service trainings in collaboration with the university. Textbooks for primary school science and for secondary school physics in Turkey include *thin edge lens* and *thick edge lens e*xpressions. So, students can have scientifically wrong explanations as mentioned above *thin edge (convex) lenses show the object thin and thick edge (concave) lenses show the object thick* because of name connotation. We can solve this problem as using convex and concave expressions for lenses both by textbooks and teachers. If we use *thin edge lens* and *thick edge lens* *e*xpressions, in addition to these concepts we should use *convex-converging* and *concave-diverging lens* concepts. Also, we should put probable misconceptions of students as "convex lenses show the object thin and concave lenses show thick" to curriculum and teachers guides to inform teachers. In this way, we can overcome deficiencies derived of these factors for all education levels and improve students' conceptual understanding as ensure to replace non-scientific and incomplete explanations with scientifically correct and full explanations.

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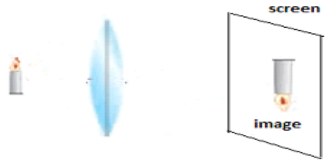
APPENDIX

Appendix Questions in Measurement Instrument and Aims of Them

<table>
<tr><th>Questions</th><th>Aim</th></tr>
<tr><td>1. Please enter the names of three instruments using lens, types of lenses, and their functions in these instruments in the table below.
<table><tr><th>Name of instrument</th><th>Type of lens used in the instrument</th><th>Function of this lens</th></tr><tr><td></td><td></td><td></td></tr></table></td><td>To determine students’ awareness about instruments used optical lenses and the functions of these lenses</td></tr>
<tr><td>2. Distinguish the converging and diverging lenses in the box. How do you distinguish them? Please explain.</td><td>To determine students’ discrimination of convex (converging) and concave (diverging) lenses.</td></tr>
<tr><td>3. The following figure shows the image of a candle.
What can be said about the image when the lens is removed? Please write a justification for your answer.

....
....
....
Because ....
....</td><td>To determine students’ understanding of image formation with convex lens.</td></tr>
</table>

Appendix Questions in Measurement Instrument and Aims of Them (Contn'd)

No.	Level	Question	Aim
4.	For primary school students	How is the image of an object formed with a converging lens. Please draw its figure and explain. Figure Explanation : …………………………………… …………………………………… …………………………………… …………………………………… …………………………………… ……………………………………	To determine students' understanding of image formation with converging lens.
	For secondary school and higher education	How are the shape and size of the image formed for an object with a converging lens, according to following positions. **a) If the object is outside the center (2F)** Shape of image…. Size of image, according to the object…… **b) If the object is between center (2F) and focal (F)** Shape of image…. Size of image, according to the object….	
5.	For primary school students	How is the image of an object formed with a diverging lens. Please draw its figure and explain. Figure Explanation : …………………………………… …………………………………… …………………………………… …………………………………… …………………………………… ……………………………………	To determine students' understanding of image formation with diverging lens.
	For secondary school and higher education	How are the shape and size of an image formed for an object with a diverging lens, if the object is between infinity (?) and the lens. Shape of image…. Size of image, according to the object……	

Appendix Questions in Measurement Instrument and Aims of Them (Contn'd)

6. The images of objects form in front of the retina for myopia. Therefore, while nearby objects are clearly visible, distant objects appear blurry. **Which kind of lens is used to correct myopia? Please write the name of this lens, draw its figure, and explain how it corrects the myopia.** Name of the lens: Correcting myopia via this lens Figure of the lens …………………………………………………………… …………………………………………………………… ……………………………………………………………	To determine students' understanding about correction of myopia (near-sightedness) with optical lenses.
7. The images of objects form behind of the retina for hypermetropia. Therefore, while distant objects are clearly visible, nearby objects appear blurry. **Which kind of lens is used to correct hypermetropia? Please write the name of this lens, draw its figure, and explain how it corrects.** Name of the lens: Correcting hypermetropia via this lens Figure of the lens …………………………………………………………… ……………………………………………………………	To determine students' understanding about correction of hyperopia (farsightedness) with optical lenses.