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An Investigation into the Learning of Ecological Concepts

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Abstract: The aim of this research; secondary, high school and university levels of the students to understand the concepts related to ecology of Bayburt in Turkey. In this study, a progressive research method was used. In this method, conceptual understanding test was used as data collection tool. Open-ended test questions were used in this study. The test consisted of 150 students, 50 were from the secondary school, 50 were from the high school and 50 from the university in Bayburt. The data obtained from the test indicate that the meanings of the ecological concept are in different categories and that this concept is not fully understood by the students at all three levels of learning. While students at secondary level relate the concepts related to ecology to their everyday use, high school and university students have more scientific definitions in their descriptions. In addition, misconceptions regarding these concepts have been identified at all levels of learning.

Keywords: *Ecological concepts, understanding levels, misconceptions.*

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Introduction

Biology covers important subjects about life. Thanks to biology, people can understand the development, nutrition, health and environment of themselves and their family as well as many significant developments in the world (Alexander, 1982; Ohlsson and Ergezen, 1997). People can know and protect the environment, understand its significance in human life and grow up to be healthy individuals thanks to biology education (Urey, Colak and Okur, 2009). Barr (2007) stresses that education in biology and other health sciences should have priority over education in other scientific areas. If individuals live in an environment in which biology and health education are not appreciated and are not provided with necessary education in these areas, they cannot grow up and develop in a health way.

Human pressure on many elements in physical environment confronts us today as the primary reason of current environmental problems. To deal with such problems, studies in recent years focus on human factor (Alexander, 1982; Barr, 2007; Ewans et al., 2007; Toman et al., 2015). It is unavoidable that humans are at the centre of the resolution of environmental problems as an important factor in the emergence of these problems in the first place (Bozkurt, 2001). For that reason, we need to raise the consciousness of individuals about their responsibilities in overcoming environmental problems, which can be achieved with an effective environmental education (Campell, Waliczek and Zajicek, 1999; Fernandes Manzanal et al, 1999; Altin et al., 2002; Urey, Colak and Okur, 2009).

Environmental education is necessary at all levels of education starting from preschool to higher education (Darcin et al., 2006). Informing individuals about the environment and providing them with positive attitudes are the main aims of environmental education (Fernandes Manzanal et al, 1999; Uzun and Saglam, 2006; Farmer et al., 2007). Environmental education is not only a subject that needs to be learned, but also a way of thinking and behaviour (Davis, 1998). Environmental education also aims that people can understand the ecological balance and their role in it, form opinions as to how they can live in harmony with the environment and acquire necessary skills for active and responsible participation (Erol and Gezer, 2006). Ecology that is studied under biology is a field usually dealing with theoretical concepts. Due to the abundance of the relationships between ecological concepts, it is difficult for students to learn these concepts thoroughly. Therefore, students prefer memorizing to learning them (Ozcan, 2000), and this does not differ in diverse educational levels.

In their studies, Adeniyi (1985), Bozkurt (2001), Erol and Gezer (2006) claim that students in different levels of education have many misconceptions, which may pose problems in the working of education system. This study aims to

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identify the level of understanding of students at secondary school, high school and university concerning ecological concepts.

Methodology

This study uses developmental research method as a descriptive research approach to determine the level of learning of ecological concepts among students in different educational levels. Instead of identifying the level of development by studying on a sample for a long time to determine the level of learning of ecological concepts, the research consists of studies simultaneously conducted on a sample that can be equivalent of the research sample (Yildirim and Simsek, 2013). In this way, the research is conducted in the shortest time by studying with the samples in different age groups instead of following the same sample to complete the study (Cepni, 2012). Considering such aspects, the study has the characteristics of a cross-sectional study using developmental research method.

The study was conducted in a secondary school, high school and university in central Bayburt. The research sample consists of 3 senior classes, each randomly selected from the secondary school, high school and university. The number of participating students and their distribution by gender are presented in Table 1.

Table 1. Research Sample

Education Level	Gender		Total
	Female	Male	
Secondary School	21	29	50
High School	27	23	50
University	28	22	50

Data Collection Tools

To collect data, the study uses conceptual understanding test and individual interviews. The properties of the data collection tools are given below.

Conceptual Understanding Test

The test used in the study comprises 10 open-ended questions with 2 questions for each of the subjects of food chain, food web, biomass, energy flow and greenhouse effect. To present the findings obtained from the test data, we used certain abbreviations whose full forms are given below. For example, TS-1 indicates "the first of the secondary school students who responded to the test".

T: Test, S: Senior secondary school student, H: Senior high school student, U: Senior university student, 1: First student, 2: Second student, 3: Third student, 4: Fourth student, 5: Fifth student

In addition, we also used studies conducted by Munson (1991), Urey et al. (2011) and Bozkurt (2001) in our study. It is considered that the reliability of the test questions used in these studies is confirmed. The validity of the test questions was also confirmed by referring to expert opinions, relevant literature and pilot study.

Data Analysis

Below you can find information about how the data obtained from the test to determine the students' level of understanding of the investigated concept.

Conceptual Understanding Test

This study uses the categories of understanding suggested by Abraham et al. (1992) to assess the test including open-ended questions. These categories and their content are given in Table 2.

Table 2. Categories and their content to analyze the questions in the test

Level of Understanding	Evaluation Criteria
Full Understanding	Answers cover all aspects of the validated response.
Partial Understanding	Answers cover one or more aspect(s) of the correct answer but not all of them.
Partial Understanding with Specific Misconceptions	Answers show partial comprehension but they also contain misconception.
Specific Misconceptions	Answers are scientifically incorrect.
Specific Misconceptions	Blank space, answers including statements such as "I do not know", "I do not understand".
No Understanding	Repetition of the question, Irrelevant or unclear responses.

During the analysis, the percentage distribution of the responses given by the students according to these categories was determined and presented in tables. For the analysis, it was decided to group the students' responses for the main questions based on their similarity. In addition, authentic responses selected from these responses are directly given here to set example.

The flow diagram of the study is shown in Figure 1. Also, the following part of the study presents the findings obtained from the analyses comprehensively.

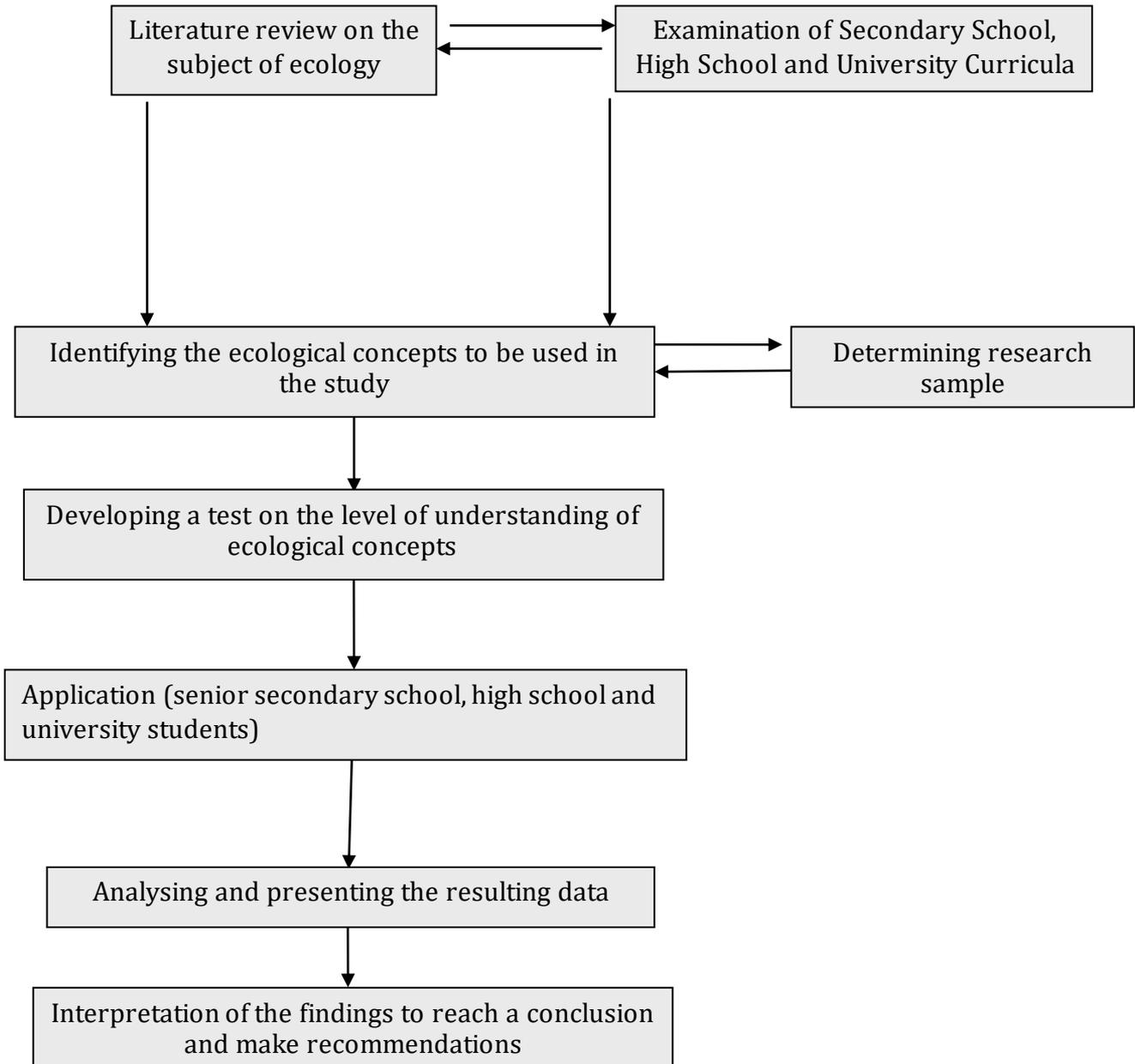


Figure 1. Flow diagram of the study

Findings and Discussion

In this study, conducted to determine the level of understanding of ecological concepts among the students in different educational levels and to indicate the conceptual change between these levels, the findings are given below.

Test Findings

The level of understanding of ecological concepts among senior secondary school, high school and university students was determined using the test prepared as part of the study. The findings on the level of understanding of the students at different educational levels concerning the concepts asked in the test are presented below.

Students' Level of Understanding of the Concept of Food Chain

The first two questions in the test aims at determining the students' level of understanding of the concept of food chain. According to the results, Table 3 presents the senior secondary school, high school and university students' level of understanding of the concept.

Table 3. Students' level of understanding of the concept of food chain (%)

Question No.	Full Understanding			Partial Understanding			Partial Understanding with Specific Misconceptions			Misconceptions			No Understanding		
	S	H	U	S	H	U	S	H	U	S	H	U	S	H	U
	1	10	20	36	10	24	28	20	20	16	40	20	10	20	16
2	16	20	32	20	24	26	24	20	18	30	24	16	10	12	8
Avr.	13	20	34	15	24	27	22	20	17	35	22	13	15	14	9

S: Secondary Schools (n=50) H: High School (n=50) U: University (n=50)

In the 1st and 2nd questions on food chain, the students were asked about the steps in the food chain and eating habits in these steps. As seen in Table 3, the rate of students who have full understanding of the questions is highest in university students and least in secondary school students. The students in different educational levels who are in the category of full understanding describe eating styles and eating steps in the food chain with similar statements. For example, a secondary school student answered that: "While a living organism consumes another living organism as food, this organism itself becomes a nutritional source for another organism. This type of chain of relationships in the nature is called food chain. The first step of the food chain is occupied by producers. In the second step lie the organisms that eat plants, and in the third step lie the organisms eating the organisms in the second step. On the other hand, there are decomposers in every step (TS-17)".

In partial understanding category, it is found that while talking about the steps and eating styles in the food chain, the students express some of the steps and do not explain eating styles clearly. Table 3 indicates that the highest educational level with the highest partial understanding rate belongs to the university students. For example, the answer of a university student is as follows: "Food chain is an order that results from living organisms' getting the energy they need from each other" (TU-17). On the other hand, the lowest rate in this category is seen in secondary school students.

Just as in the specific misconception and partial understanding categories, secondary school students have the highest rate in the misconception category. However, it is seen that this rate diminishes as the level of education increases. For instance, the following response of a secondary school student is representative of other students' answers: "As the amount of energy increases from bottom to top in food pyramid, energy need also increases from bottom to upper levels." As is seen Table 3, the rate of no understanding declines with the increase in education level. A similar finding is also revealed in the study conducted by Ozcan (2000). While he displays this situation in his study, he claims that the science of biology is a conceptual lesson, thus, the interaction between the concepts must be introduced to the students, and stresses that the meaning of the concepts must be understood rather than memorizing.

Students' Level of Understanding of the Concept of Biomass

The third and fourth questions in the test attempt to determine the students' level of understanding of the concept of biomass. Table 4 presents the senior secondary school, high school and university students' level of understanding concerning the concept of biomass.

Table 4. Students' level of understanding of the concept of biomass (%)

Question No.	Full Understanding			Partial Understanding			Partial Understanding with Specific Misconceptions			Misconceptions			No Understanding		
	S	H	U	S	H	U	S	H	U	S	H	U	S	H	U
	3	4	12	30	16	16	32	20	24	16	40	32	16	20	16
4	10	20	36	20	28	32	24	20	16	36	24	14	10	8	2
Avr.	7	16	33	18	22	32	22	22	16	38	28	15	15	12	8

S: Secondary Schools (n=50) H: High School (n=50) U: University (n=50)

The third and fourth questions in the study attempt to determine the students' level of understanding of the concept of biomass. The third question actually complements the second question. According to Table 4, the university students have the highest rate of full understanding regarding these questions. Furthermore, the rate of full understanding rises as the level of education increases. An examination of the statements of the students who fully understood the questions reveals that the students predominantly say that producers have greater biomass than consumers. For example, a student responds that "The biomass of living organisms diminishes rapidly from producers to consumers. Those at the bottom of the food chain need to have more biomass than those at upper levels. Currently, a significant portion of the world's biomass comes from giant trees in the rain forests. Biomass of plants is significantly higher than that of animals (TU-38)". When the answers of the students in the partial understanding category are analysed, it is

seen in Table 4 that the university students have the highest rates. It is also found that the students in this category use correct statements, but are unable to express the answer quite precisely. We can see it in the statements of a university student: "It is the common name of all materials coming from the organisms that are living or lived recently (TU-19)".

When the questions asked to assess the understanding of the concept of biomass is examined, it is found that the rates of misconceptions diminish as the level of education increases. The highest rate of misconceptions is seen at secondary school level. Misconceptions stem from wrong mental schemas in the minds of the students concerning eating styles. To put it better, we can give as example the answer of a secondary school student: "Biomass increases from bottom to top in the food chain, because the number of living organisms at lower steps declines as living organisms at every step feeds on those at a lower step (TS-24)". Such a misconception is also found by Adeniyi (1985) in a study conducted on students. He states that this misconception results from the assumption of the students that living organisms at the higher levels of food chain are stronger, bigger and need more energy. In our study, we find quite a lot of statements based on this justification. In the no understanding category, the percentage of the student answers declines with increasing education levels.

Students' Level of Understanding of the Concept of Food Web

The fifth and sixth questions are aimed at determining the students' level of understanding of the concept of food web. According to the data obtained from the answers, the level of understanding of this concept among senior secondary school, high school and university students is given in Table 5.

Table 5. Students' level of understanding of the concept of food web (%)

Question No.	Full Understanding			Partial Understanding			Partial Understanding with Specific Misconceptions			Misconceptions			No Understanding		
	S	H	U	S	H	U	S	H	U	S	H	U	S	H	U
5	6	20	36	10	36	24	16	28	20	44	16	16	24	0	4
6	8	18	32	14	38	28	28	30	28	36	10	8	14	4	4
Avr.	7	19	34	12	37	26	22	29	24	40	13	12	19	2	4

S: Secondary Schools (n=50) H: High School (n=50) U: University (n=50)

When the answers of the students to the fifth and sixth questions are analysed, it is found that the university students have higher rates of full understanding. For example, the following answer of a university student represents the current situation perfectly: "Food web is a template that indicates what feeds on what within an ecological community. Food web is classified in two categories: autotrophs and heterotrophs (TU-42)".

The analysis of the statements of the students responding in the partial understanding category reveals that teachers talk about the transfer of energy in food web in a superficial manner. It is seen that partial understanding rate is the highest among the high school students (Table 4). To provide a better explanation for partial understanding, we can give as example the answer of a high school student: "In transition from a food level to another in the food web, food energy cannot entirely be transferred (TH-30).

As for the misconceptions category, secondary school students have the highest rates. However, this rate declines as education level increases. It is found that the students in this category use the concepts of food chain and food web interchangeably. This can be seen in the statements of a secondary school student: "Food chain is the simplest version of food web (TS-27)". In addition, the secondary school students have the highest rates in the no understanding category. Munson (1991) and Bozkurt (2001) also reached a similar conclusion in their studies.

Students' Level of Understanding of the Concept of Energy Flow

The students' understanding of the concept of energy flow is identified with the question seven and eight. According to the data, the secondary school, high school and university students' level of understanding of this concept is given in Table 6.

Table 6. Students' level of understanding of the concept of energy flow (%)

Question No.	Full Understanding			Partial Understanding			Partial Understanding with Specific Misconceptions			Misconceptions			No Understanding		
	S	H	U	S	H	U	S	H	U	S	H	U	S	H	U
7	16	20	32	20	24	26	24	20	18	30	24	16	10	12	8
8	4	12	30	16	16	32	20	24	16	40	32	16	20	16	14
Avr.	10	16	31	18	20	29	22	22	17	35	28	16	15	14	11

S: Secondary Schools (n=50) H: High School (n=50) U: University (n=50)

An examination of the students' answers to the seventh and eight questions about energy flow indicates that the university students have the highest rate as is the case with the concepts of food web and biomass. Students who show full understanding explain energy flow in food chain in detail. For example, a university student states that "A great amount of the energy stored through food chain is used for the vital needs of that organism. Only 10% of the energy is passed from one group to another in the food chain. In other words, every living organism transfers 10% of its energy to another organism that eats it. This energy transfer in the food chain is represented in a pyramid model (TU-31)".

The highest rate of partial understanding of the concept of energy flow is found among the university students as is the case with full understanding. When the answers of the students with partial understanding are examined, it is seen that they refer to the certain properties of the concept. For example, the statement of high school student is a representative of the situation: "This energy obtained from the Sun is a unidirectional energy flow that goes to producers, consumers and decomposers and undergoes changes in every living organism (TH-13)".

The analysis of the statements with misconceptions indicates that secondary school students have the highest rates in this category. When the statements involving misconceptions are examined, it is found that the students use expressions involving misconceptions based on thermodynamics law in physics. This can be clearly seen in the answer of a secondary school student: "The amount of energy does not change from bottom to top in the food pyramid, because the amount of energy remains unchanged in the nature (TS-8)". Finally, in the no understanding category, the percentages of the student answers diminish with increasing education levels. Munson (1991) and Bozkurt (2001) also reached a similar conclusion in their studies.

Students' Level of Understanding of the Concept of Greenhouse Effect

The ninth and tenth questions in the test aimed at determining the students' level of understanding of the concept of greenhouse effect. Table 7 presents the senior secondary school, high school and university students' level of understanding of the concept of greenhouse effect.

Table 7. Students' level of understanding of the concept of greenhouse effect (%)

Question No.	Full Understanding			Partial Understanding			Partial Understanding with Specific Misconceptions			Misconceptions			No Understanding		
	S	H	U	S	H	U	S	H	U	S	H	U	S	H	U
	9	4	12	30	16	16	32	20	24	16	40	32	16	20	16
10	8	18	32	14	38	28	28	30	28	36	10	8	14	4	4
Avr.	6	15	31	15	27	30	24	27	22	38	21	12	17	10	9

S: Secondary Schools (n=50) H: High School (n=50) U: University (n=50)

In the ninth and tenth questions on greenhouse effect, students seem to have misconceptions about the causes and consequences of greenhouse effect, the thinning of ozone layer and acid rains. As is seen in Table 7, university students mostly have full understanding in these questions. Students in different educational levels in the full understanding category make similar statements about the factors leading to greenhouse effect. The statement of a university student can be given as example: "The clouds and sky reflect the sunlight and some gases in the atmosphere such as carbon dioxide, water vapour and methane absorb this light, keeping the Earth warm. This process is called greenhouse effect (TU-10)". When the statements of the students with partial understanding are examined, it is found that teachers explain the specifics of greenhouse effect superficially. The highest rate of partial understanding is seen among the university students (Table 4). To better describe partial understanding, we can give as example the following answer of a high school student: "There has been an increase in the greenhouses gases in the atmosphere. The reasons for that are the use of fossil fuels, destruction of forestland due to fires and the emission of large amounts of greenhouse gases to the atmosphere (TH-33)".

In the analysis of the answers for the questions on understanding of the concept of greenhouse effect, it is seen that the rates of misconceptions decline as the level of education increases. Misconception is found most among the secondary school students and least among the university students. The misconceptions stem from wrong mental schemas in the minds of the students concerning eating styles for the causes and consequences of greenhouse effect. To better describe it, we can give as example the following statement of a secondary school student: "As result of greenhouse effect, earthquakes, volcanic eruptions, desertification, floods and cancer take place (TS-20)". In addition, the rates of students with 'no understanding' increase as the level of education rises, as is seen in Table 7. The highest rate in this category belongs to the secondary school students while the university students have the lowest rate of 'no understanding'. The study conducted by Bahar (2000) reveals that most of the university students were not informed about or had misconceptions about current issues such as ozone layer depletion and greenhouse effect before taking the "Environmental Science" course.

Results and Recommendations

The following results were obtained based on the findings of and interpretations about this study that is aimed at identifying the level of understanding of ecology among senior secondary school, high school and university students:

1. In our age that ecological problems have become increasingly evident, ecological concepts are not understood adequately in all three educational levels. As the level of educations increases, the rates of full understanding concerning the concepts also rise in general.
2. While the use of ecological concepts in the daily life stands out in secondary school level, scientific definitions and school knowledge come to the forefront at high school and university.
3. That students learn ecological concepts incompletely or wrong beginning from secondary school level may result from the fact that their experiences are not appropriately constructed in the process of learning of these concepts.
4. Students at secondary school have lack of understanding and misconceptions concerning fundamental concepts of ecology. This will make it difficult for them to understand the new concepts they will encounter in their future experiences, leading to new misconceptions. Thus, misconceptions may differ with the increase in education level.

Based on the results of the study conducted to determine senior secondary school, high school and university students' level of understanding of ecology, the following recommendations are made:

1. Teachers and senior primary school students may also be included in the sample group for the future studies on this subject.
2. Starting from primary school, the teaching of primary ecological concepts should be planned in a consistent way and considering the level of education.
3. When developing guide materials, the aim should be preparing materials that will appeal to more senses. Recalling the preliminary knowledge, materials that help associating to the newly learned concept can be used for this purpose.
4. There should be projects and events involving activities about ecology for daily life starting from primary school, and it should be ensured that students see current misconceptions in the life and eliminate them.
5. Studies on ecological misconceptions held by teacher candidates and students at different educational levels should be followed by lecturers, and the ways of resolving such problems should be explained to the teacher candidates.

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