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Investigation of the Nature of Metaconceptual Processes of Pre-Service Biology Teachers*

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ABSTRACT

Purpose of Study: The aim of this study is to investigate the nature of pre-service biology teachers' metaconceptual processes that were active as they participated in metaconceptual teaching activities. **Methods:** Several instructional activities, including poster drawing, concept mapping, group and class discussions, and journal writing, were carried out to activate the metaconceptual processes of 32 second-grade, pre-service biology teachers in order to change their alternative conceptions regarding seed plants. Case study was used as a research method. Among the 32 participants, five participants who activated five participants who activated rich and diverse metaconceptual processes and who reflected well and clearly on their mental processes in their journals were selected for the case study. The journal entries written by these five students before, during, and after the teaching activities were used as a data source. Content analysis was used to code the journals of the pre-service teachers according to the types and the content of metaconceptual processes. **Results and Conclusions:** The results indicated that students engaged in several types of metaconceptual activities, which can be classified under metaconceptual awareness, metaconceptual monitoring, and metaconceptual evaluation. Metaconceptual processes were activated interdependently in different forms, ranging from simpler first-order metaconceptual awareness to more sophisticated metaconceptual evaluations. **Recommendations:** In designing metaconceptual teaching activities, teachers should take the interdependent and multifaceted nature of these processes into consideration.

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Introduction

Since it has been coined by Flavell (1979), a growing body of literature has highlighted the role that metacognition plays in student learning. The promising results of many studies that promote student learning through the facilitation of metacognition have attracted the attention of many researchers (Baird, 1986; Gunstone & Mitchell, 1998; Hennessey, 2003; White, 1988). Although metacognition has been one of the most prominent constructs studied in cognitive psychology, mathematics, and science education, it was described as a "fuzzy concept" due to its multidimensional nature (Flavell, 1981, p. 37). Nevertheless, various definitions of metacognition have been proposed in the literature. Flavell (1987) defined metacognition as "knowledge and cognition about cognitive objects, that is, about anything cognitive" (p. 21). Brown (1987, p. 66) emphasized the executive control processes described metacognition as "one's knowledge and control of own cognitive system." She described executive control processes as the operation of the mental processes by which individuals organise and monitor their own thinking. Hennessey (2003) underlined the importance of awareness by defining metacognition as one's inner awareness about one's learning process, such as what one knows or one's current cognitive state (Hennessey, 2003). Similarly, according to Kuhn and Dean (2004), metacognition refers to "awareness and management of one's own thought" (p. 270).

Although various researchers have provided different definitions of metacognition in the literature, three common aspects of metacognition are present throughout all the classifications: (a) knowledge about cognition, (b) control and regulation of cognitive activities, and (c) awareness of mental activities and content (concepts) (Saçkes & Trundle, 2016). These aspects have appealed to many researchers from such diverse areas as reading comprehension, problem solving, memory development, cognitive development, and intelligence (Campione, 1987). In recent years, one of the subject areas in which researchers have increasingly appreciated the importance of metacognition has been science education, specifically science concept learning.

Metacognition and Conceptual Change

The results of the studies that have focused on science concept learning have showed that students arrive at learning situations with existing conceptions that are different from the scientific conceptions (Caramazza, McCloskey, & Green, 1981; Driver & Easley, 1978; Driver & Erickson, 1983). Among the various terms that have been used to label these conceptions, "alternative conceptions" has become popular. The resistance of student alternative conceptions to change has been a significant problem in teaching and learning science. Numerous studies showed that students' difficulties in learning science stem from their preexisting conceptions about natural phenomena that are not consistent with scientifically accepted ones (Champagne, Gunstone, & Klopfer, 1985; West, Fensham, & Garrard, 1985). Recognition of the importance of student alternative conceptions has led researchers in the field of science education and cognitive psychology to search for theoretical frameworks to explain how alternative conceptions develop and how learners restructure their existing conceptions. Drawing upon an analogy between the knowledge constructed in the scientific community and the concepts constructed in students' minds, Posner, Hewson, Gertzog, & Strike (1982) proposed the conceptual change model. This model emphasises learners' recognition of the limitations of their alternative conceptions. Learners should understand and find the new conceptions plausible and fruitful to change their alternative conceptions with scientific conception. Several researchers who work in cognitive psychology have highlighted the importance of learners' ontological and epistemological presuppositions in the development of alternative conceptions (Chi, Slotta, & Leeuw, 1994; Vosniadou, 1994). diSessa (1993) pointed out that learners' use of p-prims which are context-dependent, self-explanatory knowledge pieces used to explain a phenomenon. According to this view, student conceptions were considered to be fragmented rather than cohesive or theory-like.

Although there are some differences in the views of these researchers about the nature of student conceptions, they did not consider conceptual change as a simple replacement of the previous conceptions with new ones. Rather, conceptual change was regarded a complicated process that involves a major multifaceted restructuring of the mental structure and its underlying elements. This restructuring is more likely to occur and be efficient if learners become aware of their existing conceptions and elements of their cognitive structure, compare and contrast existing and new scientific ideas, and notice the limitations of existing ideas (Yuruk, 2005). The nature of these processes has led researchers to focus on metacognitive processes that are acting on learner conceptions.

The intentional conceptual change perspective, which is relatively a more recent model of conceptual change, advocated for a "warmer" perspective of conceptual change (Sinatra & Pintrich, 2003). Researchers who have adopted this perspective argued that, along with the cognitive factors, conceptual change depends also on learners' metacognitive, motivational, and affective processes. (Sinatra & Pintrich, 2003). Luque (2003**)** highlighted the importance of metacognition in conceptual change by suggesting that learners must be aware of the need for the change, be able to know what to change, and be able to regulate their change processes using cognitive and metacognitive strategies. The interest of researchers in metacognition has been triggered by the convincing results of several studies that have focused on the role of metacognition in conceptual change. These studies showed that metacognition may play a crucial role in conceptual change in different ways. By engaging in metacognitive processes, learners recognise the inconsistencies between their alternative ideas and scientific concepts (Pintrich et al., 1993; Thorley, 1990; Vosniadou, 1994, 2007; Yuruk, 2007; Yuruk, Beeth & Anderson, 2009). This helps students to monitor changes in their understanding throughout instruction (Mason & Boscolo, 2000; Yuruk, 2007) and promotes a more coherent and durable conceptual understanding (Georghiades, 2000, 2004; Trundle et al., 2007; Yuruk et al., 2009; Yuruk & Eroğlu, 2016).

Metaconceptual Processes

The term "metacognition" has been used as an umbrella term that includes various types of knowledge and processes, some of which are not directly related to concept learning. Researchers who have investigated the role of metacognition in conceptual change generally prefer to use the term "metaconceptual" instead of "metacognition" to denote the second-order processes that are directly related to conceptual learning (Delgado, 2015; Kirbulut, Uzuntiryaki-Kondakcı, & Beeth, 2016; Saçkes & Trundle, 2016; Thorley, 1990; Vosniadou, 2003; Yuruk, 2005; Yuruk et al., 2009). Thorley (1990) defined the term "metaconceptual" as the kind of awareness that allows learners to reflect on the content of their conceptions.

In an effort to categorize the types of processes under the heading of metaconceptual processes, Yuruk (2005) proposed three types of metaconceptual processes: (1) metaconceptual awareness, (2) metaconceptual monitoring and (3) metaconceptual evaluation. Yuruk (2005) described metaconceptual awareness as "a process in which the learner explicitly refers to her/his personal stock of information including current or past ideas regarding a concept, presuppositions, experiences, and contextual differences" (p. 157). She differentiated two types of metaconceptual awareness: first-order and second-order metaconceptual awareness. First-order metaconceptual awareness is a process in which learners explicitly recognise stored or dynamically-generated ideas or the elements of their conceptual ecology. For example, if a learner states that s/he believes that force is something that can be transferred from one object to another in response to a question regarding force, s/he explicitly recognises her or his current mental representation about force concepts. Second–order metaconceptual awareness refers to learners' awareness of their ideas and the elements of conceptual ecology that they previously had in their minds. For example, if a learner states that s/he thought that a flower was a colourful part of a plant during a group discussion about flower concepts a week ago, s/he is referring to the idea that s/he had a week ago.

Yuruk (2005) defined metaconceptual monitoring as the "online" and "in the moment" processes "that generate information about an ongoing cognitive activity, thinking process, or one's present cognitive state" (p. 160). Unlike the metaconceptual awareness, metaconceptual monitoring involves learners' monitoring their cognitive state with respect to new conceptions. There are five types of processes under the heading of metaconceptual monitoring: monitoring understanding of an idea, monitoring information coming from other people or sources, monitoring the consistency between existing ideas and new information, monitoring existing ideas, and new experiences and monitoring changes in ideas.

Metaconceptual evaluation involves learners' judgmental decisions about competing ideas. In doing this, they provide justifications for their ideas. They may compare and contrast the plausibility and usefulness of competing ideas, or they may choose one idea among several alternatives and provide justifications for the validity of the chosen idea as they engage in metaconceptual evaluation (Yuruk, 2005).

Yuruk (2005) argued that metaconceptual processes are multi-faceted and interdependent and occur at various levels of complexity. She warned that, depending on the nature of the instructional environment, students' cognitive structure and content area may cause different metaconceptual processes to occur, or distinct characteristics of them might be observed. Metaconceptual processes carry sophisticated, higher-order thinking processes that are difficult to engage by learners in traditional learning environments. In this study, metaconceptual teaching interventions that aim to facilitate pre-service biology teachers' engagement in metaconceptual processes were implemented. The aim of this study was to explore the nature of the metaconceptual processes that were activated throughout these metaconceptual teaching interventions. A closer look at the nature of metaconceptual processes is crucial for a better understanding of how to facilitate and improve metaconceptual processes in learning environments.

Method

Research Design

In this study, a case study design which is one of the qualitative research methods was employed in order to determine the nature of pre-service teachers' metaconceptual activities throughout the metaconceptual teaching interventions. The case study is used in situations in which multiple evidence or data sources are used. It is also used as a method to examine a phenemenon or an event in-depth and when researchers are interested in understanding the "process" (Merriam, 1998, p. 33). This study employed the embedded case study design for which the unit of the analysis was five pre-service biology teachers. In this study, in order to activate the pre-service teachers' metaconceptual processes as explained above, several instructional activities, namely metaconceptual teaching activities were implemented for a period of 10 weeks. Journal entries that students wrote throughout the metaconceptual teaching activities were used as the data source for this case study.

Participants of the Study

Thirty-two pre-service biology teachers who were enrolled in the department of biology education of a state university were involved in metaconceptual teaching interventions. These students were in their second year of the program and had not taken any undergraduate level courses specifically related to seed plants. However, they had taken general botany, cryptogam courses, and related laboratory courses. The class was scheduled to meet once a week for seed plants laboratory. Intensity sampling (Patton, 1990) was used to identify the participants for case study. An intensity sample involves the selection of information-rich cases that intensely manifest the phenomenon of interest. Five students were selected among the 32 participants who activated rich and diverse metaconceptual processes throughout the instructional activities and reflected on their mental processes well in their journals. In the entire class, the number of female students was much higher compared to the number of male students. During the instructional interventions, there were group activities. An effort was made to select the participants among the students who work in different groups. Two participants worked in the same group and the other three students worked in separate groups. Four out of the five students were female and one student was male.

Metaconceptual Teaching Activities

In this study, in order to examine the nature of students' metaconceptual processes, several instructional activities were used to facilitate their engagement in the targeted metaconceptual processes. These instructional activities consisted of an amalgamation of various types of activities including poster drawings, journal writing, concept mapping, and class and group discussions. These activities were implemented in a ten-week period in the seed plant laboratory. These activities were not implemented independently in a specific order. Class discussions were carried out usually after activities that were executed as a group, including poster drawings and group discussions. Pre-service teachers were requested to write journals before and after poster drawings, after drawing concept maps, following the group/class discussions and after the teacher introduced the scientific phenomena. Therefore, journal entries written by the pre-service teachers highly reflected the richness and the diversity of metaconceptual processes that they activated during the metaconceptual activities. The metaconceptual teaching interventions used in this study are described below.

Poster production. Poster drawing was used to facilitate pre-service teachers' engagement in metaconceptual awareness and metaconceptual monitoring. Posters about flowering and seed plants, fruits, and seeds were prepared in groups of four people. Towards the end of the teaching activities, the posters prepared by the students during the early stages of instruction were given back to them. Students were asked if they wanted to make any changes in the previously prepared posters. Examples of the prompts for the poster drawing activity are provided below.

Prepare a poster reflecting what you know about flowering and seed plants with your group. Your poster may include elements below.

- Definitions (flowering plants and non-flowering plant, seed plants, and non-seed plants, flower, seed)
- Examples (give examples of flowering plants and non-flowering plants, seed plants and non-seed plants)
- Figures, relating diagrams and concept maps
- Function (basic functions of flowers)
- Give examples of the plants that you have difficulty categorising under flowering and seed plants.
- Discuss your ideas and reasoning before preparing your poster whose content was provided above with your group members. Present your posters with your group members to your classmates.

Concept mapping. Concept maps were used in order for the pre-service teachers to determine the relationships between the different conceptions and the differences about flowering plants and seed plants. As in the poster drawing activity, in order to make students monitor the changes in their ideas, the concept maps prepared by the students were given back to them and they were asked to think about the changes they wanted to make in their concept maps. The prompts used for the concept mapping activity are presented below.

Associate the concepts given below by drawing a concept map. You can draw the concept map in your journal.

- Plant, flowering plant, non-flowering plant, seed plant, flower, seed, fruit, leaf, reproduction organs.
- Draw a relationship between the words given above and other words that have come to your mind by creating a concept map.
- Put the examples given below into suitable places in the concept map.
- Populus, fern, pine, onion, nut, apple tree, rose plant, parsley, cabbage, carrot, wheat, willow, lettuce, banana, grass.

After creating your concept map, pair up with one of your classmates and explain your concept maps to each other. Discuss the similar and different aspects between your concept maps.

Journal writing. Journal writing aims to encourage pre-service teachers to refer to their existing conceptions, monitor their understanding and the differences in different views, judge the validity of competing ideas, recognise the limitations of their views, look for consistency among their initial and current ideas across different contexts, and monitor the changes in their ideas that emerged throughout the metaconceptual teaching activities. These aspects of the journal entries encourage participants to cover most of the targeted metaconceptual processes. Pre-service teachers were requested to write journal entries nine times during the instructional activities. Below are some examples of the journal prompts used in this study.

You discussed your initial ideas about fruits and seeds while you were preparing your posters. Write about the following issues in your journal.

During your discussion,

1. Did you notice any differences between your ideas and other group mates' ideas?

2. In what ways were their ideas different from yours?

3. Which idea is more attractive to you? Why?

4. Have you changed any of your initial ideas during your group discussions? If yes, why do you think your current ideas are better than your initial ideas?

5. Have you noticed any subjects that you did not know before?

6. Were there any examples that you had difficulty categorising as fruits or seeds?

7. Are there any concepts that are still not clear in your mind about the subjects that were discussed?

Classroom and group discussions. The classroom and group discussions aimed to share the opinions held by the members of the class about flowering plants.

Classroom discussions were generally executed after the poster drawing, concept mapping, and group discussions. During the classroom discussions, the instructor did not define the scientifically acceptable concepts until there were no other things to be expressed by the students about the targeted concepts.

Data Source and Data Analysis

During the instructional interventions, the journal writing activity was used in combination with other instructional activities. Since the pre-service teachers' journal entries highly reflected their cognitive and metaconceptual processes throughout the various instructional activities, they were used as a data source to identify the types and the nature of students' metaconceptual processes. Journals from all students were examined first individually by each researcher. Then, three researchers came together to discuss the richness and variety of the metaconceptual processes found in the journals. Among all the journals, five pre-service teachers' journals were selected as a data source. These journals were chosen due to the clarity of the students' ideas or mental processes, and the richness of the diverse types of metaconceptual processes. To differentiate among various types of metaconceptual processes, content analysis was used to code the pre-service teachers' journals according to the types and the content of metaconceptual processes. Data analysis focused on seeking confirmation concerning each of the five pre-service teachers' engagement in several types of metaconceptual processes. Researchers examined the data to find segments that exemplified each category of the metaconceptual processes. When a segment included the characteristics of more than one type of metaconceptual process, that segment was placed in more than one category. During the data analysis, the data segments were assigned to codes through a consensus among the three researchers. Tables were generated by using the data segments that were coded into different metaconceptual activities. These tables included only the data segments that best represented each type of metaconceptual process rather than all data segment of five participants. Moreover, they were selected to be included in the tables so as they demonstrated a diversity of metaconceptual processes in different topics. The data segments of all the participants were not included in the tables because the aim of this study was not to examine all the metaconceptual processes activated by each participant, but rather to identify the structure and the nature of the metaconceptual processes that became explicit throughout the instructional activities. To ensure the trustworthiness of the findings of the study, strategies such as prolonged engagement, peer debriefing, and thick descriptions were used. All the researchers were present in the research setting for about 10 weeks during the implementation of the study. Researchers regularly congregated to discuss the coded data segments. Thick descriptions of the experiences, context of the research site, and the instructional activities performed in classroom were provided.

Results

Data collected from five pre-service biology teachers were used to explain the nature of each type of metaconceptual process by providing exemplary excerpts taken from their journals. Each type of metaconceptual process was described by providing examples from all content areas covered by the designed instructional activities (e.g. flowering plant, seed plant, and non-seed plant; flower, single and composite flower; seed, fruit, single and compound fruit; monocotyledon, and dicotyledon plants). Examples for each of the categories used by students are provided below. The nature of each type of metaconceptual process is explained by using the examples given in the tables.

Metaconceptual Awareness

Yuruk (2005) stated that there are two types of metaconceptual awareness: (a) first-order metaconceptual awareness, and (b) second-order metaconceptual awareness. The data collected from five participants included indications that these two types of metaconceptual awareness were activated throughout the instructional interventions.

A. *First-Order Metaconceptual Awareness*

Excerpts that provided evidence for students' engagement in first-order metaconceptual awareness are exemplified in Tables 1, 2, and 3.

Sample journal entries for student engagement in first-order metaconceptual awareness of mental models and ideas/conceptions are provided in Table 1.

Table 1.

First-Order Metaconceptual Awareness of Mental Models and Ideas/Conceptions

Topics	*Related Data Segments*
Seed and flowering plants conceptions	Student N: *Flowering plants mean that a plant that has colourful leaves.*
	Student E: *All flowering plants are seed plants and all non-flowering plants are non-seed plants at the same time. As examples for flowering plants, cherry and apricot, for non-flowering plants, we can give willow. Cherry and apricot are flowering plants, they blossom and from the seed form cherry and apricot and grow again. For non-flowering plant, willow is given as an example because the leaf differentiates and doesn't form a colourful thing like a flower.*
Simple and compound flower	Student E: *The first thing coming to my mind when simple and compound flower conceptions are mentioned is stamen/anther and pistil. If it has only one of these, it is a simple flower, if it has both of them, it is a compound flower.*

Table 1 continued

Topics	*Related Data Segments*
Simple and compound fruit	Student C: *Simple fruit: Since fruit grows from the development of the ovary, simple conception shows that it grows from only one ovary. E.g.: apricot* *Compound fruit: It occurs from more than one ovary. E.g.: strawberry*
	Student I: *Simple and compound flowers can be like simple and compound fruit. For example, blackberry is a compound fruit. So, its flower is also compound. A plum is a simple fruit. Its flower is also simple, because the flower produces the fruit.*
Fruit and seed	Student C: *Vegetable is a vegetable if the leaf is the part which is eaten. If the part that is eaten is juicy and abundantly nutrient, it is fruit.* *We can give lettuce, cabbage as examples for vegetables. As examples for the fruit, we can give peach, banana.*
Gymnosperms and angiosperms	Student E: *Seed plants are categorised into two groups as gymnosperms and angiosperms. When gymnosperms are mentioned, pine comes to mind at first. When gymnosperm plants are mentioned, I think of the falling of the seed formed with the opening of the fruit naturally. In angiosperms, it is the fact that fruit and the seed are in the same place, meaning that the seed is covered by the fruit. For example, apricot.*
	Student N: *If the seed is in an open place and can be affected by the environment directly, this plant's seeds are also in an open position and it is called a gymnosperm plant. If the seed is covered by an external membrane and it is not affected by the outer effects, this plant's seed is an angiosperm and the plant is an angiosperm plant.*

The data segments coded as first-order metaconceptual awareness show that students were aware of their different ideas that they had about the differences between flowering and non-flowering plants, simple and compound flowers, simple and compound fruits, fruit concepts, and the differences between gymnosperms and angiosperms. The parts of student journal entries given in Table 1 demonstrate that students were able to explicitly state their conceptions in different content areas. For example, student E was able to state her idea that a non-flowering plant does not have colourful leaves. She gave a willow as an example for the non-flowering plants due to the absence of colourful leaves, and she categorised cherries and apricots as flowering plants due to their blossoms; however, scientifically, a flowering plant does not necessarily have colourful leaves. It is understood that she referred to her past experience about the blossoming of apricot and cherry trees, and that of willow trees not having apparent colourful leaves. Her journal entry indicated that she was aware of the criteria that she used to categorise flowering and non-flowering plants.

Student E devised a categorisation between flowering and non-flowering plants based on the colourful leaves. She also formulated a categorisation between simple and compound flowers based on the number of the types of reproductive organs. It is evident that she became aware of her categorisation criteria that simple flowers have only one of the reproductive organs and compound flowers have both of the female and male reproductive organs.

Although a fruit that develops from a compound flower may be a compound fruit or a simple fruit, student C made a generalisation about compound fruits. She explicitly stated that a simple fruit develops from a single ovary, and a compound flower develops from more than one ovary. She gave strawberries as an example for a compound fruit, although it is an aggregate fruit.

Although there is no scientific definition for vegetable according to the scientific community in the content area of seed plants, the journal entry provided by student C demonstrates that she had a conceptual category in her mind about vegetables. Based on her experience in her daily life, she differentiated vegetables and fruits. She categorised vegetables and fruits based on the characteristics of the part of the plant that is eaten. According to her, if the part of the plant that is eaten is a leaf, it is vegetable, such as lettuce and cabbage. She described fruit as the "*juicy and abundantly nutrient*" part of the plant, such as peaches and bananas. The excerpt taken from her journal entry shows that she was able to make her idea explicit about a scenically, non-existent category of a concept based on her experience from the daily use of this concept in the spoken language.

The journal entries provided above show that students referred to their alternative conceptions. There were also students who explicitly explained partially scientifically acceptable ideas. One of them was student N. She defined angiosperm plants as the plant whose seed is covered by "*an external membrane and it is not affected by the outer effects*", while she described gymnosperm plants as the plant whose "*seed is in an open place and can get affected by the environment directly.*"

Another type of first-order metaconceptual awareness that was activated throughout the instructional intervention was awareness of what you do not know. Excerpts from students' journal entries that exemplify their engagement in first-order metaconceptual awareness of mental models and ideas/conceptions are provided in Table 2.

As seen in Table 2, Student M learnt that forming a flower was a kind of leaf metamorphosis. She was aware that she did not know the steps of this metamorphosis. She drew an analogy between frog metamorphosis and leaf metamorphosis. Due to this analogy, she could not construct a mental representation of leaf metamorphosis. It is understood that she thought leaf metamorphosis was a gradual process that took place whenever a plant blossoms. It is evident that the ideas discussed during the instructional activities caused this student to become aware that she could not construct a mental image of leaf metamorphosis.

Table 2.

First-Order Metaconceptual Awareness of What You Do Not Know

Topics	*Related Data Segments*
Definition of the flower and its parts	Student M: Forming of the flower had been discussed and it was emphasised a lot. I couldn't understand it at first, but later I learnt that flower is a leaf metamorphosis. *However, we know every step while we are learning metamorphosis phases in frogs; does it occur in similar steps in the process of turning of the leaf into a flower? This kind of information was up in the air.**

*The sentences written in italics directly represent the targeted metaconceptual process.

Table 3 presents an example of students' journal entries that show student engagement in first-order metaconceptual awareness of contextual differences.

Table 3.

First-order Metaconceptual Awareness of Contextual Differences

Topics	*Related Data Segments*
Fruit and seed	Student N: *Fruits and vegetables are daily used conceptions and they are different from the conceptions used in biology. In biology, there is no concept of vegetable. Fruit is normally sweet, pulpy, and forms to be eaten, but biologically, pepper, aborigine are also fruit, and their taste isn't sweet.*

Student N's journal entry provides evidence for her awareness about the differences in the use of vegetable and fruit concepts in daily life and biology. She noticed that there was no vegetable concept in biology. She gave some examples to vegetables and stated that they are actually fruits in biology, although they are called vegetables in daily life. It is evident that student N was aware of the differences of the use of some concepts in different contexts.

B. Second-Order Metaconceptual Awareness

Sample excerpts from journal entries for student engagement of Second-Order Metaconceptual Awareness of Initial Ideas/ Mental Models are provided in Table 4.

Table 4.

Second-Order Metaconceptual Awareness of Initial Ideas/ Mental Models

Topics	*Related Data Segments*
Definition of the flower and its parts	Student I: *Before taking this course, I had been thinking that a flower was a plant consisting of colourful leaves, good-looking, and it was as an ornament in most of the plants (daisy, rose) and had no other function. Since I defined the flower as good-looking to the eye and as a colourful form, I was saying that plants such as populus and pinus had no colourful leaves. Because there isn't any suitable colourful, good-looking forms to the eye (in my flower definition), I was saying that they had no flowers.*
	Student N: *Previously I was thinking that flowers had good-looking leaves and smelt good. That's why I was classifying the plants with no beautiful colourful flowers into non-flowering plants category, but I knew that they grew with seeds, but I couldn't see the flowers.*
	Student E: *We have written in all our definitions for the flower that it is the result of leaf metamorphosis.*
Seed and flowering plants conceptions	Student N: *In the classroom activities, we had some wrong ideas about what the non-flowering plant was, myself included. We made two groups as seed and non-seed plants while classifying the plants. We made another two groups for the seed plants as flowering and non-flowering plants. The reason why we put the non-flowering plants into the seedless plants group was the fact that we knew there were seeds of some plants, but we didn't see their flowers. The most obvious example we were giving was grass as an example.*
	Student E: *We have categorised the plants as seed and non-seed. This was a conception approved by scientists*, but categorising the plants as flowering and non-flowering was not an accepted conception. *The reason why we categorized the plants as flowering and non-flowering was the fact that we hadn't seen the flowers (meaning colourful petals), although we had seen some of the plants' seeds.*
	Student N: We defined the non-flowering plant wrong and put it into wrong category in the concept map. *By definition, we said that it was the plant whose seed was not coming from the flower.* But we understood that seed cannot grow in those. That's why the definition was completely wrong. *We showed the non-flowering plants as a subcategory of seed plants*. However, non-flowering plant was already the same as the non-seed plant. *Moreover, we included the plants whose flowers haven't been seen, such as lettuce, parsley, grass, walnut, banana into the non-flowering plants*. Later, we corrected them as flowering and seed plant.

Table 4 continued

Topics	*Related Data Segments*
Simple and compound flower	Student E: The other conception that was not accepted by the scientists was simple and compound flowers. *We said that if it has only one of the reproductive organs, it is a simple flower, if it has both of the reproductive organs, it is a compound flower. The reason why we defined simple and compound flowers like this was the idea that having only one of these parts makes the flower more primitive, that's to say simple, having two of them is considered together, next to each other, that's to say compound.*
Fruit and seed	Student I: Also, I didn't know what vegetable-fruit conceptions were properly. *I was considering that fruit formed from one-year plants as vegetables. For example, tomato, onion, zucchini, cucumber, bean, etc. I was thinking of fruit as the same as tasty and juicy fruit that can be eaten (cherry, apple, pear, etc.). I was assuming that other plants had no fruit. For example, populus, grass, rose, pine, etc.*

Students engage in second-order metaconceptual awareness when referring to an idea that was made explicit in the past (Yuruk, 2005). The excerpts provided in Table 4 indicate that students were able to reflect on their ideas about flowering and seed plants, flowers, single and compound flowers, seeds, and fruit concepts that they explicitly recognise during different instructional activities. Under the headings of the definition of a flower and its parts, flowering and seed plant conceptions, it was seen that students previously thought that a flower should have colourful leaves and a nice smell. One of the students thought flowers were an ornament that a plant has. Regarding the categorisation of plants as seed and non-seed plants, or flowering and non-flowering plants, students mainly referred to their ideas that they activated during the concept mapping activity. For example, student N was aware that her group categorised plants firstly as seed and non-seed plants. Then, under the seed plant category, they classified seed plants into flowering and non-flowering plants. She was also aware of the reasons for making such a categorisation. She stated that they made such a categorisation because they knew some plants have seeds, but flowers cannot be seen on these plants. It is understood that their categorisation of flowering and non-flowering plants under seed plants originated from their definition of flower as having colourful leaves. Student N became aware that they gave some plants as examples of non-flowering plants, such as lettuce, banana, walnut, parley, and grass.

In terms of the simple and compound flower concepts, student E was aware of the criteria that she used to classify these flowers. For example, she referred to the idea simple and compound flowers were classified based on the number of reproductive organs. She thought that if a flower has one of the reproductive organs, it is a simple flower, and if it has both of the reproductive organs, it is a compound flower. She stated that they thought simple flowers were primitive. It is obvious that the students perceiving the meaning of the word "simple" as "primitive" caused them to make such a categorisation.

Student I was aware of how stated that his differentiation of vegetables and fruits. He stated that he defined vegetable as being "fruit formed from one-year plants", such as tomato, onion, bean, and cucumber. He explained that he "*was thinking the fruit as the same as tasty and juicy fruit which can be eaten (cherry, apple, pear, etc.)*."

Students' journal entries that provided evidence for their engagement of second-order metaconceptual awareness of "what you did not know" are listed in Table 5.

Table 5.

Second-Order Metaconceptual Awareness of What You Did Not Know

Topics	*Related Data Segments*
Seed and flowering plants conceptions	Student E: In the end of these discussions, what is a non-flowering plant? Is it in seed or non-seed plants? What are the examples of non-seed plants? Banana, populus, willow, grass, parsley, are in which group? *I realized that I didn't know.*
	Student M: *While forming the concept map, the trickiest part was determining what the non-flowering plants were and where they belonged in the concept map.*
Fruit and seed	Student C: *We live together with the plants actually, but we just realised and learnt some of their features. For example, we haven't asked questions such as, why do corns have stylus maydis? What does it help? I was thinking those stylus maydis were protective, but later I understood that these are the stylus under the rest of the top of the ovary.*

The journal excerpts from students E and M show that they became aware that they did not know how to categorise non-flowering plants. Student E was aware that she could not classify some examples of plants that they encountered in daily life. Under the heading of fruit and seed concepts, it is evident that student C did not know what the stylus maydis of corn was.

The examples under the heading of second-order awareness indicate that students became aware of their problems in categorising plants as flowering or non-flowering plants, vegetables and fruits, simple and compound flowers, and also in defining what a flower was. The findings regarding second-order metaconceptual awareness demonstrate that, in order to engage in second-order metaconceptual awareness, students should initially be active in terms of first-order metaconceptual awareness. In other words, first-order metaconceptual awareness is a requirement for the activation of second-order metaconceptual processes.

Metaconceptual Monitoring

Yuruk (2005) described metaconceptual monitoring processes as the "online", "in the moment" processes that are related to "an ongoing cognitive activity, thinking process, or present cognitive state" (p. 284). There are different types of processes under the heading of metaconceptual monitoring.

A. *Monitoring of Understanding of an Idea*

Student engagement in metaconceptual monitoring is examined under different types of metaconceptual monitoring processes. Examples of student engagement in monitoring of understanding of an idea are provided in Table 6.

Table 6.

Monitoring of Understanding of an Idea

Topics	*Related Data Segments*
Simple and compound flower	Student M: *There have been some conceptions that I have had difficulty in understanding, of course Latin words in general. I haven't still comprehended some of them. I still have some questions such as, how can it be simple and compound? What/how does pseudocarp happen/occur/mean?*
Gymnosperms and angiosperms	Student I: *I had difficulty in understanding the simple-compound fruits and gymnosperms-angiosperms. That's to say, I was getting confused about which plant was the gymnosperm, which one was the angiosperm, and again, which fruit was simple, which one was compound.*

The excerpt from students journals show that they were able to monitor their understanding regarding simple and compound flower, gymnosperms and angiosperms. For example, student M stated that she had difficulty in understanding some Latin terms and the use of the words "simple and compound" in describing flowers and fruits. As student M monitored the ideas that she did not understand, I monitored that he had difficulty understanding simple-compound fruits and gymnosperms-angiosperms.

B. *Monitoring Ideas/Information from Other People/Source*

During the activities, students were able to notice the information provided from different sources and people. Table 7 includes examples from students' journal entries that show their engagement in monitoring ideas/information from other people or sources.

Table 7.

Monitoring Ideas/Information from Other People/Source

Topics	*Related Data Segments*
Seed and flowering plants conceptions	Student E: Everybody agreed on categorising the plants as seed and non-seed in the prepared concept maps and recent discussions. *However, a group put the non-flowering plants into both seed and non-seed plants. Also, they categorised the plants as flowering and non-flowering in general,* but they couldn't explain how the seed was formed in non-flowering plants.
Simple and compound flower	Student I: … *friend categorised the simple and compound flowers according to having a reproductive plant organ. If there is only one reproductive organ, it is simple, if both are present, it is compound, s/he said.*
Simple and compound fruit	Student N: *Some friends were thinking that the compound fruit was formed by more than one flower.*

Student E was able to monitor how different groups during the poster drawing activity classified plants. For example, she noticed that a group included non-flowering plants under the heading of both seed and non-seed plants. She noticed that a group who differentiated flowering and non-flowering plants could not explain how seeds were formed in non-flowering plants. Student I monitored the ideas of students who categorised simple and compound flowers based on the number of reproductive organs. Students N recognised that her friends thought that "*compound fruit was formed by more than one flower*". The excerpts indicate that students were aware of the ideas of other groups in the class. It shows that they monitored the ideas discussed or presented by other students during the instructional interventions.

C. Monitoring the Consistency between New Ideas and Existing Ideas

Students were not only aware of the other students' ideas, they were also able to monitor the consistency between their own ideas and the ideas coming from different sources. Table 8 presents sample excerpts from students' journal entries that provide evidence of students' engagement in this monitoring process.

As seen in Table 8, student I was able to monitor the differences in ideas between him and his friends about the categorisation of simple and compound flowers. He stated that, as his friend differentiated simple and compound flowers based on the number of reproductive organs, he made this categorisation based on the nature of the fruit. Students N engaged in a similar type of metaconceptual process. She was aware of her friends' idea that compound fruits were formed by more than one flower, although she thought that compound fruits were formed by more than one ovary.

Table 8.

Monitoring the Consistency between New Ideas and Existing Ideas

Topics	*Related Data Segments*
Simple and compound flower	Student I: *There was an idea difference in male and female plant conceptions and simple and compound plants. To me, if a simple plant grows a simple fruit, it is a simple flower, if it grows a compound fruit, it is a compound flower. … friend categorised the simple and compound flowers according to having a reproductive plant organ. If there is only one reproductive organ, it is simple, if both were present, it is compound, s/he said.*
Simple and compound fruit	Student N: *Also, in the discussions we have made, we thought about the compound fruit definition differently than friends. Some friends were thinking that the compound fruit was formed by more than one flower. I was thinking the compound fruit was formed by more than one different ovary.*

The excerpts indicate that in order to engage in monitoring the consistency between new ideas and existing ideas, students first must become aware of their own ideas and they also have to monitor the ideas coming from other people or sources. Therefore, these metaconceptual processes are a prerequisite for student engagement in monitoring the consistency between new ideas and existing ideas.

D. Monitoring Change in Ideas

As the ideas in students' minds change, students were able to monitor the changes in their ideas. Some excerpts from students' journal entries that demonstrate monitoring changes in their ideas are shown in Table 9.

As seen in Table 9, the excerpt from the journal entry of student M shows that she realised that she did not know the difference between flowering and non-flowering plants or seed and non-seed plants. She notice that her definition of flower was previously wrong. She previously defined flower as part of the plant that had perianth. She stated that her definition of flower changed after taking the course, as she realised that to identify a part of a plant as a flower, it must have reproductive organs rather than the colourful petals. She learnt that a flower does not necessarily have beautiful leaves. Similar to student M, student E became aware that she had misconceptions about flower concepts. She noticed that she thought that "*the flower formed as the result of leaf metamorphosis*." She learnt that "*the flower was carrying the leaves that have faced the metamorphosis*." The explanations of student N regarding the changes that she made in her concept map indicated that she was able to monitor the changes in her ideas regarding the definition and categorisation of non-flowering plants. She was aware that she previously put non-flowering plants as a category under the heading of seed plants. She noticed that non-flowering plants "*was already the same as the non-seed plant.*"

Table 9.

Monitoring Change in Ideas

Topics	*Related Data Segments*
Definition of the flower and its parts	Student M: *I realized that I could not understand the difference between flowering and non-flowering, seed and non-seed plants before taking this course. Also, I understood that the flower concept was wrong in our minds.* For example, although we saw the flower of wheat all the time, I did not think that it was a flower. Because when thinking about flowers, an image of a flower that has perianth (calix+corolla) always appeared in my mind, and there was a very different definition of flower in my mind. According to the definition of flower in my mind, a flower must have perianth. *After taking this course, I've learnt that the flower is a reproductive organ of flowering plants, and the parts that a flower must carry are the reproductive organs.*
	Student E*: I have made the biggest misconception in defining the flower, because we were saying that the flower formed as a result of the leaf metamorphosis, but actually, the flower was carrying the leaves that have faced the metamorphosis. These two definitions were totally different from each other.*
Seed and flowering plants conceptions	Student N: We defined the non-flowering plant wrong and put it into wrong category in the concept map. By definition, we said that it was the plant whose seed was not coming from the flower, but seeds cannot grow in those. That's why the definition was completely wrong. We showed the non-flowering plants as a sub-category of seed plants. However non-flowering plant was already the same as the non-seed plant. Moreover, we included the plants whose flowers are not seen, such as lettuce, parsley, grass, nut, banana into the non-flowering plants. *Later, we corrected them as flowering and seed plants.*
Fruit and seed	Student C: We live together with the plants actually, but we just realised and learnt some of their features. For example, we haven't asked some questions such as, why do corns have stylus maydis? What does it help? I was thinking those stylus maydis were protective, *but later I understood that these are the stylus under the rest of the top of the ovary.*
Gymnosperms and angiosperms	Student N: *I've also learnt that, except these, in gymnosperm plants, the seed is in an open position among the cone scales and these seeds aren't wrapped by the fruit leaves called carpel, and, as a result of this, no fruit formation was observed.*

She also stated that she categorised plants such as lettuce, parsley, grass, and nuts, which do not have colourful leaves, as non-flowering plants. She was aware that she learnt that these plants were also examples of flowering plants. Student C monitored that she changed her idea regarding the stylus maydis of corn. Previously, she thought that the stylus maydis was a protective part of the plant. Later, she learnt that it was "*the rest of the top of the ovary.*" Student N noticed that she learnt that, in gymnosperm plants, the seeds were not covered by carpel, and fruit formation was not observed in these plants. It is obvious from her journal entry that student N did not know this information before.

The journal entries that students provided indicate that students were able to monitor the changes in their ideas regarding different topics. In order to engage in this metaconceptual process, students must first become aware of their previous ideas and they must also become aware of their current ideas. To monitor the change in their ideas, they must compare their previous and existing ideas. Therefore, first-order metaconceptual awareness of their ideas and second-order metaconceptual awareness of their previous ideas are a prerequisite for student engagement in monitoring the changes in ideas. Additionally, students can also monitor what they learn as new information, namely the information that they did not know before.

Metaconceptual Evaluation

Metaconceptual evaluation is a process through which students evaluate the validity or plausibility of different ideas. Evidence of student engagement in metaconceptual evaluation from their journal entries is provided in Table 10.

Ass seen in Table 10, the journal entry written by student E shows that she did not find her friends' idea regarding putting non-flowering plants under the heading of both seed plants and non-seed plants during concept mapping activity. This idea was not plausible to her due to its deficiency in explaining how seeds are formed from non-flowering plants. The same student did not find her friends' idea regarding simultaneously categorising grass as a seed plant and as a non-flowering plant acceptable. She did not find this idea plausible due to its capability in explaining how seeds are formed in grass. In evaluating her friends' idea, it is evident that she firstly monitored the idea coming from other sources, and then she made a judgmental decision regarding the plausibility of her friends' idea. Student N meta-conceptually evaluated her idea about compound fruit with the idea of her friends. She noticed that she previously defined compound fruit as a fruit which "*was formed by more than one ovary*" and her friends defined it as a fruit which "*was formed by more than one flower*." Student N became aware that her previous idea was wrong and her friends' idea was correct.

Table 10.

Metaconceptual Evaluation

Topics	*Related Data Segments*
Seed and flowering plants conceptions	Student E: Everybody agreed on categorising the plants as seed and non-seed in the prepared concept maps and recent discussions. However, a group put the non-flowering plants into both seed and non-seed plants. Also, they categorised the plants as flowering and non-flowering in general, *but they couldn't explain how the seed was formed in non-flowering plants.*
Fruit and seed	Student E: Also, about grass, it was said that it is a seed and a non-flowering plant. *I was also thinking similar to this idea at that time. This idea was acceptable to my mind (because I did not see the flower of grass). The unacceptable side of this idea was that there is a part in the grass, and this part forms the seed. It was unacceptable to my mind since they could not explain how that part forms the seed.*
Simple and compound fruit	Student N: Also, in the discussions we have made, we have thought about the compound fruit definition differently than friends. Some friends were thinking that the compound fruit was formed by more than one flower. *I was thinking the compound fruit was formed by more than one ovary, but I have learnt that this thought of mine wasn't correct, because one fruit is formed from one flower, no matter how many ovaries it has.* When we look at compound fruit examples, such as mulberry, it is formed by more than one flower. That's why my thought has changed.

In the above examples provided from students' journal entries, metaconceptual processes from different students about different concepts were demonstrated. The excerpt provided below in Table 11 is a rich example that shows a single student's engagement in different metaconceptual processes.

As seen in Table 11, the journal entry of student I provides rich evidence for his engagement in different metaconceptual processes, such as first- and second-order metaconceptual awareness of his ideas, second-order metaconceptual awareness of what he did not know, metaconceptual monitoring of the change in his ideas, monitoring his understanding of his ideas, and metaconceptual evaluation. Student I monitored that his idea about the definition of the flower, vegetable-fruit, and seed-non-seed plant definitions and flowering-non-flowering plants had changed throughout the instruction. He noticed how his definition of flower affected his other ideas. Therefore, he described the definition of flower as the "*most centred idea*" in changing his opinions. He became aware that he defined flower as the part of the plant that had colourful leaves.

Table 11.

A Rich Example of One Student's Metaconceptual Processes

Student I's journal entry	*Metaconceptual Processes*
Some of my opinions have changed since I started to take this lesson. The definition of the flower, vegetable-fruit and seed-non-seed plant definitions and the flowering-non-flowering plant definitions. To me, the most centred idea in changing of my opinions was the definition of the flower[1] because we were defining the flower as ''a form that has colourful parts and was formed after the metamorphosis of the leaf." That's why we were saying that plants with no colourful form did not have flowers[2]. And again, I didn't know that fruit is grown from the flower, every flower absolutely grows fruit and seeds[3]. For example, I had never thought that fruit or the seed was grown from the flower of the rose plant. That's why I was thinking that the flower on this plant was just an ornament. Also, we were thinking that populus, willow had no flowers since it didn't have any colourful leaf parts[4], but we've learnt that we knew the definition of the flower wrong[5]. I've learnt that the flower isn't formed as a result of the leaf metamorphosis, it carries the leaf that has faced metamorphosis, it is the reproductive organ of the plant and the ovule in the flower turns into the seed, and the ovary turns into fruit, that's why all flowering plants grow seeds and fruits [6]. I have had no more questions about it[7]. I have learnt which plant is seed, non-seed, flowering, or non-flowering plant[8]. I was saying that there was no flower on the plants such as populus before[9], but I've learnt that the necessary organs that should be on a flower are reproductive organs and colourful leaves (petal and sepal) are supporting reproductive organs and protective forms.[10] So, there is no colourful form on populus' flower[11]. And that's why I was saying there was no flower, but now I understand there is [12].	1. Monitoring Change in Ideas 2. Second-Order Metaconceptual Awareness of Initial Ideas/ Mental Models 3. Second-Order Metaconceptual Awareness of What You Did Not Know 4. Second-Order Metaconceptual Awareness of Initial Ideas/ Mental Models 5. Second-Order Metaconceptual Awareness of What You Did Not Know and Metaconceptual Evaluation 6. Monitoring Change in Ideas 7. Monitoring of Understanding of an Idea 8. Monitoring Change in Ideas 9. Second-Order Metaconceptual Awareness of Initial Ideas/ Mental Models 10. Monitoring Change in Ideas 11. First-Order Metaconceptual Awareness of Mental Models and Ideas/Conceptions 12. Monitoring of Understanding of an Idea

He described plants that had no colourful leaves as plants having no flowers. He was aware that he previously categorised willow and populus as non-flowering plants. He also realised that he learnt some concepts that he did not know before. For example, he became aware that he did not know that a fruit was produced from flowers. He monitored the changes in his definition of flower and also how seeds and fruit are formed from different parts of ovary of the flower. He made his current ideas regarding the definition of flower explicit. He currently knows that "*the necessary organs which should be on a flower are reproductive organs, and colourful leaves (petal and sepal) are supporting reproductive organs and protective forms*." He monitored his understanding of the concepts he learnt by saying that he had "*no more questions about*" how flowering plants form seeds and fruit. He also understood that populus has flowers. He meta-conceptually evaluated his previous definition of flower by stating that "*we knew the definition of the flower wrong.*" The metaconceptual processes that student I engaged in demonstrated the complex and interdependent nature of metaconceptual processes. Student I could engage in a wide range of different metaconceptual activities, which range from simpler processes, such as first-order metaconceptual processes, to more complex processes, such as metaconceptual evaluation.

Discussion and Conclusion

The aim of this research was to explore the nature of metaconceptual processes that were activated as pre-service biology teachers participated in different teaching activities. The journal entries written by different students showed that the classification of metaconceptual processes proposed by Yuruk (2005) and Yuruk et al. (2009) is a fruitful framework to categorise students' metacognitive processes that acted on the conceptions in their minds. Different types of metaconceptual processes defined previously by Yuruk (2005) became active when students were prompted to think about science concepts rather than to think with science concepts. This result reiterated the multifaceted character of metaconceptual processes which was previously reported by Yuruk (2005), Yuruk et al. (2009) and Kirbulut (2012). Some of the metaconceptual processes including first-order metaconceptual awareness of ontological presuppositions, first-order metaconceptual awareness of experiences, second-order metaconceptual awareness of contextual differences, second-order metaconceptual awareness of ontological presuppositions, second-order awareness of experiences, monitoring the consistency between existing idea and new experience which were previously defined by Yuruk (2005) were not observed in this study. This indicates that although metaconceptual processes are multifaceted, which means that there is a variety of metaconceptual processes, they are not a "all or none" phenomenon which was previously reported by Yuruk (2005). Different metaconceptual processes can be observed in different contexts, depending on the prompts used to activate them or the ability of the students.

Metaconceptual processes observed in this study were not limited to students' mental processes activated on a single concept, but rather they were observed in different topic areas. Although metaconceptual processes were observed in different concepts, students' journal entries indicated that some concepts were more central for learning other concepts, such as the flower concept. A journal excerpt from student I was an example of how metaconceptual processes acting on the more central concepts helped him fix the gaps in his mind. For example, student I noticed how making a scientifically correct definition of a flower affected his categorisation of plants as flowering and non-flowering plants, and the classification of various examples from daily life as flowering and non-flowering plants.

The analysis of students' journals demonstrated that metaconceptual processes were activated in different forms ranging from simpler first-order metaconceptual awareness to a more sophisticated metaconceptual evaluation. The level of sophistication increases as the metaconceptual process requires more abstract thinking and as it requires student engagement in more than one type of metaconceptual process at the same time (Yuruk, 2005). The data collected in this study suggested that metaconceptual processes at different sophistication levels were in students' repertoire of learning behaviours when they were appropriately facilitated through instructional activities.

In terms of the abstractness of higher-order thinking, for example, metaconceptual evaluation requires more abstract and complex thinking compared to explicitly stating current or past ideas about a natural phenomenon or monitoring other people's ideas. As students engaged in metaconceptual evaluation, they did not only think about the idea, but they also thought about the validity, applications, and limitations of the ideas. For example, a student found her friends' idea that grass is a non-flowering plant unacceptable due to its inability to explain the formation of seeds in grass. This student did not simply monitor her friends' idea, but she was also able to think about the validity and limitations of this idea. Therefore, some metaconceptual processes may be more sophisticated or complex compared to others. However, student engagement in more sophisticated metaconceptual processes may require earlier engagement in less sophisticated activities. As in the previous example, metaconceptual evaluation of other people's ideas requires students to previously monitor the ideas coming from other sources. Similarly, second-order metaconceptual awareness of one's ideas about a certain concept requires students to previously engage in first-order metaconceptual awareness about that concept.

Some of the metaconceptual processes involve student engagement in more than one metaconceptual process at the same time. For example, in order to activate metaconceptual monitoring of the change in ideas, students must simultaneously activate first-order metaconceptual awareness and second-order metaconceptual awareness of the ideas, and compare and contrast their current and past ideas. Similarly, in order to activate monitoring the consistency between new ideas and existing ideas, students must monitor the ideas coming from different sources and become aware of their existing ideas.

Many researchers who have conducted studies in the field of conceptual change highlighted the role of metaconceptual activities in changing students' alternative conceptions with scientific conceptions (Pintrich, Marx & Boyle, 1993; Vosniadou, 2003; Georghiades, 2004; Yuruk, 2005; Yuruk, 2007; diSessa, 2008; Yuruk et al., 2009; Kirbulut, 2012). Therefore, to improve students' understanding of science concepts, teachers should design instructional activities that explicitly stimulate students' engagement in metaconceptual processes. The findings of this study contribute to our understanding of the interdependent nature of metaconceptual processes, which should be taken into consideration by researchers and teachers in designing instructional activities that aim to activate students' metaconceptual processes. In designing this kind of instruction, teachers should first understand why and in what ways metaconceptual processes play a critical role in changing students' misconceptions. Then, in order to provide students with appropriate prompts, teachers should understand the multifaceted and interdependent nature of metaconceptual processes. Hence, in designing instructional activities, teachers should keep in their minds that activation of certain metaconceptual processes may require students to previously engage in different processes, or that student engagement of a sophisticated metaconceptual process may require the facilitation of different metaconceptual processes at the same time. Teachers should also find out central concept(s) that may affect the formation of other alternative conceptions. They should put extra effort in designing activities that help students to become aware of the differences between their existing ideas regarding the central concept and the scientific concepts. After students change their alternative conceptions regarding the central idea with the help of activation of metaconceptual processes, teachers should scaffold the formation of other related concepts.

The findings of this study give rise to several suggestions for future research. The relationship between students' metaconceptual processes and different variables, such as affective, motivational, and contextual factors, should be investigated. Quantitative or qualitative assessment tools to measure students' metaconceptual processes can be developed. Researchers or teachers could find different ways to facilitate metaconceptual processes through different tools in different learning environments, such as technologically-enhanced learning environments. The effect of amalgamating metaconceptual processes within different learning methods on students' conceptual understanding could be investigated. This study was conducted with pre-service science teachers. The ability of younger students in activating metaconceptual processes could be studied. The nature of metaconceptual processes activated by younger students could be examined. Finally, investigating the nature of metaconceptual processes activated in other topic areas, such as math and social studies concepts, could contribute to our understanding of these higher-order thinking processes.

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Biyoloji Öğretmen Adaylarının Üstkavramsal Faaliyetlerinin Doğasının İncelenmesi

Atıf:

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Özet

Problem Durumu: Flavell (1979) tarafından ilk olarak ortaya atılmasından bu yana üstbilişin öğrenme sürecindeki önemi pek çok araştırmacı tarafından ortaya konulmuştur. Üstbilişle ilgili günümüze kadar ortaya konan tanım ve sınıflamalara bakıldığında üstbilişin üç temel bileşeninin olduğu görülmektedir: (a) biliş hakkında bilgi, (b) bilişsel faaliyetlerin kontrol edilmesi ve düzenlenmesi (Saçkes & Trundle, 2016).

1980'li yıllardan bu yana fen eğitimi ile ilgili yapılan çalışmaların büyük bir kısmında öğrencilerin anlamlı öğrenmesini engelleyen alternatif kavramlara odaklanıldığı görülmektedir. Alternatif kavramların varlığı ve değişime gösterdiği direnç gerek fen eğitimi gerekse bilişsel psikoloji alanında çalışan pek çok araştırmacının ilgisini çekerek kavramsal değişimle ve alternatif kavramların oluşumu ile ilgili farklı kuramsal çerçeveler oluşturmalarına neden olmuştur. Bunlardan biri de kavramsal değişim modelidir. Bu model kavramsal değişimin gerçekleşmesi için gerekli olan şartları ortaya koymakta ve bireyin kavram ekolojisinde yer alan öğelerin (inançlar, analojiler, metaforlar vb.) kavramsal değişimdeki rolüne değinmektedir (Posner vd., 1982). Bilişsel psikoloji alanında çalışan farklı araştırmacılar ise alternatif kavramların oluşumunda bireyin epistemolojik inançları (Vosniadou, 1994), ontolojik varsayımları (Chi vd., 1994) ve bağlama bağlı oluşturulan bilgi parçacıklarının (diSessa, 1993) önemine vurgu yapmışlardır. Ortaya konan kuramsal çerçevelerde farklılıklar olmasına rağmen araştırmacılar, kavramsal değişimin basitçe alternatif kavramın yerini bilimsel kavrama bırakması olmadığını, kavramsal değişimin gerçekleşebilmesi için bireyin mevcut kavramının sınırlılıklarını fark etmesi, mevcut kavramla yeni kavramı çok yönlü karşılaştırarak değerlendirmesi gerektiğini savunmaktadırlar. Bu süreçler bireylerin üstbilişsel olarak aktif olmasını gerektiren süreçlerdir.

Kavramsal değişim sürecinde üstbilişsel faaliyetlerin önemi pek çok araştırmacı tarafından vurgulanmıştır (Georghiades, 2004; Vosniadou, 2003; Yürük et al., 2009). Üstbiliş genel bir ifade ile bireyin düşünme faaliyetleri üzerinde düşünmesi ya da bireyin bilişsel faaliyetleri hakkındaki bilişsel faaliyetleri olarak tanımlanmaktadır (Flavell, 1979; Rickey & Stacy, 2000). Ancak üstbiliş kavramsal değişim sürecini açıklamada geniş bir kavram olarak kalmaktadır. Yürük (2005) ve Yürük et al. (2009) kavramsal düzeyde gerçekleşen üstbilişsel faaliyetleri üstkavramsal faaliyetler olarak tanımlamışlar ve bu faaliyetleri; üstkavramsal farkındalık, üstkavramsal izleme ve üstkavramsal değerlendirme olarak üç kategoriye ayırmışlardır. Üstkavramsal farkındalık, bireyin mevcut ya da daha önce sahip olduğu kavramsal ekolojisinin öğeleri ya da neyi bilmediğinin farkında olması olarak tanımlanmıştır. Üstkavramsal izleme faaliyeti, bireyin devam eden bilişsel süreci veya bilişsel durumu hakkında bilgi üretmek için aktif olan süreçleri içerir. Üstkavramsal değerlendirme faaliyeti de bireyin var olan ya da yeni fikrin doğruluğu, akla yatkınlığı ve kullanışlılığı hakkında yargıya varmasını içerir.

Araştırmanın Amacı: Çalışmanın amacı biyoloji öğretmen adaylarında üstkavramsal öğretim etkinlikleri sırasında aktif hale gelen üstkavramsal faaliyetlerin niteliğini ortaya koymaktır.

Araştırmanın Yöntemi: Araştırma bir durum çalışmasıdır. Biyoloji öğretmen adaylarının tohumlu bitkilerle ilgili sahip oldukları alternatif kavramların doğru kabul edilenlerle değişmesini sağlamak için 32 biyoloji öğretmenliği 2. sınıf öğrencisinin üstkavramsal faaliyetlerini aktif hale getirecek öğretim etkinlikleri uygulanmıştır. Üstkavramsal faaliyetlerin öğrencilerde aktif hale getirilmesini sağlamak amacıyla poster hazırlama, günlük yazma, kavram haritası oluşturma, sınıf ve grup tartışmaları gibi farklı öğretim etkinliklerinden faydalanılmıştır. Bu etkinlikler 10 haftalık bir süreçte uygulanmıştır. 32 öğrenci arasından etkinlikler esnasında zihinlerinde fazla sayıda ve türde üstkavramsal faaliyetlerin aktif olduğu ve bu faaliyetleri günlüklerinde açık şekilde ifade eden beş öğrenci durum çalışması için seçilmiştir. Üstkavramsal faaliyetleri belirlemek amacıyla veri kaynağı olarak bu beş öğrenci tarafından öğretim süreci öncesinde, sırasında ve sonrasında yazılan günlükler kullanılmıştır. Günlük yazma etkinliği farklı üstkavramsal faaliyetleri aktif hale getirmek amacıyla öğretim süreci boyunca sıklıkla uygulanmıştır. Öğretmen adaylarına verilen günlük yönergeleri ile öğretmen adaylarının kendi mevcut kavramları ve fikirlerinin arkasında yatan sebepler hakkında düşünmeleri, karşı karşıya kaldıkları farklı fikirleri anlamalarını izlemeleri, doğrulukları hakkında yargıya varmaları, fikirlerinin sınırlılıklarını fark etmeleri, mevcut fikirleri ve farklı kaynaklardan gelen yeni fikirlerin tutarlılığını ve fikirlerindeki değişimi izlemeleri sağlanmaya çalışılmıştır. Bu özelikleri ile günlükler diğer öğretim etkinlikleri esnasında aktif hale gelen üstkavramsal faaliyetleri yansıtmaktadır. Durum çalışması için seçilen öğrencilerin günlükleri içerik analizi yapılarak kodlanmıştır. Öğrencilerde aktif hale gelen üstkavramsal faaliyetler; üstkavramsal farkındalık, üstkavramsal izleme ve üstkavramsal değerlendirme kategorileri ve konu içeriği açısından sınıflandırılmıştır.

Araştırmanın Bulguları ve Sonuçları: Elde edilen bulgular daha önce Yürük (2005) tarafından ortaya konan üstkavramsal faaliyetlerin pek çoğunun bu çalışmada da öğrencilerde aktif olduğunu göstermiştir. Öğrencilerin günlükleri, tohumlu bitkiler başlığı altında yer alan farklı konularda, farklı çeşitte üstkavramsal faaliyetlerin aktif hale geldiğini ortaya koymaktadır. Bu faaliyetlerin bazılarının birbirine bağımlı olduğu gözlenmiştir. Örneğin bir kavramla ilgili ikinci dereceden farkındalığın gerçekleşebilmesi için bireyde geçmişte o kavramla ilgili birinci dereceden farkındalığın aktif olması gerekir. Bulgular bazı üstkavramsal faaliyetlerin birden fazla üstkavramsal faaliyeti içerebileceğine de işaret etmektedir. Örneğin bir kavramla ilgili kavramlardaki değişimin izlenmesi, o kavramla ilgili birinci ve ikinci dereceden farkındalığı içermektedir. Günlüklerden elde edilen bir başka bulgu ise üstkavramsal faaliyetlerin basitçe birinci dereceden farkındalık olabileceği gibi daha soyut ve üstdüzey düşünmeyi gerektiren üstkavramsal değerlendirme de olabileceğidir.

Araştırmanın Önerileri: Tüm bu bulgulardan yola çıkılarak üstkavramsal faaliyetleri aktif hale getiren öğretim etkinlikleri tasarlandığında bu faaliyetlerin çok yönlü ve birbirine bağımlı yapısı dikkate alınmalıdır. Üstkavramsal faaliyetleri aktif hale geçirecek öğretim etkinlikleri tasalanırken, konuyla ilgili merkezde olan ve diğer alternatif kavramların oluşmasında rol oynayabilecek kavram ya da kavramların saptanmasına ve etkinliklerin özellikle bu kavram ve bununla ilgili bilimsel kavram arasındaki farklılıkların fark edilmesini sağlayacak şekilde düzenlenmesine özen gösterilmelidir.

Anahtar Kelimeler: Üstkavramsal faaliyetler, tohumlu bitkiler, kavramsal değişim, biyoloji öğretmen adayları.