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Kuram ve Uygulamada Eğitim Bilimleri • Educational Sciences: Theory & Practice - 11(1) • Winter • 459-464

The Effect of Metaconceptual Teaching Activities on Pre-Service Biology Teachers' Conceptual Understanding about Seed Plants

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Abstract

The term metaconceptual refers to metacognitive knowledge and processes that are acting on and related to one's conceptual system. In this study, metaconceptual teaching activities were implemented to facilitate pre-service teachers' engagement in metaconceptual processes. It was the purpose of this research to investigate the changes in pre-service teachers' alternative ideas regarding flowering plants after being exposed to metaconceptual teaching activities. The participants consisted of 32 pre-service teachers who were enrolled in a college level second-year laboratory class about flowering plants. A 13 item open-ended question set was administered a week before and a week after the instructional interventions. In order to facilitate students' engagement in metaconceptual processes, they were exposed to several instructional activities including poster drawing, journal writing, concept mapping, and class and group discussions. Alternative conceptions that pre-service teachers had prior to and following the instructional interventions were identified and the ones that changed, did not change and developed after the instruction were examined. The results of this study show that metaconceptual teaching activities were effective at changing pre-service teachers' alternative conceptions regarding flowering plants.

Key Words

Metaconceptual Teaching Activities, Seed Plants, Flowering Plants.

One major source of difficulties that students and teachers have in learning and teaching science concepts is students' strongly held ideas that are inconsistent with those accepted by the scientific community. Changing these conceptions with scientifically accepted ones is not an easy and straightforward process (Bahar, 2003) as it requires learners to recognize and evaluate their existing and new conceptions associated commitments, everyday experiences, and contextual factors (Chi, Slotta, & Leeuw, 1994; diSessa, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Ueno, 1993; Vosniadou, 1994). These processes demand learners to engage in more abstract and higher level thinking about one's own theories, namely metacognitive processes. Kuhn, Amsel and O'Loughlin (1988) defined metacognition as "thinking explicitly about a theory one holds (rather than only thinking with it)" (p. 7). Many researchers acknowledged the role of learners' metacognitive activities in the change in their conceptions (Beeth, 1998; Ferrari & Elik, 2003; Hennessey, 1999, 2003; Vosniadou, 1994, 2003; White & Gunstone, 1989; Yürük, Beeth, & Andersen, 2009). According to Pintrich and Sinatra (2003), an implicit assumption about metacognition has been already made in the models about conceptual change. Although there are studies that emphasize the role of metacognition in the conceptual change process the number of the empirical studies that shows this relationship is limited.

Metacognition is a multidimensional construct involving various kinds of knowledge and processes. Several researchers have used a variety of theoretical frameworks to describe and study this construct. This construct can be broadly defined as "thinking about one's own thinking" (Rickey & Stacy, 2000) or "cognition about cognition" (Flavell, 1979). Brown (1987, p. 66) described metacognition as "one's knowledge and control of own cog-

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nitive system." Research studies conducted about metacognition focus mainly on problem-solving, reading, and memory. One's knowledge about problem-solving or reading strategies, and monitoring and regulating the execution of those strategies, awareness and employment of heuristics, one's knowledge about the limitations of his/her memory or learning styles are some examples to the metacognitive processes (see Brown, 1987; Flavell, 1979; Schraw & Moshman, 1995). Although these forms of metacognitive knowledge and processes have potential to successfully perform a given task such as problem-solving and reading a text (Hennessey, 2003), they may be inadequate to lead to a change in learners' conceptual structure (Yürük et al., 2009). Achieving a major restructuring requires metacognitive knowledge and processes that are acting on or related to the learners' conceptual system. These processes are called as metaconceptual processes (Yürük et al., 2009). Yürük (2005; 2007) and Yürük et al. (2009) categorized three types of metaconceptual processes: (a) metaconceptual awareness, (b) metaconceptual monitoring and (c) metaconceptual evaluation. Metaconceptual awareness refers to one's awareness of and reflection on existing and past concepts, one's interpretation of experiences, ontological and epistemological presuppositions, and the context in which a concept is used. Metaconceptual monitoring involves processes that generate information about one's cognitive state or thinking process. Monitoring information coming from other people or sources, the comprehension of conceptions, the consistency between the existing and new conception, and changes in ideas are subsumed under the heading of metaconceptual processes. Learners who engage in metaconceptual evaluation make judgmental decisions about the validity of competing conceptions.

Plants are one of the important topics in elementary, high school, and biology teacher education programs. Several studies show that people are less interested in plants compared to animals and have lower level of perception and attitude about plants (Hoekstra, 2000; Kinchin, 1999; Schussler & Olzak, 2008; Tunnicliffe, 2001; Tunnicliffe & Reis, 2000; Wandersee & Schussler, 1999, 2001).

Various studies indicate that students from different age levels have several alternative conceptions about plants (Barman, Stein, Barman, & McNair, 2003; Bebbington, 2005; Bell, 1981; Dikmenli & Kurt, 2004; Çokadar & Özel, 2008; Gatt, Tunnicliffe, Borg, & Lautier, 2007; Tunnicliffe, 2001; Türkmen, Çardak, & Dikmenli, 2002; Türkmen, Dikmenli, & Çardak, 2003). These studies showed that students mainly identified plants based on their external characteristics and categorized plants in a scientifically unacceptable way. Some other studies demonstrated that children did not have an enough and scientifically accepted conceptual understanding about seeds, fertilization, and the development of fruits (Jewell, 2002; Mak, Yip, & Chung, 1999; Schussler, 2008). Children of different age levels do not only have alternative conceptions regarding plants but many studies show that preservice teachers also have a scientifically unacceptable conceptual understanding regarding plants, seed, flower, fruit, and fertilization (Mutlu & Özel, 2008; Uşak, 2005; Yakışan, Selvi, & Yürük, 2007). Considering the results of these studies as Sanders (2007) emphasized, there is a need for studies that investigate teachers' and learners' perceptions of plants and the effect of different instructional approaches on their conceptual understanding of plants.

Purpose of the Study

Yakışan et al. (2007) identified pre-service biology teachers' alternative conceptions regarding flowering plants. In this study, metaconceptual teaching activities were designed to facilitate pre-service teachers' engagement in metaconceptual processes. The purpose of this study is to investigate the changes in pre-service teachers' ideas regarding flowering plants after being exposed to metaconceptual teaching activities. In doing so, pre-service teachers' alternative conceptions regarding flowering plants were identified prior to and following the instructional interventions and the alternative conceptions that changed, did not change and developed after the instruction were examined.

Method

Participants of the Study and the Instrument

A pre-test post-test single group research design (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2008) was used to investigate the effect of metaconceptual teaching activities. This study took place in a college level second-year laboratory class about flowering plants. The participants consisted of 32 pre-service teachers who were enrolled in the department of biology education of a state university. 24 of the pre-service teachers were females and 8 were males. These students had not taken any undergraduate level course related to seed plants. The class was scheduled to meet once a week for 240 minutes.

A 13 item open-ended question set was administered to students to portray the changes in their conceptual understanding in a variety of topics about flowering plants, such as the definition of flowering plant, seed plant, and non-seed plant, flower, single and composite flower, seed, fruit, single and compound fruit, monocotyledon, and dicotyledon plants. In addition to the open-ended questions, students were asked to label variety of plants as a seed plant or non-seed plant and as flowering plant or non-flowering plant. The test was given to students a week before and a week after the instructional interventions.

Instructional Issues

In this study, in order to facilitate students' engagement in the above mentioned metaconceptual processes, they were exposed to several instructional activities including poster drawing, journal writing, concept mapping, and class and group discussions. These activities were implemented in a ten-week period. These activities were not implemented in a particular order. However, students were asked to make journal entries before and after poster drawing, following the group/class discussions and after the teacher introduced the scientific phenomena. Class discussions were performed usually after group activities, including poster drawing and group discussions.

Poster Production: Students in groups of 3-4 were prompted to produce posters about flowering plants 3 times during the instructional interventions. During this activity, students exchanged their ideas within their groups. Students were also required to present their posters to their classmates. In order to help students monitor the consistency between their initial thoughts and current ideas, posters were given back to the students near the end of instructional interventions. Students were asked to think whether or not they want to change the ideas they presented in their initial posters. Below is an example to the directions for poster drawing activity:

Journal Writing: Journal writing provided students with the opportunity to bring out their ideas into open. The journal prompts were chosen so that they encouraged students to step back and reflect on their existing conceptions, examine the reasons why they were attracted to their views, monitor their understanding, make judgments on the validity of different ideas, recognize the limitations of their views, look for consistency between their existing ideas and ideas coming from different sources, and monitor the changes in their ideas.

Concept Mapping: Concept mapping was used to help students see the relationships and differences among variety of conceptual entities related to flowering plants. They were asked to arrange the given terms first individually and then students as a group of two shared, compared, and contrasted the concept maps they created.

Classroom and Group Discussions: Through classroom discussions it was aimed to bring the opinions held by the member of the class explicit. Students were encouraged to state explicitly their own ideas and compare and contrast among different ideas. Students were stimulated to discuss their ideas about the given conceptual entities usually during or after poster and concept map presentations. During the class discussions, the instructor did not introduce the scientifically acceptable concepts until students have nothing to say about the target concepts.

Data Analysis

In order to examine the changes in students' alternative conceptions their ideas about flowering plants that they had before and after the instruction were identified. Students' responses to the administered open-ended questions were analyzed by following the step below:

Table 1.
Example of the Analysis of a Student Reponses

Student A	Alternative Conceptions	Before Instruction	After Instruction
*1	Seed plants involve both flowering and non-flowering plants.	+	—
*2	All flowers must have female reproductive organs.	+	+
*3	Monocotyledons are annual plants, dicotyledons are perennial plants.	—	+

*1: This alternative conception existed in the pre-instructional responses of the student but it was changed with a scientifically accepted conception.

*2: This alternative conception existed in both pre- and post-instructional responses of the student.

*3: This alternative conception was identified only after the instructional interventions.

Table 2.
Alternative Conceptions Identified Before and After the Instruction

TOPICS	ALTERNATIVE CONCEPTIONS	Alternative Conceptions Before Instruction *[a]		Change in Alternative Conceptions*[b]		No Change in Alternative Conceptions *[c]		Alternative Conceptions Identified only After the Instruction *[d]	
		f	%	f	%	f	%	f	%
Seed and Flowering Plants	A1. Seed plants involve both flowering and non-flowering plants	9	28.1	9	100	0			
	A2. Flowering plants involve plants that produce and do not produce seeds.	2	6.3	2	100	0			
Flower and Parts of a Flower	B1. A flower must have colored leaves.	13	40.6	12	92.3	1	7.7		
	B2. All flowers must have female reproductive organs.	3	9.4	2	66.7	1	33.3		
	B3. All flowers must have male reproductive organs.	1	3.1	1	100	0			
	B4. Flowers are formed from leaves.	3	9.4	3	100	0		1	3.1
Composite and Single Flower	C1. A composite flower has all four layers of parts while a single flower lacks one or more of the layers.	12	37.5	10	83.3	2	16.7	1	3.1
Pollination and Fertilization	D1. Pollination occurs at the stigma of the female reproductive organ.	2	6.3	2	100	0			
	D2. Pollination often occurs between the male and female reproductive organs of the same flower.	2	6.3	2	100	0			
	D3. Fertilization is the fusion of two pollens.	4	12.5	3	75	1	25.0		
	D4.Fertilization occurs at different parts of a flower except its ovary.	2	6.3	2	100	0			
	D5. Fertilization and pollination refer to the same thing.	0	0.0	0		0		1	3.1
Fruit and Single and Compound Fruits	E1. Single and compound fruits are differentiated according to the number of seeds they have.	6	18.8	6	100	0			
	E2. A fruit develops as a result of the differentiation of different parts of a flower except its ovary.	4	12.5	4	100	0			
	E3. A compound fruit develops from a composite flower	1	3.1	1	100	0			
	E4. Single fruit develops from one carpel, while compound fruit develops from more than one carpel.	0	0.0	0		0		1	3.1
Seed	F1. A seed is produced from the accumulation of the nutrients formed from the remaining of the dried flower.	1	3.1	1	100	0			
	F2. Continuity of generation is maintained by fruits.	3	9.4	3	100	0			
The Relationship Among Flower Fruit and Seed	G1. Once fruits start to develop flowers fall.	6	18.8	6	100	0		2	6.3
	G2. Fruits form as a result of the development of seeds.	8	25.0	8	100	0		2	6.3
	G3. Seeds are produced after the formation of fruits.	3	9.4	3	100	0			
Naked-Seed and Covered-Seed Plants	H1. A plant whose seed is enclosed in a hard seed coat is called covered-seed (angiosperm) plant, while a plant whose seed is not surrounded by a hard seed coat is called naked-seed (gymnosperm) plant.	12	37.5	10	83.3	2	16.7	2	6.3
	H2. In naked-seed plants, the ovary consisting of more than one carpel is open and split.	0	0.0	0		0		1	3.1
	H3. In covered-seed plants, the seed is surrounded by the sepals.	1	3.1	1	100	0			

Monocotyledon and Dicotyledon Plants	I 1. Monocotyledons are annual plants, dicotyledons are perennial plants.	5	15.6	3	60	2	40	3	9.4
	I 2. Monocotyledons do not have seeds and flowers.	1	3.1	1	100	0			
	I 3. Monocotyledons have either female or male reproductive organs while dicotyledons have both female and male reproductive organs.	1	3.1	0	0.0	1	100	1	3.1

* [a]: For each alternative conception listed in the table the number of students who held that alternative conception before the instruction and the percentage of these students are provided.

* [b]: The number and the percentage of students who changed the alternative conception identified before instruction are provided. The percentage is calculated by dividing the number of students who changed that alternative conception by the number of the students who held that alternative conception before the instruction.

* [c]: The number and the percentage of students who did not change the alternative conception identified before the instruction are provided. The percentage is calculated by dividing the number of students who did not change that alternative conception by the number of the students who held that alternative conception before the instruction.

* [d]: The number and the percentage of students who held that alternative conception only after the instruction but not before the instruction are provided.

1. Segments of each student's pre-instructional responses were coded in terms of the content of science ideas and the agreement between those ideas and accepted scientific view. Through this procedure each student's pre-instructional alternative ideas were identified.
2. All of the student's post-instructional responses were searched for the existence of alternative conceptions that were identified in the pre-instructional responses of the same student.
3. For each student a table that shows student's pre-instructional alternative conceptions was created. The changes in those alternative conceptions and new alternative conception that emerged after the instructional interventions were added to this table. An example of a table created for each student is provided below (Table 1).
4. At this step, the alternative conceptions identified before and after the instruction were classified under main topics about flowering plants.
5. For each alternative conception, the percentage and frequency of students who had that alternative conceptions before the instruction, who changed that alternative conception with scientifically accepted conception after the instruction and who had that alternative conception only after the instruction were calculated by using the tables created for each student.

At each step of the data analysis, the data segments were assigned to the codes through as consensus of the three researchers.

Discussion

The results of the study are summarized in Table 2. It shows the number and percentage of the students who held the listed alternative conceptions before and after the instruction and the percentage of the change in those conceptions. As Table 2 shows, most of the alternative conceptions that existed prior to the instruction were changed with scientifically accepted conceptions. However, the results also indicate that there are a couple of alternative conceptions that remained unchanged or emerged throughout the instructional interventions. This finding gives signs of the positive impact of metaconceptual processes on promoting students' conceptual understating about flowering plants. This finding strengthens the theoretical claims about the positive role of metacognition in science learning (e.g. Davis 1996; Thomas & McRobbie, 2001).

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