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IMPROVING PRESERVICE BIOLOGY TEACHERS' SPATIAL THINKING IN PLANT ANATOMY COURSE THROUGH FRAMING

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ABSTRACT

In this study, we reported the implementation of framing in plant anatomy course and how framing improves preservice biology teachers' spatial thinking. Thirty-five preservice biology teachers served as subjects. Spatial thinking were evaluated based on four cognitive processes in spatial thinking: (1) producing representations, (2) maintaining and managing representations in working memory, (3) scanning the representation in working memory, and (4) transforming representations. Results indicated that framing improved preservice biology teachers' spatial thinking in which all four spatial thinking parameters significantly improved after learning plant anatomy with framing. Framing in a plant anatomy course can improve preservice biology teachers' spatial thinking because questions, guiding sentences, and worked examples aided them in overcoming cognitive stress when engaged in a difficult task.

Keywords: plant anatomy; spatial thinking; framing; learning biology; preservice biology teacher

ABSTRAK

Dalam studi ini, kami melaporkan implementasi *framing* dalam mata kuliah anatomi tumbuhan dan bagaimana *framing* dapat meningkatkan pemikiran spasial calon guru biologi. Tiga puluh lima calon guru biologi menjadi subjek penelitian ini. Keterampilan berpikir spasial dievaluasi berdasarkan empat proses kognitif dalam pemikiran spasial: (1) menghasilkan representasi, (2) mempertahankan dan mengelola representasi dalam *working memory*, (3) memindai representasi dalam *working memory*, dan (4) mentransformasikan representasi. Hasil penelitian menunjukkan bahwa *framing* meningkatkan pemikiran spasial calon guru biologi dengan keempat parameter berpikir spasial meningkat secara signifikan setelah pembelajaran anatomi tumbuhan dengan *framing*. *Framing* dalam mata kuliah anatomi tumbuhan dapat meningkatkan pemikiran spasial calon guru biologi karena pertanyaan-pertanyaan, kalimat-kalimat panduan, serta *worked examples* membantu mereka dalam mengatasi stres kognitif saat terlibat dalam tugas yang sulit.

Kata kunci: anatomi tumbuhan; berpikir spasial; *framing*; pembelajaran biologi; calon guru biologi

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INTRODUCTION

Previous researches suggested that students had basic knowledge about plant structure (Anderson, Ellis, and Jones, 2004; Barman, Stein, McNair, & Barman, 2006) or when they do have knowledge about plant structure, they did not understand the functions of the structure (Zangori and Forbes, 2016) in which incorrect conceptions occur across the educational level. Yenilmez and Tekkaya (2006) study, for example, found that elementary students' alternative conceptions of plant stomata roles in plant respiration was persistent. Lin (2004) study in 477 high school students also suggested that students did not fully understand plant growth and development, with as many as nineteen misconceptions were identified. A recent study by Vitharana (2015) also showed that students have misconceptions about plant stomata and vascular tissues (xylem and phloem). Lastly, Ermayanti (2015) found that even preservice biology teacher have an insufficient understanding of plant internal structure and function.

Plant anatomy course covers plants' internal structure and organization, cells, tissues, and organs (Barclay, 2002; Evert, 2006; Rudall, 2007). Brodersen and Roddy (2015) argue that major obstacles in understanding plant structure and function is due to the challenge in visualizing the three directional (3D) structure with two-dimensional (2D) technique. Suprapto, Rustaman, Redjeki, and Rahmat (2012) study showed that learning with 3D media resulted in a better understanding of plant anatomy. As Suprapto et al. (2012) also pointed out, plant anatomy course demanded the students to have spatial perception skills and high cognitive abilities (Lazarowitz and Naim, 2013). Spatial thinking involve knowing about (1) space, (2) representation, and (3) reasoning (see National Research Council, NRC, 2006). Berdnarz and Berdnarz (2008) further elaborate that spatial thinking consists of the knowledge, skills, and habits of mind to use space, tools of representation, and reasoning processes to structure, solve, and express solutions to problems. Lazarowitz and Naim (2013) implemented hands-on active learning for learning cell structures and physiological function, but even though improvement did happen, students still did relatively poorly in higher-order questions demanding higher spatial perception skills.

Engle (2006) stated that learning should resulted in the ability to apply what has been learned into a different but related situation or *transfer of learning*. Students' low ability in solving higher-order questions could indicate transfer of learning problem. Further, Engle (2006) believes that if a transfer of learning is going to happen, learners should choose to use what they have learned, and such choices could be influenced by how learning and contextual transfer are framed socially. There are six aspect of learning situations that can be framed: Participants, temporal horizon (time), location, topics, roles and practices (students positioned as the creators of their understanding), and purposes (Engle, 2006). Further, Engle (2011) used tutoring methods and instructional transfer support for learning transfer, such as hints, references, cues, examples, comparison, and abstraction. Engle (2011) approach was successfully implemented in biology courses, which highlighted the potential of using the framing approach in another biology course, such as plant anatomy. Moreover, the surprisingly scarce research concerning students' spatial thinking in plant anatomy further demonstrates the importance of exploring spatial thinking in plant anatomy course through framing. In this current study, we reported the implementation of framing in plant anatomy course and how framing improves preservice biology teachers' spatial thinking.

METHOD

This study covered plant anatomy concepts such as plant meristematic cells and tissue, ground tissue, vascular tissue, and stem organs. The framing approach was develop based on previous studies (Engle, 2006; Engle, 2011; Berland and Hammer, 2012). Questions, guiding sentences in spatial thinking, and examples of 2D/ 3D images related to well-constructed concepts (worked examples) were used to frame spatial thinking based on spatial thinking taxonomy (Injeong and Bednarz, 2009). Guidance sentences were sentences that direct students to think spatially in plant anatomy concept and were developed based on previous needs analysis. Learning steps in plant anatomy course with framing were presented in Table 1.

Thirty-five preservice biology teachers served as subjects. Spatial thinking skills were evaluated based on four cognitive processes in spatial thinking: (1) producing representations, (2) maintaining and managing representations in working memory, (3) scanning the representation in working memory, and (4) transforming representations (Kosslyn, 1978). The spatial thinking test consisted of multiple-choice questions that were previously proved to be valid and reliable ($\alpha = 0.83$, $r = 0.63$ to 0.76). Spatial thinking test results were categorized as very good (75-100), good (61-74), 51-60 (moderate), poor (35-50), and very poor (25-34). Improvement after learning plant anatomy with framing was evaluated based on normalized gain criteria (Hake, 1998). The difference in spatial thinking skills before and after the framing was analyzed statistically with SPSS version 22.

RESULTS AND DISCUSSION

Results indicated that framing improved preservice biology teachers' (henceforth will be referred to as students) spatial thinking in which all four spatial thinking parameters significantly improved after learning with framing (Table 2, N-gain average = 0.62, $p= 0.024$, $p<0.01$). Based on plant anatomy concepts, students have an excellent command of producing and scanning meristematic cells and tissue but still had a moderate command of maintaining and managing

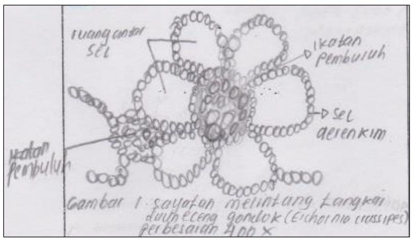
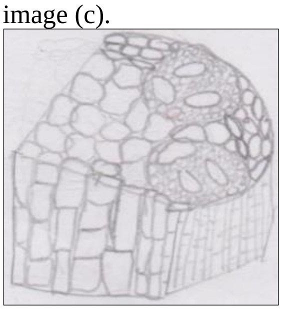
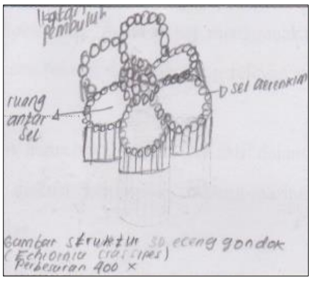
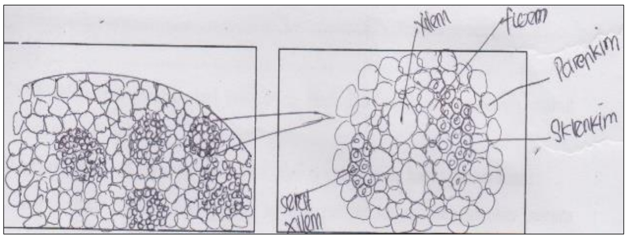
Table 1. Learning Steps In Plant Anatomy Course with Framing

Steps	Framing	Examples of expected cognitive processes of spatial thinking
Receiving information	Questions and worked examples	Scanning (Scanning) representations by recognizing the characteristics of each network in terms of shape, position, color, size, by observing worked examples of 2D plant networks.
Identify and exploring concepts	Questions, guidance sentences and worked examples	Scanning representations in memory, for example making observations and recognizing network characteristics of microscopic observations by utilizing worked examples and concepts that have been learned in theory learning and making (producing representations) of microscopic observations in 2D.
Construct a representation, 2D to 3D or vice versa	Questions, guiding sentences, worked examples	Maintain and manage representations in working memory and use them to reason in solving spatial problems. For example: building 3D images from 2D images of microscopic observations of plant tissue.
Verbally communicating the results of the representation	Question, worked examples	Transforming representations, for example by focusing observations on a particular network and enlarging the part in 2D or 3D representations.
Improving the representation of 2D & 3D concepts or images	Worked examples	Manage representations in working memory and use them to reason and solve spatial problems, for example, presenting verbally, concepts or representations of 2D or 3D images.

Table 2. Preservice Biology Teachers Spatial Thinking Skills Before and After Framing in Three Plant Anatomy Concepts

No	**Parameters**	**Pretest**	**Posttest**	**Ngain (g)**	**Plant Anatomy Concepts**		
					Meristematic cells and tissue	**Ground tissue**	**Vascular tissue and stem organs**
1.	Producing representations	30.00	73.95	0.63	89.29	85.71	84.29
2.	Maintaining and managing representations in working memory	22.21	69.79	0.61	55.00	47.43	49.29
3.	Scanning the representation in working memory	20.00	71.94	0.65	89.29	76.57	69.29
4.	Transforming representations	15.00	64.46	0.58	68.57	32.86	48.57
	Average	21.80	70.035	0.62	75.54	60.64	62.86

Table 2. Preservice Biology Teachers Spatial Drawings Example

Spatial thinking	Preservice Biology Teachers Spatial Drawings Example
1. Producing representations	Generates 2D image representations from microscopic observations.  a. 2D Image of Aerynchema
2. Maintaining and managing representations in working memory	Construct a 2D image representation to 3D or vice versa (for example, image (a) to image (c).   b. 3D Image of *Zea mays* stem c. 3D Image of Aerynchema
3. Scanning the representation in working memory	Annotate the image appropriately (as shown in figure a)
4. Transforming representations	Observing plant networks from a variety of different perspectives and focusing observations on certain parts of the network and representing it again to clarify the structure of a network.  d. Accentuate the image of the vessel network in the cross-section of the monocot stem

representation in working memory. For ground tissue, vascular tissue, and stem organs concepts, students had excellent skills in producing and scanning representation in working memory but still have inadequate skills in maintaining, managing, and transforming representation (Table 2). Nevertheless, students' improvement in maintaining, managing, and scanning representation in working memory after framing suggested that framing can help students overcome cognitive stress when engaged in a difficult task. Autin and Croizet (2012) study also corroborated these findings. In their study, reframing metacognitive interpretation of task difficulties resulted in improved working memory capacity and efficiency because it reduced physiological obstacles resulting from the task's demand.

Students can already generate the 2D representation of plant anatomy from microscopic observation (Figure 1a), but unfortunately, they still have not mastered the skills to construct 2D to 3D representation or vice versa accurately. As shown from Figure 1b and 1c, students still struggle with arranging what they see under the microscope to form a 3D structure so that instead of drawing plant internal structure as interconnected parts, they draw it as separate parts. 63.5% of their drawing did not reflect a logical connection between each structure. In a similar vein, Zangori and Forbes (2016) also found that learners often draw plant structure without making a necessary remark of its function. It is also important to note that most students (55.2%) could not make representational transformations such as enlarging microscope focus (Figure 1d), while 44.8% could only make a simple drawing of observation transformation.

Managing and maintaining, as well as making a transformation representation is a complex process because students should be able to envision and make a mental representation of each plant part and its connection with other parts from various perspectives of observations (transverse, longitudinal, or radial). Hoyek, Collet, Rastello, Fargier, Thiriet, and Guillot's (2009) study suggested that improving students' ability to learn anatomical structure is attainable if educators train learners to make anatomical structure rotation. Further, Hoffler (2010) meta-analysis study emphasizes that when learners have low spatial ability, supporting them with dynamic and three-dimensional visualization is significantly beneficial.

This study proved the potency of framing as an instrumental approach to support students' spatial thinking development, but there is still room for improvement. Students' responses to the framing scheme in this study showed that sometimes students were not fully understood questions or cues used for framing.

"...If angular thickening happens, how is the structure of a collenchyma cell when you look at it from the top or front angle? How does the network look like?"

Russell-Gebbett's (1984) classic study fittingly summarizes the importance of spatial ability for understanding three-dimensional structures in biology: learners should understand the abstraction of sectional shapes and spatial relationships of internal parts in differing sectional planes. The guiding questions could become meaningless when students are struggling to understand which angle is top or front. Therefore, it is advised to make a more explicit question to support students' mental visualization. For the question mentioned above, a clear perspective could be added.

*"...If angular thickening happens, how is the structure of a collenchyma cell when you look at it **from the transversal or longitudinal side**? How does the network look like?"*

By making a clear direction from where the students should look at the cell, they will have a better chance of making a correct mental visualization.

CONCLUSION

Framing in a plant anatomy course can improve preservice biology teachers' spatial thinking because questions, guiding sentences, and worked examples aided them in overcoming cognitive stress when engaged in a difficult task such as understanding plant internal structures. As a suggestion for improvement when educators want to implement framing in their classroom, questions, guiding sentences, and worked examples should be made more straightforward and easier to understand.

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