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Impacts of Reasoning Stimulation with Multiple Representasions Supported by Argumentation Towards the Achievement of System Thinking

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Abstract: This research was conducted to test the instructional effectiveness that provides representative and argumentation tasks to stimulate reasoning, in order to promote system thinking on the topic of plant basic tissue systems. Testing is done through one group postest only design toward 30 pre-service biology teacher. Research data is in the form of reasoning complexity using multiple representations and thinking abilities that are collected through the analysis of completed worksheets and written tests. The results showed the use of multiple representations supported by arguments stimulating reasoning and correlating with the achievement of system thinking abilities. Learning that gradually involves direct observation activities, visualization and the use of models and modeling that uses discourse support for argumentation provides scaffolding in systems thinking.

Key words: Reasoning, multiple representasions, systems thinking, argumentation, abilities, visualization

INTRODUCTION

System reasoning implementation provides a way to acquire a coherent understanding of the system (Verhoeff *et al*., 2008). Some evidence suggests that system reasoning is able to provide a coherent understanding of complex systems such as understanding earth systems (Batzri *et al*., 2015); water cycle system (Lee *et al*., 2017) as well as health systems and also mechanistic explanations of biological systems (MacLeod and Nersessian, 2015). However, there are still a number of challenges that students must face to understand complex systems. System features that are complex and in the form of abstract system components and processes that occur simultaneously (Hmelo-Silver and Azevedo, 2006; Hashem and Mioduser 2011; Eilam, 2012), identify components and processes, recognize multiple interactions and relationships between subsystems and hidden dimensions (Lee *et al*., 2017) and linking natural phenomena to the macroscopic level with system dynamics at the microscopic level (Eilam and Reisfeld, 2017).

Learning that uses models and modeling can facilitate the acquisition of system reasoning to understand complex systems coherently, for example with problem-posing approaches (Westra, 2008) and blue planet inquiry programs (Assaraf and Orion, 2009; Benz-zvi-Assarf and Orion, 2005). However, learning with complex representational tasks and integrating them with systems thinking has implications for some barriers to learning such as difficulties in raising problems related to dynamic knowledge of the system (Boersma and Waarlo, 2003), understand the limits of abstract systems (Westra, 2008), integrate system modeling activities with the development of systems understanding and conceptualization (Verhoeff *et al*., 2013) and tend to rely on visible components only to understand system dynamics (Batzri *et al*., 2015) resulting from both static and unscientific models (Benz-zvi-Assaraf and Orion, 2005; Sommer and Lucken, 2010). It shows that learning practices involving complex representational work need to be bridged by complexity of system thinking (Tsingos-Lucas *et al*., 2016).

System reasoning through representational work and supported by arguments: Students often engage with multiple representations while studying science including biological systems but they often do not have a domain of representative knowledge. The key to achieving a coherent understanding in studying complex systems is interacting with knowledge and translating or transforming knowledge from one representation to another at the procedural and conceptual level (Nichols *et al*., 2013), so that, it is necessary to develop reasoning skills using multiple representations (Anderson *et al*., 2013) by involving them using, manipulating or translating representations or generalizing information from and in multiple

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Table 1: The pedagogical action of the MRSA learning model

Phases	Description of main learning activities	Expected learning outcomes
Orientation	Oriented the problem of basic tissue systems associated with plant systems, based on concrete models of natural phenomena	Students are aware of the complex relationship of the basic tissue system with the dynamics of system life in plant organisms as a whole
Exploration	Explore the components and processes of basic tissue system through concrete model observations that are translated in 2D Models	Students are able to identify the multiple components of basic tissue system, the relationship of parenchyma component structure, to its function
Knowledge integration	Organize the interaction of components and processes in a complex relationship framework based on the results of translation and inference from the cell system model as a unit of parenchymal tissue using a diagram	Students are able to think of dynamic relationships horizontally, linking the relationships between components and processes of the cell system as functional units of the parenchymal tissue
Modelling	Creating a model to represent complex relationships between cell systems and various parenchymal tissue systems and organ function or plant adaptation	Students are able to think of a hierarchical relationship of "cell-organ-organism" as the application of the cell system as a structural and functional unit of plant organisms
Argumentation	Using the model as a tool to solve the problem of how the relationship between plant organisms and the environment in the past and the future is based on changes in the structure of the parenchymal tissue	Students are able to find evidence to understand the hidden dimensions of the adaptation of the parenchymal tissue system and use that knowledge as a tool for temporal thinking by retrospecting and predicting how the structure of the parenchymal tissue system due to the interaction of plant organisms with the environment
Reflection	Reflect representational tasks as a tool for reasoning and arguing about the system during learning process	Students are able to recognize the cognitive strategies used in reasoning about complex systems based on experience using multiple representations and arguments

representations to explain, solve problems or reason collaboratively about scientific phenomena (Nichols *et al*. 2013). On the other hand, representation provides a substrate for discourse and scientific argumentation (Collins, 2011). It shows that when students are provided with appropriate representational resources and representational tasks, it will achieve a complex understanding of the system.

Learning Multiple Representations Supported Argumentation (MRSA) is a model designed to utilize multiple representations and argument support for performing system reasoning practices in six phases: orientation, exploration, integration, modeling, argumentation, reflection (Sumarno *et al*., 2016). The use of multiple representations integrated with the knowledge domain of plant structure and plant adaptation, designed to stimulate reasoning about complex systems. Representational instructions and tasks in the learning model (Table 1) are also designed taking into account the pedagogical functions of multiple representations.

System thinking in the context of basic tissue systems: The tissue system is a functional unit that connects all organs of plants has specific characteristics and a variety of spatial relationships (Campbell *et al*., 2008). Structural adaptation of the cells of the tissue system components results in the system being able to carry out multiple functions to support the organ system as well as the plant's body such as organic material synthesis, storage and specialization, supporting organs, defense and transportation. The basic tissue system is a dynamic complex system because the structure, function and behavior of the system involves the dynamics of the cell system as well as the organ system and the body organ's system in response to the environment, either through structural responses or physiologic responses that can be detected based on circumstances, activities as well as spatial and temporal organizational life (Trujillo *et al*., 2016). Based on this description, teaching basic tissue with a complex system perspective leads to an understanding of the relationship between structure and function and gives students the opportunity to deal with the dynamics of basic tissue systems in an evolutionary and ecological context. Adapting the System Hierarchical Thinking (STH) Model (Ben-zvi-Assaraf and Orion, 2005; Tripto *et al*., 2013), the characteristics of thinking systems on a basic tissue at least show the abilities presented in Table 2.

Research questions: This study aims to examine the extent to which representational practicability supported by argumentation in the learning design of the MRSA Model to stimulate the reasoning of the system and how effectively the reasoning of the system by using multiple representations and argument support facilitates the achievement of system thinking skills in the learning of basic tissue systems. Based on this, the research question is formulated as follows:

- How does the system reasoning on the topic of basic tissue system as a result of stimulation through representational work supported by argumentation?
- How does the impact of system reasoning with multiple representations supported by arguments towards system thinking skills?

Table 2: Characteristics of system thinking in the context of tissue systems

System thinking	Description
Identify system components and processes in the system	These characteristics in relation to the basic tissue system are the ability to identify the components of the tissue system, for example, the parenchymal tissue system including the cortex, the pith, the mesophyll, the plastids, the vacuoles, the chloropas, the amyloplasts, the aerenchymes, the chlorencimas and the processes such as lysigen, schizogen
Identify relationships between system components	The expression of these characteristics in basic tissue systems is for example, the recognition of the relationship between protoplast structures and compositions and cell walls with basic tissue functions
The ability to identify dynamic relationships in the system	Understanding the transformation of basic tissue systems involves dynamic relationships within the system such as the correlation of the development of intercellular cavities and protoplast components as well as the relationship of plastid expression and tissue specialization
Understand the hidden dimensions of the system	Recognize the patterns and reciprocal relationships of macroscopic and microscopic structures, for example understanding the color phenomena of bractea, pollination or hypoxic conditions, environmental humidity with the dynamics of the relationship of tissue system components
Thinking temporally: retrospection and prediction	Understand that some of the interactions presented in the system occur in the past based on tissue system conditions as well as predicting the future tissue system conditions in the future as a result of the interaction that occurs today, for example, the ability to understand that the structure, composition of protoplasts and the behavior of the parenchymal tissue system are found to be the result of evolution due to adaptation to environmental changes; understand environmental conditions based on structure, protoplast composition and behavior of tissue systems; predict global warming with the adaptation of the structure of the parenchymal tissue

MATERIALS AND METHODS

Participants: Participants in this one group posttest design research were 30 students (5 men and 25 women) who attended the course of plant development structure. All participants who take part in this program have participated in the Basic Biology course which examines the basic principles of Biology and graduates with a minimum "sufficient" predicate category.

Materials and procedure: Participants every week attend lecture sessions for 6 h with 3 h learning sessions held in the laboratory and 3 h learning sessions held in the classroom. Learning sessions in the laboratory are carried out with the procedure of participants observing natural phenomena in the macroscopic structure of plants and discussing multiple alternative relationships of these phenomena with microscopic structures of plants based on the knowledge they already have. Next the participants used a microscope exploring microscopic structures and analyzing the components and structures of cells that forms tissue by comparing sketches of observations with other representational modes. At the end of the learning session in the laboratory, participants discuss and integrate the findings of the exploration and connect the structure and function of the components to the processes in the tissue and their development.

In a classroom learning session, participants modeled the macroscopic phenomena of plant structure with microscopic structure, then used the model as a tool to respond to the stand point associated with plant and ecological adaptation and provided by the lecturer. Sessions continued with arguments and discussions to retrospectively and predict the development of basic tissue system structures due to ecological changes. During the lesson, the participants obtain worksheets that have been declared valid by the expert to support the learning (Sumarno *et al*., 2016). The worksheet is designed to provide scaffoldings to guide representative tasks and simultaneously as a means to write down all results of activities during learning. In addition to the lessons learned in the laboratory as well as the classroom, participants are given independent tasks to follow up representational tasks during the lesson with a worksheet guide. After following the lesson, the participants receive the post test.

Data source and analysis: The research evidence used to describe how the student system's reasoning with multiple representations during the learning process is collected extensively using completed worksheets and complex system modeling products. Both of these are data collection instruments that reflect performance in learning (Harlen, 1985) and can provide additional information about problems faced by students in carrying out representational tasks during interventions to do system reasoning (Durmaz and Mutlu, 2017). As explained in the previous section, the worksheet has been validated by science education experts and it was decided that the worksheet can be used for performance-based assessment.

Checking of completed worksheet is done in two stages. First, the examination is done to the student answers from the exploration activities that identify the components and processes of the basic tissue system as well as to interpret the relationship of cell structure of the basic tissue formation with its function. Examination is carried out by calculating the number of components and the process of identification results as well as the relationship between the structure and the correct function of the results of the interpretation. Both examinations are carried out on the results of reasoning during complex system orientation activities, integration of knowledge, modeling of complex systems and argumentations. The examination was conducted on the complexity of system reasoning in accordance with the systems thinking hierarchy framework (Tripto *et al*., 2013) as described below. Furthermore, for the complex system model, student's work is checked based on the existence and number of system components, the number of relationships between components in the system and between systems and interconnectedness by measuring the Web-like of Causality Index (WCI) (Plate, 2010).

Evidence of the effectiveness of instructional interventions with the MRSA learning model trains the thinking ability of the system obtained through tests on all students of the lectures. Measurement of performance thinking systems was done using Parenchyma Tissue Systems Test (PTST). PTST consists of 10 open-ended questions that have been developed based on the Systems Thinking Hierarchy (STH) framework (Tripto *et al*., 2013), covering the ability to analyze components and processes rather than systems, synthesize structural relationships and system component functions, the dynamic relationships that occur in the system, to understand phenomena based on abstract patterns and abstract relationships and to think temporally which is to rethink and predict the behavior of systems based on adaptation and ecological factors systems. PTST has been developed through an iterative process and it was found that the reliability coefficient of the test for this study reached 0.610.

Scoring of student answers from system reasoning was completed with worksheets and tests with PTST instruments based on an assessment framework adapted from systemic reasoning levels (Monroe *et al*., 2015; Hokayem and Gotwals, 2016) with the following details: level 0, no answer; level 1, if the explanation is only a claim with an explanation of a simple causal mechanism; level 2, if the explanation is a claim with an explanation of some causal but linear or loop relationship and level 3, if the explanation is in the form of claims of complex network of causal relationships.

The results of further tests were analyzed descriptively. Achievement of system thinking ability is analyzed by using one sample t test with benchmark value 2, 31 or having "sufficient" criterion. The effectiveness of instructional interventions is generalized based on the consistency of system thinking that students use when making reasoning systems based on external representation and the ability to transfer system understanding to solve problems about basic tissue systems. Furthermore, to see the consistency of reasoning system with multiple representation and achievement of system thinking then tested with Pearson correlation.

RESULTS AND DISCUSSION

Research results are organized based on research questions. In this study, first the analysis of student's system of reasoning using multiple representations and the two results of the analysis of the ability to think about complex systems after following the learning with the MRSA Model are presented.

Student system reasoning uses multiple representations: The reasoning results about the system using multiple representations, grouped into two categories. First is the quantity of identification results and interpretation of relationships between components and second is interconectedness in thinking dynamically the relationship of components within the system and between systems, understanding the hidden dimensions of the system and thinking temporally. Table 3 presents the total number and average of system component identification results and the interpretation of simple relationships between components by each group.

Component identification and simple relationship interpretation between components are carried out based on representational tasks through visualization of observations, "translate horizontally across representations" namely from visualization sketches and 2D Models of various basic tissues and decode a representation by naming tissues system components in phases exploration. Table 3 shows that on average each student is able to identify seven to nine components of the 10 targeted components. The dominant components identified by each group include chloroplasts, plastids, aerenchymes, chlorenchymes, plastids and cortex as well as intercellular space. Reasoning in interpreting, the average student is able to perform three types of interpretation of basic tissue system functions based on its structure. Most students use the protoplasmic component of the basic cell tissue formation as a proof to construct the reason. This indicates that through visualization activities followed by translating sketches with 2D Models and decoding system components

Table 3: Total and average results of identification and interpretation of relationships between components

	Group A		Group B		Group C		Group D		Group E		Group F	
System reasoning	n	M	n	M	n	M	n	M	n	M	n	M
Identification of system components	40	8.0	37	7.4	38	7.60	34	6.8	36	7.20	45	9.00
Interpretation of relationships between components	17	3.4	15	3.0	15	3.00	12	2.4	12	2.40	17	3.40

Table 4: Reasoning ability using multiple representations reflecting the interconnectedness of components and systems

	Group A			Group B			Group C			Group D			Group E			Group F		
System reasoning*)	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Horizontal dynamics thinking	5	11	6	6	12	2	5	11	4	6	12	2	7	10	3	5	11	4
Vertical dynamics thinking	6	10	4	5	10	2	6	10	1	6	7	3	7	10	2	6	9	3
Understanding hidden dimension	5	8	2	6	7	2	7	6	1	5	8	2	5	7	2	6	7	2
Temporal thinking	4	5	1	4	5	1	4	4	1	4	5	1	4	5	1	4	4	1

*) 1: Simple; 2: Semi-complex; 3: Complex

Table 5: Result of analysis of complex system model

Aspects	Group A	Group B	Group C	Group D	Group E	Group F
Presence of components	14	17	18	13	15	17
Relationship between component	17	21	22	18	21	23
Relationship within system	3	3	4	3	3	4
Relationship between system	2	4	4	3	4	4
Interconnectedness (WCI)	0.18	0.29	0.22	0.28	0.33	0.30

from the modeling itself and the model has implications for system reasoning in identifying and interpreting relationships between components.

The analysis of reasoning ability using multiple representations reflecting the interconnectedness of components and systems is presented in Table 4.

Table 4 represents that in general, students have been able to use multiple representations to do system reasoning. Most students show a series of multi-causal relationships of components and systems, both linear and multiple causal effects. It is also represented by students when modeling complex systems. The ability of students to model complex systems is represented in Table 5.

As can be seen in Table 5, through modeling, students are able to identify the components and state the relationship between the components more than in the exploration phase. This is because students involve components at various system levels in modeling. Table 5 shows the average of 3-4 dynamic relationships between components in the system and between systems. The interconectedness Index (WCI) ranges from 0.27 which shows the relationship of components in the system and between systems even though it reflects a multi-causal relationship but tends to lead to relationships containing linear causal sequences.

The evidence of how the system's reasoning, particularly in the dynamic thinking of component relationships within the system and between systems, understands hidden dimensions rather than systems as well as temporal thinking is presented in Table 6.

As presented in Table 6, the evidence (O.1.M.25) shows that direct experience of observing natural phenomena supplemented by the presentation of hierarchical diagrams of life stimulating students' hypotheses illustrates how the relationship between cortical structure phenomena and organ function or plant life is related. This indicates that students have initiated system reasoning. Response construction in (E.4.M.10) illustrates that the involvement of students in modeling the results of observations that are translated by 2D drawing model bridges students to obtain information about the structure of the system components, so that, they are able to interpret the functions of the system.

Furthermore, the results of reasoning in (I.2.M.12) illustrate that through the interpretation of the lysigen or schizogen model, students are able to elaborate on how the dynamics of the basic tissue system are represented in the medulla on Aloe vera leaves. This indicates that students are able to recognize structural changes that are represented in the model representing a series of processes to carry out functions and stimulate to use evidence of differences between basic network structures to build causal relationships between structures and functions. Evidence of reasoning in Table 6 also shows that modeling supported by social discourse through argumentation implies student's increasingly dynamic reasoning and finds hidden dimensions of complex systems. This is reflected in the evidence (P.1.M.02) which describes dynamic relationships in complex systems because it has involved the relationship between macroscopic and microscopic system levels. However, it does not involve hidden dimensions, different from (A.2.M.13) which has reflected the hidden dimensions of complex systems, so that, it can predict the behavior

Table 6: Examples of system reasoning based on representational tasks

Representational tasks	Reasoning with modes representations	Systems reasoning examples
Interpret concrete representations Translate horizontally across representasons	Interpretation of the cortex structure of several plant organs and to hypothesize the relationship of cortical structure to plant life, the structure of the organ cortex and the structure of tissue cells formation based on the diagram of the organizational hierarchy of life	Differences in potato tuber cortex and taro leaf midrib, then suspected cortical structure in accordance with organ function or way of life of plants (O.1.M.25) *)
Construct representation Translate horizontally across representasons	Sketch the tissue formation structure of the cortex of plant organs. Identify sketches and interpret tissues functions from sketches based on 2D model structure	"The results of potato tuber cortex observation found elliptical spheres, identification results show that the sphere is an amylum, thus indicating the cortex consists of tissue parenkim storage food storage, ...(E.4.M.10)*)
Interpret and use representation	Interpret the diagram of the process of lysigen, schizogen or diagram the formation of starch, then elaborate the processes in the cortex of plant organs including the leaf medulla based on the interpretation of the diagram.	Aloe vera leaf medulla, have large and slimy parenchymal cells. The presence of mucus to increase water retention in both cytoplasm and vacuole. The large size of the cell is thought to have a large vacuole, so, it is efficient to store water, ... (I.2.M.12)*)
Construct representation	Creating complex system models to represent complex relationships between components and systems of life-style relationships, organ structures and plant cell structures	The model describes the taro plant life in a hypoxic environment. For hypoxic plants the presence of air is very important, so, it has an organ with a cortex consisting of chlorenchyma and aerenchyma. Chlorenchyma is indicated by the presence of chloroplast granules, so that, it can photosynthesize and the presence of chlorenchymes that are around the aerenchyma allows the chlorenchyma to supply oxygen to the aerenchymal cells for metabolism. Aerenchyma itself is formed lysogenically due to enzymes produced from ribosomes involving the golgi apparatus, RE and mitochondra as energy supplies (P.1.M.02)*)
Interpret and use representation	Using complex system models for communication tools in argumentation discourse to understand hidden dimensions and retrospectively and predict complex system behavior due to environmental changes in the past and future	The rhizome on the Cyperus grass is a food reserve storage organ, so that, the rhizome cortex has a reserve deviant parenchyma which has amyloplas to form starch. But if the grass has to adapt to the dry environment, it must be an xerophytic plant. As a xerophytic plant, the cortex in plant organs must undergo structural adaptation to be able to store water including allowing once the rhizome, because it stores a lot of starch reserves, can store a lot of water and the cells need a large size as opposed to vacuole enlargement, ...(A.2.M.13)*)

Symbol *) shows a summary of data sources, for example: (A.2.M.13) shows data from reasoning in the argumentation phase by student No. 13

of complex systems. Thus, modeling has facilitated students to think in a complex system perspective and argumentation support helps students find hidden dimensions of complex systems.

Achievement of ability to think about complex systems: The results of one sample t test on the posttest results with a test value of 2.21, showed t (29) = 3.170, $p<0.05$. This shows that the learning intervention using the MRSA Model has an impact on the achievement of the ability to think the system at a minimal level is quite complex as targeted. The complexity of thinking in each aspect of the system's thinking is represented in Fig. 1.

Figure 1 shows that each student's way of thinking in a system perspective is dominated by semi-complex levels and followed by complex levels. This shows that after intervention, students demonstrate system thinking by understanding the relationships between components and systems dynamically, understanding hidden dimensions and thinking temporarily. In each of these components, student are able to demonstrate multi-causal relationships in a semi-complex and complex levels.

Furthermore, to test that thinking ability is the result of system reasoning intervention using multiple representations, the correlation test is used. The results of the system reasoning correlation tests with systems thinking are represented in Table 7.

Correlation test results show a positive correlation between system reasoning using multiple representations with the achievement of system thinking skills. Correlation between reasoning through modeling to construct to synthesize dynamic relationships vertically is significant to the achievement of the ability to think systemically on aspects of dynamic thinking, understanding hidden dimensions and temporal thinking. This indicates that there is strong consistency between the way of thinking in modeling and system thinking. This is also shown in reasoning in understanding the hidden and temporal dimensions that are facilitated by using the model in argumentation. This consistency indicates that students use cognitive experiences during modeling and use models in argumentation to systems thinking.

The research findings indicate direct observation of natural phenomena through concrete representations combined with the empowerment of multiple modes of

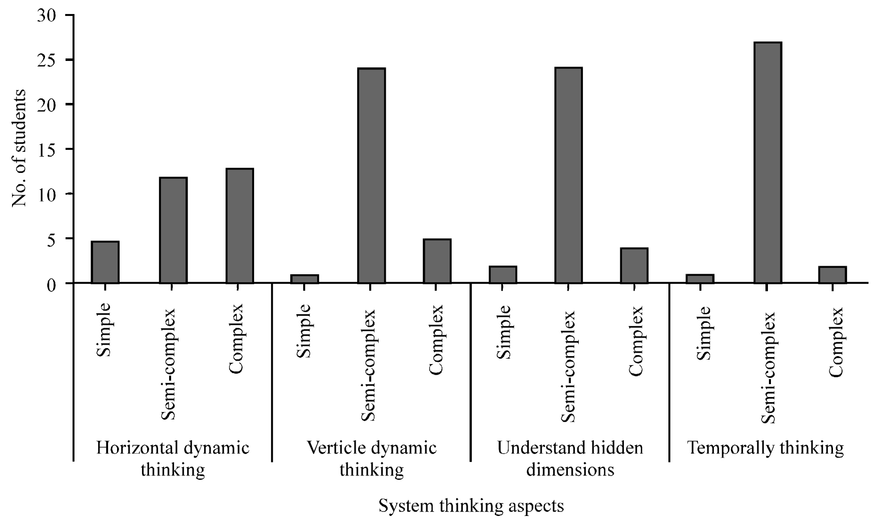

Fig. 1: The complexity of thinking of students in every component of the system thinking

Table 7: The results of the correlation test of system reasoning with systems thinking

	Achievement of system thinking			
System reasoning using multiple representations	Dynamic horizontal thinking	Dynamic vertical thinking	Hidden dimension	Temporal thinking
Component identification	0.399*	0.632	0.300	0.398*
Relation interpretation	0.358	0.709**	0.646**	0.237
Dynamic horizontal	0.467**	0.389*	0.272	0.334
Dynamic vertical	0.406*	0.561**	0.572**	0.394*
Understanding hidden dimension	0.311	0.494**	0.741**	0.357
Temporal thinking	0.325	0.409*	0.674**	0.664**

*p<0.05; **p<0.01

representation and cross-level systems of living organizational life facilitating reasoning about complex systems. A fairly strong correlation of reasoning about basic tissue systems using shared representation modes with the achievement of system thinking shows the consistency of the relationship between experience carrying representational tasks when reviewing basic tissue systems with the system thinking ability. Learning to provide integrated scaffolding with representational tasks stimulates meaningful construction of internal representations (Anderson *et al*., 2013).

The results of this research study indicate representational tasks across systems ranging from natural phenomena at the macroscopic level, basic tissue formation cell structure composing the microscopic level and returning to the macroscopic level gradually through modeling supported by arguments facilitates building knowledge of complex systems gradually. Phasing in learning begins with orienting students with natural phenomena that stimulate students to seek explanations based on a system perspective. The natural phenomenon of concrete representation at the macroscopic level, however, needs to be equipped with other representation modes. This study provides evidence of natural phenomena that are represented concretely at the macroscopic level and is equipped with a hierarchical diagrammatic representation of life organization mode stimulating system reasoning in formulating hypothetical explanations. The hypothetical formulation also shows that the use of these two modes of representation is complementary as well as limiting to using a system perspective in solving problems. This is at the same time as a starting point in starting to think systems through representational work.

Empowerment models with various representation modes provide complementary information and tools in system reasoning. Students use models that are represented in sketch mode, 2/3D images and diagrams as a tool for interpreting the results of microscopic observations and translating the processes that occur in the system and projecting how the dynamics of relationships in complex systems temporally. Based on this, through the model, students are able to identify components that are not observed in microscopic observation due to equipment constraints, interpreting relationships and abstract processes, understanding the dynamics of complex systems and abstracts. This implies empowering the model in system reasoning to help visualize components, processes and relationships between abstract system components (Quillin and Thomas, 2015).

Complex system modeling provides a means for students to connect phenomena at the macroscopic level with the structure of the system at the microscopic level. The loop model was initially introduced when orienting students to handle problems with a system perspective. The model then becomes a framework in modeling. Students visualize the dynamic relationships of components in the system and inter-systems based on the results of the interpretation of the model in the previous learning process. Evidence shows that although, some students are able to create models that represent complex multi-causal relationships between components and between systems, the model has reflected how the dynamics of systems thinking when reconstructing representations. Thus, during modeling, students are involved in understanding complex system abstractions.

The use of models from the results of complex system modeling as communication media in argumentation also has implications for understanding the hidden dimensions of the system. The experience of students in visualizing abstract concepts and scientific content, stimulates students to find components and processes as well as abstract relationships that have not been visualized in the model. This shows the argumentation in the model testing allows students to evaluate the model. On the other hand, the presentation of stand points that are related to the domain of plant adaptation knowledge, encourages students to use a mental model constructed when modeling for temporal thinking about how the adaptation of basic tissue structures works when plants experience environmental changes.

CONCLUSION

Based on the description above, in order to bridge the complexity of representational tasks with system thinking, steps are needed to train them. Learning that involves gradually observing concrete representation activities, representing observations and using models and engaging modeling and argumentation support provides system thinking scaffolding. Cognitive activities such as interpreting, translating, modeling and using a model to solve problems about basic tissue systems that are linked to the domain of plant adaptation through argumentation bridging student to gain systems thinking experience.

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