Complexity of student’s argument in reasoning plant tissue system through multiple representations

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Abstract. Understanding of pre-service Biology teachers about the structure system of complex plant tissue represented a modest reasoning ability, by doing so, it needed an effort to develop that skill. Training the reasoning skill by using multiple representations supported by argumentative explanations played an important role in understanding complex systems. Nevertheless the existing learning tools were limited to worksheets facilitating learning to understand the concepts of using external representations. The aim of this study was to examine whether instructional support by utilizing multiple representations can help students constructing their reasoning argument framework about complex systems. This study involved 30 pre-service biology teachers, which studying tissue plant system using multiple representations. The data in reasoning argument framework about complex systems were obtained using worksheets, developed according to multi-representation pedagogy and hierarchy of system thinking. The research findings showed that most of the students were able to construct complex, complicated argument frameworks. The use of multiple representations could provide benefits for students obtaining evidence to support complex relationship claims within the system.

1. Introduction
A useful way to increase botanical literacy is to encourage students to link plant structures in the environment [1]. In addition, there are other ways, such as facilitating students to explain the relationship between molecular and cellular mechanisms to the changes and structure of crop structure functions as the effect of plant interactions in the environment [2], and allow students to explain, predict, and solve biological phenomena in complex systems [3]. But, there are some obstacles which faced by the students in order to understand the complex system incoherent. Many complex system features consist of relationships between system elements and abstract processes that occur simultaneously making it difficult for students to develop a coherent understanding in depth. These conditions have already made troubles for the students to elaborate their coherent understanding deeply [4-6]. In addition, it also causes students’ difficulties in understanding the characters and lines of the abstract system, and makes a linear thinking in connecting natural phenomena at the macroscopic level to a dynamic system with a microscopic level [7-9].

The use of external representations has been applied to understand the biological system [10, 11], such as the representation of abstract phenomena towards cell system and climate change [12], facilitating the tracking and predicting complex system behaviour [5], and providing a scaffolding
toward students’ ways of thinking about interconnection system [13]. But, it’s also reported that the use of multi representation couldn't give mass contribution for the students to understand the complexity [5]. In other hands, the use of multiple representation to figure out the complex system could give cognitive load to the students [14, 15]. At the same time, it is also stated that the students lost a chance to develop the behavioral component, dynamic and complexity system [16].

The use of effective multi representation needs a productive class plan, the right learning support, and well-design learning tasks [17]. Based on the description above, there is a need for various representation arrangements understand the complex system of plant structures coherently. The pedagogical affordance framework of multiple external representations [17] needs to be adapted for designing learning tasks in accordance with the system thinking hierarchy [18]. In understanding the components, behaviours, dynamics, and complexity of plant structure systems with multi representations require representational skill to interpret, explain and make representations [19]. And, because of a clear relation between the skill of constructing reasonable arguments with representational skills [20, 21], therefore this study is conducted to examine how the students’ argument structure in making reasoning about complex plant structure system by using multi representation.

2. Method
The participants of this study were 30 pre-service Biology teachers who attended a course program of the structure of plant development at one of the universities in Central Java. The lectures were designed using Multiple Representation Supported Argumentation (MRSA) models [22]. The curriculum was also designed to explore development of basic and vascular tissue systems with evolutionary and ecological plant anatomy lens.

The data of this research was the reasoning argument structure in analysis, synthesis, and retrospection and prediction of plant tissue system [23, 24]. The data collection was done by assessing student's answer at the students’ activities sheet with following criterias: simple if arguments have one premise and one claim; complex if arguments have two or more premises supporting a single claim); and complicated if arguments have two or more premises to support two or more claim [25]. In this case, student worksheets include the parenchymal structural relations unit and organ function, mechanical tissue structure relationships and adaptations, adaptation of vascular tissue structures, and the diversity of epidermal tissue structures have been validated by experts [22].

The reasoning activity about tissue system using multiple representation on the worksheet has done in order to hypothesize the relation between macroscopic phenomena and the system structure at the microscopic level, to interpret the relation of structure and function of the system components at the microscopic level, to synthesize the dynamics of the complex relation components within the system (horizontal coherent), to synthesize dynamism complex component relation at multiple levels system (vertical coherent), as well as implementing system knowledge to retrospectively and predict the system as a result of interaction with the environment in the past and the future [18, 23, 24]. Then, the data was analyzed to explain the patterns and the development of an argument structure in reasoning about the tissue system.

3. Results and discussion
The quality of argument structure showed how the reasoning work used by students coordinated data and evidence which obtained during interaction with multiple representations had supported the claims. The result of complexity data analysis and development of a work-based argument structure with multi-representation is presented in Figures 1 and Table 1. Based on Figure 1, we can see that in conducting reasoning of complex systems, some students have been able to present data-backed claims as well as evidence and guarantor. It can be said that students have been able to reason with the plant tissue structure system that integrates the plant anatomical domain with evolution and ecology.
Figure 1 also shows that students still had difficulties to hypothesize the relation between natural phenomena at the macroscopic level presented and concrete representation mode with the system structure at the microscopic level. The complex development of argument structures in various units shows a less consistent pattern, as presented in Table 1. The student’s difficulties in hypothesizing the relation of complex system allegedly due to the difficulty of using internal representation, which were the knowledge scheme of plant structure already possessed, with the external representation of the macroscopic nature phenomenon. The previous research also showed the students had difficulties in explaining the abstract relation which was found in the system [6]. Thus, concrete representations can be used to present natural phenomena in orienting the problems, but it requires other representations which can complement the concrete representations as pedagogical actions to hypothesize relationships between systems in complex systems.

Table 1. Comparison argument complexity on each reasoning about plant tissue system at each learning unit.

| Variable | Par. | Mech. | Vasc. | Epid. | F   | p    | Mean Configuration |
|----------|------|-------|-------|-------|-----|------|-------------------|
|          | Mean | SD    | Mean  | SD    | Mean| SD   |                   |
| HPS      | 2.83 | 1.33  | 1.83  | 0.41  | 2.17| 0.41 | 3.17              |
|          | 1.72 | 1.754 | <0.05 |       |     |      |                   |
| RSF      | 1.83 | 0.41  | 3.83  | 1.47  | 4.50| 0.84 | 4.83              |
|          | 2.32 | 5.900 | <0.01 |       |     |      |                   |
| CH       | 12.50| 0.84  | 7.67  | 1.03  | 6.00| 1.10 | 5.33              |
|          | 3.01 | 20.882| <0.01 |       |     |      |                   |
| CV       | 6.33 | 1.63  | 4.33  | 0.82  | 4.67| 1.03 | 4.33              |
|          | 3.93 | 1.107 | >0.05 |       |     |      |                   |
| RP       | 3.83 | 1.17  | 4.00  | 1.10  | 4.67| 1.03 | 4.00              |
|          | 0.429| 0.429 | >0.05 |       |     |      |                   |

Note: Par = relation of parenchyma structure and organ function; Mech = relation of mechanical tissue structure and adaptation; Vasc. = adaptation of vascular tissue structures; Epid. = the diversity of epidermal tissue structure; HPS = proposed a hypothesis about the system; RSF = synthesizes the relation of structure-function components system; CH = synthesizes dynamic relation within the system or horizontal coherent; CV = synthesizes dynamic relation between systems or vertical coherent; RP = retrospect and predict the structure system.
Reasoning in synthesizing the structures relation and component system function, as shown in Figure 1, shows that over 69% of students were able to present two or more premises to support claims and more than 17% of students were able to create two or more claims supported by several premises. It shows the complexity of reasoning used by students. As presented in Table 1, the students’ reasoning complexity in synthesizing structural relation and component system functions have consistently shown improvement. In order to synthesize the relation, the students have done the mastery of microscopic structure of cell constituents with guided diagrams and photographs, they also identified the structure and sketch the observation and then infer the relationship of structure and function. Based on this, it was claimed that the use of concrete representation-drawing diagram -photograph followed by modeling microscopic structures could facilitate reasoning system.

Figure 1 also shows the complexity arguments in reasoning the synthesizing dynamic relation within a tissue system or horizontally coherent. More than 60% of students argued complex categories, and 30% categorized as arguments were complicated. It has been said that students should use several images that represent the various structures and types of tissue constituent cells to build several premises that support complex claims. However, as presented in Table 1, the reasoning for the synthesis of dynamic relationships within the system shows a consistent decrease in line with the increasing complexity of the type and structure of the cells in each tissue. It indicates that students need other representations to help integrate the interpretation of some images.

Based on the complexity of argument structure, as presented in Figure 1, students’ reasoning in synthesizing dynamic relationships between systems or vertical coherence over 90% of students shows complex and complicated patterns. The complexity of the argument's structure shows the consistency of each unit. This can be said that pedagogical action on worksheets instructed students to build a system-level relationship model at the organism level with the system structure at the microscopic level in the image diagram mode. It also facilitated students to create an internal representation of the complex dynamic relation.

Students’ argument structure pattern in retrospect the explanation of the tissue structure system due to interaction with the environment in the past, and predicting the tissue structure system in the future on average shows more than 65% of complex type and 23% more complicated type. The percentage of students with complicated argument structure was increasing and followed by decreasing of simple argument structure. This indicated that the repetition of reasoning for temporal thinking in subsequent units in learning has implications for the increased complexity of reasoning, although the increase is insignificant. Based on this, pedagogical action on the worksheet that instruct the student reflects the model had implications on the use of knowledge about the dynamics of the system to solve the system relationship problems with the environment in the past and future.

Based on the findings, the study provided an overview in the development of teaching materials that facilitates representational task-based inquiry to promote reasoning about complex systems. Representational tasks on several representations of the tissue structures presented in concrete-drawing diagram-photographs mode, facilitate students to identify, interpret and infer the explanation of complex systems. The evidence of the complexity of argument structures on the reasoning of structural relationships and functions of system components, dynamic relationships within the system and between systems, and temporal thinking suggested that students benefit in building premises to support claims about complex systems. This was because the system features are clearly represented in favor of using the knowledge domain to understand the relevance of these features to the reasoning domain of the desired system [26].

Representational tasks on various static representations on the worksheet should be equipped by the modeling representational activity. Based on the pattern and structure of the argument, reasoning about complex systems involving modeling shows complexity patterns to a level of complicated with high frequency. The development of reasoning complexity also indicated there was consistency. It’s supported the results of previous research that the students which involved in making representations or modelling had a better understanding than those involved only in representative tasks to interpret and explain representations alone [27], modeling activities can promote model-based reasoning [28], thus
modelling was what needs to be acquired in multi-representation pedagogy to promote reasoning about complex systems, specially focus at plant tissue system with with evolutionary and ecological plant anatomy lens.

4. Conclusion
Student argument in reasoning about plant tissue system using multi representation shows the dominance from the complex argument structure to complicated. Increasing the complexity level of argument structures is consistent in reasoning activities involving representation tasks of relation complex system such interpreting, identifying multiple representations followed by representational tasks modeling complex system relation.

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