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Teacher's questions in project-based learning: the impact on the quality of student's concept map components

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Abstract

Teacher questions are one of the crucial components in developing students' concept maps in project-based learning (PjBL). The study aims to measure the quality of students' concept maps and determine the PjBL stages that accommodate concept map quality using an expanded teacher question. This research was a quasi-experiment with 335 students as participants from five senior high schools. To collect the data, teachers used open questions during the PjBL learning process with three categories: main, standard, and expanded teacher questions. The concept map data were collected from students of Biology. The student's concept map score is calculated based on the achievement of the experts' Concept map. Data were analyzed using Manova. The results showed that teacher questions in the PjBL stage increased the concept map component scores, especially in valid relationships and crosslink, while other components increased, no effect, and decreased. The most influential PjBL stage that accommodates concept map quality improvement is the deciding stage. Hence, our findings supported that the deciding stage of PjBL is the primary stage to improve the quality of students' thinking. The expanded teacher's questions in the study group, the way of collecting data, and the data analysis significantly contributed to the improvement in the quality of students' thinking.

Keywords: Teacher question, Project-based learning, Concept map

Introduction

Project-based learning (PjBL) is widely used from elementary school to university (Hung et al., 2008; Kokotsaki et al., 2016). PjBL is the learning model that aims to improve the quality of the learning process and identifies academic achievement as an authentic product of learning (Bell, 2010; Hung et al., 2008; Kokotsaki et al., 2016; Tsybulsky et al., 2020). PjBL is considered to have a better impact on student achievement than conventional learning (Kinchin, 2019; Kinchin et al., 2019; Tsybulsky et al., 2020). Student learning achievement can be measured using several indicators, such as written tests, performance assessments, or learning output. The learning output in the form of authentic artifacts is highly correlated with the level of thinking skills attained during the learning process (Bell, 2010; Blumenfeld et al., 1991; Helle et al., 2006; Kokotsaki et al., 2016). Learning output from authentic products cannot be separated from learning process (Af'idayani et al., 2018; Quansah, 2018).

The learning process basically is the communication between teacher to student or student to student in the form of questions, statements, and a series of activities related to learning material (Forster et al., 2019). Teacher-to-student interactions in the classroom is carried out with statements and closed and open questions (Albergaria-Almeida, 2010; Forster et al., 2019; Hannel, 2009). Therefore, a teacher's question is vital in engaging students to use their thinking skills. Teacher questions play a significant role in improving the quality of the learning process. They can guide students' thinking and provide critical responses to improve the quality of the learning process (Forster et al., 2019; McDonald et al., 2017; Zheng & Wang, 2019). Open-ended questions typically provide greater opportunities for students to think at a higher level (Forster et al., 2019).

Moreover, open-ended questions stimulate more intense teacher-to-student discussion, facilitating learning new concepts and thinking skills during the learning process (Smith & Hackling, 2016). Hence, the open questions in PjBL encourage students to attain higher thinking skills. Open-ended teacher questions in PjBL are also oriented toward helping students understand the topics to construct output concept map (Bell, 2010; Kokotsaki et al., 2016; Tsybulsky et al., 2020). However, solving the main problem usually requires many open-ended questions by the teacher that are relevant to the stages of student activity in PjBL as expanded teacher questions.

Bell (2010), Helle et al. (2006), Hung et al. (2008), Krajcik and Blumenfeld (2006), Solomon (2003), and Tsybulsky et al. (2020) stated that concept map is an authentic learning product that shows the thinking process through meaningful links compiled by students between two concepts as a student's thought process (Cañas et al., 2017), which have implications for scores expressed as concept map quality (Kinchin, 2000; Maker & Zimmerman, 2020; Novak et al., 1984). The quality of concept map based on the link between concepts as component scores related to students' ideas and thought processes is the result of a learning process that is influenced by the teacher's open-ended questioning in the learning process in the stages of PjBL.

The efforts of students to obtain equal opportunities to solve problems require small groups that facilitate cooperation, which are referred to as collaborative problem solving (CPS) (Griffin & Care, 2014). CPS technically requires more expanded teacher questions to obtain more profound, complex, and significant solutions. The expanded teacher questions trigger the student's thought process to engage with ideas (Smith & Hackling, 2016) from the expanded teacher questioning in PjBL.

Expanded questions might reduce students' working memory, making the learning process easier (Correia & Aguiar, 2019). There are three types of teacher questions in PjBL: main, standard, and expanded. The main question is the core of the problem based on the material. The main question is often difficult to resolve because it is complex and requires a complex recall process, requiring a large memory load. To reduce the memory load requires the expanded questioning, which is referred to as the expansion of the question. The standard question is a structured question that accommodates the activities of teachers and students following the topic studied at the PjBL. The expanded teacher's question uses open-ended questions, with many answers, ideas and solutions. Closed-ended questions are still not advisable as such typical questions do not provide a broad opportunity for students to elevate and expand their thinking skills (Chin, 2006). In addition, the expanded teacher questions spur, conduct, and monitor activities related to bringing up ideas (Razzouk & Shute, 2012).

Teacher's questions in PjBL significantly enhance students' conception and understanding (Turgut, 2008). However, the effect of expanded teacher's questions at each stage of PjBL on students' output has not been clearly explained. The learning output visualizes students' higher thinking skills or achievements. One of the learning output in learning is the concept map (Cañas et al., 2017; Kinchin, 2019). Hence, the research problems relate to how the expanded teacher question in the PjBL stage affects the quality of concept map and which of the PjBL stages best accommodate students' thought processes based on improving concept map component scores via expanded teacher questions.

A concept map is a graphic that illustrates the simplest way to understand material learned (Kinchin, 2018; Kinchin et al., 2019; Plotz, 2019). Constructing concept map requires higher thinking skills (HOTs) (Cañas et al., 2017). Several HOTs required in concept map construction are analyzing, evaluating, and creating skills (Anderson & Bloom, 2001). Concept map is an assessment tool that is used as an instructional technique (Cetin et al., 2016; Novak et al., 1983); in this research, concept map is the assessment tool based on its component score. Concept map also has potential effects on improving the quality of the learning process (Cañas et al., 2017; Kinchin, 2019; Kinchin et al., 2019; Machado & Carvalho, 2020).

Concept map is a visual representation of information and usually has an interconnected proposition between concepts. If the proposition is valid, it is declared a correct relationship. concept map has several components: valid relationship, hierarchy, crosslink, branching, pattern, and example. Each concept map component has a score to assess the concept map constructed by students (Freeman & Urbaczewski, 2020; Novak et al., 1984).

The quality of students' concept maps needs to be assessed based on the link and complexity of conceptual relationships. Meaningful conceptual learning is intended to connect new information to existing knowledge to reconstruct current knowledge (Bergan-Roller et al., 2020; Evrekli et al., 2010). Valid relationship is a crucial aspect of students' concept map quality. This aspect can be utilized to measure students' understanding and the role of the expanded teacher's questions in the learning process.

According to the background, this study has two main objectives. First, measuring the quality of students' concept map components. Second, determining the PjBL stages that best accommodate concept map quality through expanded teacher question.

Literature review

Project-based learning

Project-based learning (PjBL) is a learning strategy that encourages students to create authentic products. The purpose is to solve real-world problems based on the application of various scientific concepts (Barron & Darling-Hammond, 2008; Bell, 2010; Hung et al., 2008; Krajcik & Blumenfeld, 2006; Tsybulsky et al., 2020). Each stage of PjBL requires students' active participation during systematic instruction involving complex real-world problems (Chen & Yang, 2019). In addition, PjBL is collaborative-based constructivist learning with authentic issues, similar to inquiry-based learning (Barron & Darling-Hammond, 2008; Bell, 2010; Boubouka & Papanikolaou, 2013; Kinchin, 2019; Kızkapan & Bektaş, 2017; Krajcik & Blumenfeld, 2006). The learning activities of PjBL are designed to develop ideas or solutions using appropriate problem-solving skills (Razzouk & Shute, 2012). The problem-solving activity during the learning process can improve learning quality through cognitive and social aspects (Scoular & Care, 2018; Goldman et al., 2020).

The concept map is the authentic target learning output of PjBL, which is often too complicated for students to understand. The complexity of tasks exceeds students' working memory capacity, which might disrupt a meaningful learning process (Correia & Aguiar, 2019). An alternative strategy to avoid students' excessive memory capacity is by addressing expanded teacher questions at each PjBL stage. Expanded teacher questions can also help students solve complex problems during the learning process (Nappi, 2017; Tsybulsky et al., 2020).

The complexity of PjBL content and pedagogy is affected by three factors. First, it is necessary to activate students' prior knowledge and experience to solve complex problems (Ummels et al., 2015). Therefore, the teacher should generate a question guide to facilitate students' thinking process. The quality of the teacher's questions depends on the teacher's self-competence in the topic mastery. Questioning is a valuable instructional strategy for teachers to organize and encourage students learning activities (Blumenfeld et al., 1991;

Hannel, 2009). Questioning becomes the central part of communication during learning, even though every teacher has a different teaching style. Second, PjBL is designed to produce authentic products as an artifact of student's thinking process as a concept map (Bell, 2010; Blumenfeld et al., 1991; Helle et al., 2006; Hung et al., 2012; Kokotsaki et al., 2016; Tsybulsky et al., 2020). Third, the authentic product of PjBL is the concept map represents thinking at the end of a learning process that requires self-reliance (English & Kitsantas, 2013). Therefore, to construct a concept map as authentic result of learning, students need the activation of prior knowledge with questions assist activation of knowledge of the PjBL.

The expanded teacher's questions used in each PjBL stage are a bridge to construct the conceptual link students learn while maintaining students' motivation during the learning process (Hannel, 2009; Nappi, 2017). In PjBL, students should be responsible and involved while setting the learning goal to maintain motivation from the beginning to the end. Students' motivation is an influential part of learning to achieve better outcome than other learning factors (Gess-Newsome et al., 2019).

The role of teacher's questions in project-based learning

Teachers often use questioning techniques to engage student curiosity on specific topics, especially during teaching and learning. The other aim of questioning is to assess students' understanding (Nappi, 2017; Ong et al., 2016). Teacher's questions have been an integral part of the learning process and an essential part of the thinking process since Socrates's time (Chin, 2006; Degener & Berne, 2017; Hannel, 2009; Nappi, 2017; Osborne, 2014; Paul & Elder, 2007). Students cannot achieve critical thinking skills spontaneously, instead, they need a sequence of steps in process that includes the questioning stage (Cañas et al., 2017). However, students' responses to teacher questions are often not immediately detected as the teacher's questions exceeds the capacity of their memory load (Aguiar et al., 2019; Correia & Aguiar, 2019). Therefore, it requires expanded and continuous questions conducted at each stage of PjBL during the learning process.

Expanded teacher's questions have the function of attracting students' attention and interest, clarifying doubts or misconceptions about divergent and convergent questions, uncovering and evaluating operational knowledge, revealing metacognitive knowledge, and stimulating students to think critically; questions are not as a punishment tool (Bulent et al., 2016). The questions during learning serve as parts of evaluation and monitoring of students' progress at each learning activity stage, including collaboration, dialog, curiosity, and task management.

The teacher's expanded questions are necessary for students to engage in higher-order thinking skills (Forster et al., 2019). The questions should not be closed-ended to encourage students' thinking processes (Chin, 2006; Forster & Penny, 2020). An open-ended question type allows divergent responses and appreciates dialogue, leading students to use new concepts (Ong et al., 2016; Smith & Hackling, 2016). Thus, the questions should come in a limited number, focus, detail, and be coherent with the main issues.

Teachers' questions and authentic concept map artifacts are two critical components of PjBL (Bell, 2010; Blumenfeld et al., 1991; Kokotsaki et al., 2016). Teacher's questions serve to recall students' prior knowledge (Cañas et al., 2017), organize ideas and possible solutions (Razzouk & Shute, 2012), and aim to reassure the creation of authentic artifacts (Blumenfeld et al., 1991; Hannel, 2009; Helle et al., 2006; Kokotsaki et al., 2016). Therefore, expanded teacher's questions in PjBL are designed to obtain students' responses in solving problems when developing concept map as learning output.

Expanded teacher's questions are essential aspects of the PjBL learning process that has three aspects: proper classroom environment to ask questions, existing experts in their respective fields, and understanding of students' responses (Hannel, 2009). Understanding the requirements of a teacher's question in a learning process is crucial. It plays an important role in monitoring all students' activities to solve problems (Bell, 2010; Ong et al., 2016). Teacher's questions during learning are pedagogic and support students in developing concept map as a learning output. Teacher questions in a learning process are similar to expanded teacher questions, significantly enhancing the thinking process and becoming a significant part of PjBL (Nappi, 2017; Osborne, 2014).

The expanded teacher's questions at each PjBL stage accommodate students' activities, ideas, and solutions while becoming a thinking guide of the traditional practice (Bulent et al., 2016; Cañas et al., 2017; Zheng & Wang, 2019). In addition, the teacher's questions direct cooperation in solving a project that might cover complex problems (Dado & Bodemer, 2017). Solving complex problems requires more questions to help students decode or enrich vocabulary and understand sentences, cumulative knowledge, critical considerations, and distinguishing broader meanings (Degener & Berne, 2017).

Concept map as conceptual product of project-based learning

A concept map is a product of students' conception and mind-mapping ability. The concept is a term that indicates the mental representations of a category of event objects or entities (Jonassen et al., 1997; Novak & Cañas, 2008). Mapping is a diagram that visualizes the hierarchy of knowledge that has been and is being studied (Davies, 2011). The concept map is a learning product that entails an exercise, homework, and assessment related to concept mastery (Briscoe & LaMaster, 1991). Concept map generally consists of one or two words and are top-down diagram that starts from the main topic to a smaller sub-topic followed by an example (de Gomes et al., 2020; Zwaal & Otting, 2012).

The concept map is a graphics (McCabe, 2011; Nesbit & Adesope, 2006) as an authentic concept product that represents students' cognitive skills in higher-order thinking (Cañas et al., 2017; Helle et al., 2006; Novak & Cañas, 2008; Novak et al., 1983; Tsai & Huang, 2002). The concept map is an integrated classification of knowledge built from primary and special questions or references (Kinchin, 2000; Novak & Cañas, 2008). Teacher questioning at the learning process stage becomes a trigger to connect the concepts learned. The concept map diagram represents students' mind-mapping that allows for externalization and exploration of their conceptual understanding of the given topics (Atkinson et al., 2019; Hay, 2007; Hay et al., 2008; Jonassen et al., 1997; Novak & Cañas, 2008).

The concept map can be used as an instructional technique or assessment in learning (Cetin et al., 2016; Kinchin, 2000, 2020). Concept map, as instructional technique or assessment has a difference in learning application. Concept map as an assessment tool in PjBL is related to accommodating students' conceptual products (Davies, 2011). Concept map assessment can be used as a standalone assessment or combined with other evaluation methods (Maker & Zimmerman, 2020) because a concept map cognitively and comprehensively describes the topic but does not describe students' performance (Mukhopadhyay et al., 2019). The use of concept map in learning depends on the target and learning objectives. The concept map is a graphics used to assess students' learning achievement and requires experts' judgment (Freeman & Urbaczewski, 2020; Novak et al., 1984).

Methods

This study followed a quasi-experimental research design. The subjects involved 335 high school students from five senior high schools in Central Java, Indonesia. The selection of the school samples used purposive random sampling by considering the biology teachers' ability based on working experience. Each school had control and experimental groups with balanced student abilities based on paired F tests from the end-of-semester scores. Table 1 shows the number of participants from each school involved in this study.

Before the study, teachers participated in the Focused Group Discussion (FGD) about the PjBL instructional strategy with the researcher to develop a standardized PjBL lesson plan. The instructional monitoring process in the classroom was based on Forbes (2011) and modified according to each PjBL stage. The evaluation result of the implementation

Table 1 The participants of the study

Number of participants	Schools					Total
	1	2	3	4	5	
Control	32	32	36	32	35	167
Experiment	32	32	34	34	36	168
Total	64	64	70	66	72	335

of lesson plan created by the teacher during the FGD showed that teachers' achievement and eligibility ranged from 85 to 98%. The teacher achievement and eligibility percentage adapted to Inquiry Scoring Rubric for Lesson Plan (Forbes, 2011).

The instructional process in control and experimental groups was to use PjBL in all schools using PjBL with the teacher's main question posed as a problem: "How is the *Marchantiophyta* classification of life?" The teacher used open-ended questions to guide learning in the control and experimental groups. However, expanded questions after the main and standard questions were given to the experimental group, while the control group only received the main question and the standard question from the teacher.

The school has control and experimental groups. The teacher's experimental class in the first school conducted an expanded teacher question only on the planning stage, planning an investigation process according to the driving question, while the next four stages used standard teacher questions. The teacher at the second school used an expanded question to search for the theoretical background (searching stage), while the planning, presenting, deciding and evaluating stages of PjBL used a standard teacher question. The teacher at the third school used expanded questions in presenting that theoretical background to the class and discussing the issue (presenting stage), while the first, second and fourth and fifth teachers used standard question teachers. The teacher at the fourth school used the expanded teacher question in deciding the study group (deciding stage), while the planning, presenting, and evaluating stages of PjBL used the standard teacher question. The teacher at the fifth school used expanded questions in evaluating data, concluding, presenting the project in class, and discussing the PjBL stage (evaluating stage), while the planning, searching, presenting and deciding stage teachers used standard questions. The main, standard, and expanded teacher questions for the control and experimental groups in each school are shown in Figure 1.

Figure 1 shows the main, standards, and expanded teacher questions in the control and experimental groups. In the planning stage, the expanded teacher questions were predictive questioning and inference. The searching stage used a combination of probing, inference, and predictive question types. In the presenting and deciding PjBL stages, the teacher used to transfer and reflective questions (Walsh & Sattes, 2011). The expanded teacher questions are composed of open-ended question to engage students in finding the core of the concept (Mishra & Iyer, 2015).

The learning objective was to group plants into different divisions based on their general characteristics. The *Marchantiophyta* classification was selected as the learning topic of this study because it emphasized conformity with the targeted concept map as an authentic product, with learning objectives and grouping by their characteristics, so that it looks organizational, hierarchical and creates a good concept map example graphically (McCabe, 2011; Nesbit & Adesope, 2006).

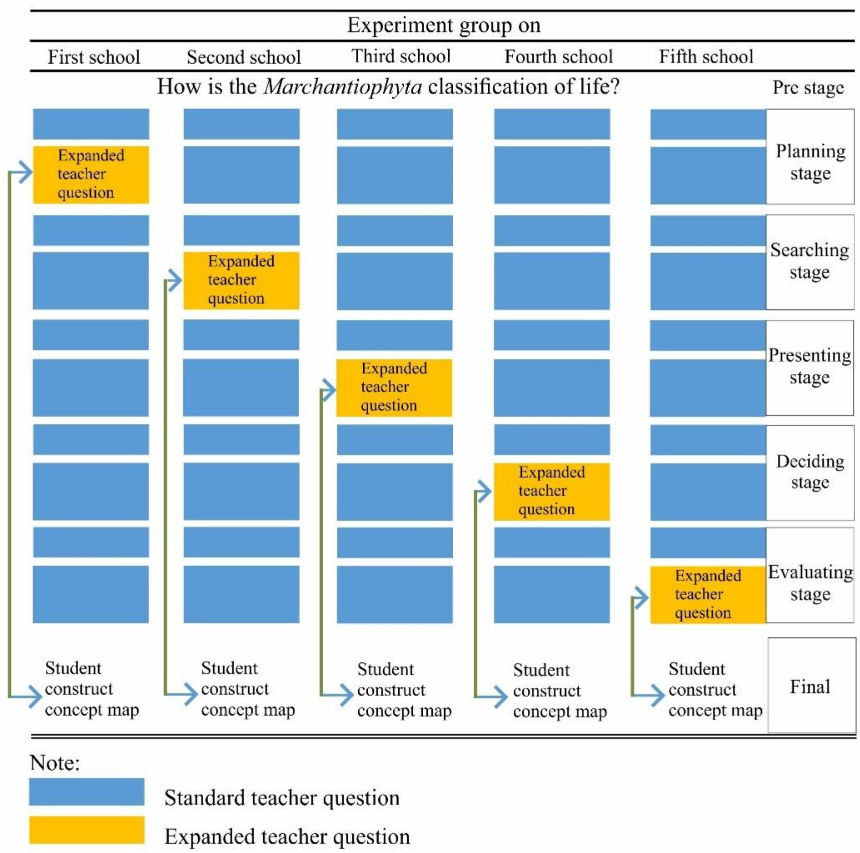


Fig. 1 The application of main, standard, and expanded question

The main question is, "How is the *Marchantiophyta* classification of life?" The allocated time for the classroom was 180 minutes. After the classroom session, students were required to create a concept map as independent homework based on the teacher's concept map example (Sellmann et al., 2015). The deadline to submit the assignment was 24 hours from the class discussion.

The questioning technique used by the teacher in the experimental group is to provide standard questions and expanded questions for each activity in each stage of PjBL. Meanwhile, the control group was only given standard questions.

Table 2 shows the main, standard, and expanded teacher's questions in each PjBL stage during the classroom session. The main and standard teacher questions are related to learning problems for the control and experimental group. The expanded teacher's question is used only in the experimental group class with open-ended questions.

The concept map experts in this study used using the *CMap Tool®* as concept map maker software. Figure 2 illustrates the ideal concept map components. Each concept map component can be evaluated using the concept map link of components scoring criteria.

Table 2 Examples of the main, standard, and expanded teachers' questions

PjBL stages	Sample questions		Question type
	Control group	Experiment group	
Pre stage	How is the *Marchantiophyta* classification of life?	How is the *Marchantiophyta* classification of life?	Main question
Planning an investigation process according to the driving question	What is the problem formulation that is the target to be studied?	What is the problem formulation that is the target to be studied?	Standard question
	How do you plan to investigate *Marchantiophyta* based on scientific rules related to the formulation you want to learn?	How do you plan to investigate *Marchantiophyta* based on scientific rules related to the formulation you want to learn?	
		Do you need to make the group more effortless for you to observe?	Expanded question (1st school)
		What do you need to prepare to create a working group for observing activities?	
Searching for the theoretical background of the driving question	What should you do to find information based on the formulation of the problem?	What should you do to find information based on the formulation of the problem?	Standard question
	What do you need to observe to classify *Marchantiophyta* based on problem formulation?	What do you need to observe to classify *Marchantiophyta* based on problem formulation?	
	How do you seek relevant information to support your activities?	How do you seek relevant information to support your activities?	
		What kind of information do you need?	Expanded question (2nd school)
		How do you get the information you need?	
Presenting the theoretical background to the class and discussing about the issue	Do all the traits you find to match the literature you read?	Do all the traits you find to match the literature you read?	Standard question
	How do you share your findings?	How do you share your findings?	
	What are the characteristics of the *Marchantiophyta* based on observed species and literature studies?	What are the characteristics of the *Marchantiophyta* based on observed species and literature studies?	
	Can you find similarities and differences between the characteristics of the *Marchantiophyta* species?	Can you find similarities and differences between the characteristics of the *Marchantiophyta* species?	
		What can be done to group mosses based on their similarities and differences in the characteristics you observe?	Expanded question (3rd school)
		Can you display in a schema that grouping these traits?	

Table 2 (Cont'd.)

PjBL stages	Sample questions		Question type
	Control group	Experiment group	
Deciding the study group, the methods of collecting data and data analysis	What do you learn from observations on the characteristics of *Marchantiophyta*?	What do you learn from observations on the characteristics of *Marchantiophyta*?	Standard question
	How do you decide whether the species you observe belong to the same group?	How do you decide whether the species you observe belong to the same group?	
	How to learn about *Marchantiophyta* easily?	How to learn about *Marchantiophyta* easily?	
	What can you make of one trait related to another?	What can you make of one trait related to another?	
		Are there any traits that all the species you observe?	Expanded question (4th school)
		Are there any similar features in the species you observe?	
Evaluating data, concluding, presenting the project in class as preferred, and leading discussion	Is there a shortage of an example of a concept map presented by one of your friends?	Is there a shortage of an example of a concept map presented by one of your friends?	Standard question
	Can you create a better concept map from your friend's presentation example?	Can you create a better concept map from your friend's presentation example?	
	Can you perfect the sample concept map your friend has created?	Can you perfect the sample concept map your friend has created?	
		Can you relate the characteristics of the species you observe?	Expanded question (5th school)
		Group the characteristics of the species you read in the literature and the ones you observe.	

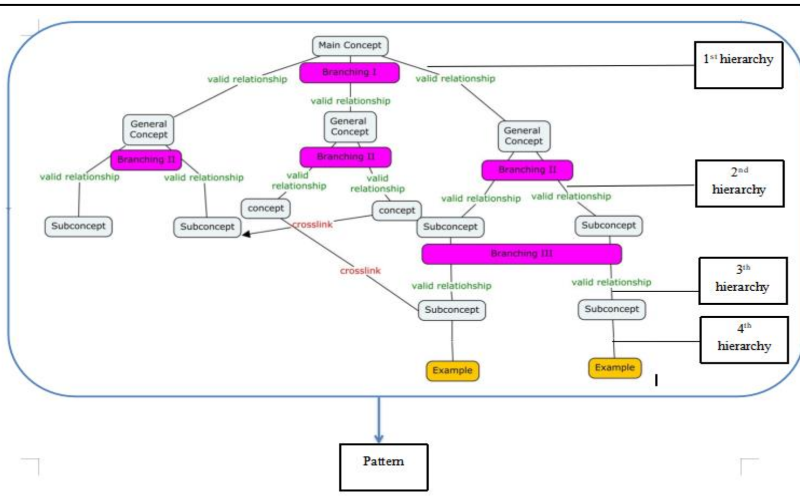


Fig. 2 Concept map components (Novak et al., 1984)

Table 3 Scoring of concept map components

No	Concept map components	Score for each component*	Number of possible components	Maximum score
1	Valid relationship	1	299	299
2	Hierarchy	5	5	25
3	Branching			
	• 1st level	1	1	1
	• 2nd level	3	3	3
	• 3rd level	3	3	3
	• 4th level	3	3	3
4	Pattern	5	1	5
5	Crosslink	10	104	1040
6	Specific example	1	80	80
	Total	29		1359

**Scoring criteria refer to Glime (2006)*

There are six concept map components whose count is based on concept map experts. Standard scoring refers to Maker & Zimmerman (2020) and Novak et al. (1984). The component concept map experts in this research have a score shown in Table 3. The percentage of concept map component score is based on the total component concept map expert (see Appendix).

The score of the students' concept map component is evaluated based on a comparison with the concept map expert (Furtado et al., 2019). The material organization refers to the characteristic of *Marchantiophyta* by Glime (2006). The final score is calculated using the following formula:

$(students\ concept\ map\ components\ score / maximum\ score)$ x 100%.

Data were statistically analyzed with Manova test using SPSS 24 for Windows.

Results

Concept map quality as a result of expanded teacher question

Concept map quality based on the component link of concepts as a score is an effect of the expanded teacher's questioning in PjBL. It was analyzed using multivariate analysis of variance (*Manova*). The normality and homogeneity tests were conducted as perquisites for the Manova statistical test. Table 4 and Table 5 show the normality and homogeneity test results for the average concept map component scores of the students.

According to Table 4 and Table 5, the data of concept map components score was normal and homogeneous. Therefore, the study data met the requirements of the Manova statistical analysis. Table 6 shows the average concept map component score in the control and experimental groups, the results of the Manova statistical analysis and the results of the *least significant difference* (LSD) test.

Table 4 The result of normality test for concept map component scores

Components	Groups	1st stage	2nd stage	3rd stage	4th stage	5th stage
Valid relationship	Control	0.001	0.002	0.014	0.011	0.001
	Experiment	0.099	0.016	0.004	0.000	0.099
Hierarchy	Control	0.000	0.000	0.000	0.000	0.000
	Experiment	0.000	0.100	0.000	0.000	0.000
Branching	Control	0.000	0.000	0.000	0.000	0.000
	Experiment	0.000	0.000	0.000	0.000	0.000
Pattern	Control	0.000	0.000	0.000	0.000	0.000
	Experiment	0.000	0.000	0.000	0.000	0.000
Crosslink	Control	0.000	0.003	0.353	0.000	0.015
	Experiment	0.250	0.071	0.007	0.000	0.000
Specific example	Control	0.040	0.000	0.000	0.000	0.000
	Experiment	0.000	0.000	0.000	0.000	0.000

*The significance level of data normality is <0.05

Table 5 The result of homogeneity test for concept map component scores

Components	1st stage	2nd stage	3rd stage	4th stage	5th stage
Valid relationship	0.058	0.615	0.127	0.064	0.058
Hierarchy	1.000	0.100	0.247	0.095	0.071
Branching	0.159	0.100	0.233	0.195	0.043
Pattern	0.066	0.100	0.247	0.095	0.071
Crosslink	0.050	0.000	0.149	0.111	0.825
Specific example	0.065	0.014	0.126	0.189	0.236

*The significance level of data homogeneity is >0.05

Table 6 The result of LSD and Manova statistical test

Components	Groups	LSD test*					Manova test**
		1st stage	2nd stage	3rd stage	4th stage	5th stage	
Valid relationship	Control	13.33^{a}	13.91^{a}	20.21^{a}	15.52^{c}	13.33^{ab}	0.00
	Experiment	26.13^{b}	27.37^{b}	25.29^{d}	20.18^{b}	26.13^{a}	0.038
Hierarchy	Control	59.41^{a}	61.87^{a}	78.89^{a}	88.75^{b}	72^{c}	0.00
	Experiment	60.62^{a}	61.87^{a}	90.30^{b}	92.94^{bc}	64.44^{a}	0.00
Branching	Control	72.81^{a}	72.81^{b}	94.14^{bc}	90.62^{c}	87.14^{ed}	0.00
	Experiment	72.81^{a}	72.81^{b}	100^{c}	94.70^{d}	73.33^{be}	0.00
Pattern	Control	59.41^{a}	61.87^{a}	78.89^{b}	88.75^{c}	72^{d}	0.00
	Experiment	60.62^{b}	61.87^{a}	90.30^{c}	92.94^{d}	64.44^{a}	0.00
Crosslink	Control	18.04^{a}	19.71^{a}	23.31^{b}	7.51^{c}	11.18^{d}	0.00
	Experiment	29.34^{b}	47.98^{b}	27.15^{c}	33.38^{ba}	39.15^{ba}	0.00
Specific example	Control	9.59^{a}	4.88^{a}	13.99^{c}	9.57^{ab}	7.55^{ab}	0.00
	Experiment	6.12^{b}	6.60^{b}	14.09^{c}	10.11^{c}	5.70^{acd}	0.00

**The different notation (a, b, c, d) indicates the significant differences in the scores*

***The significance level of the Manova test is <0.05*

Table 7 Concept map components gap percentage of control and experiment group

Components	Effect on PjBL stages					Total*		
	1st stage	2nd stage	3rd stage	4th stage	5th stage	+	0	-
Valid relationship	+	+	+	+	+	5	0	0
Hierarchy	0	0	+	+	-	2	2	1
Branching	0	0	+	+	-	2	2	1
Pattern	+	0	+	+	-	3	1	1
Crosslink	+	+	+	+	+	5	0	0
Specific example	-	+	0	+	-	2	1	2
Total						19	6	5
Percentage (%)						63.3	16.7	20

* The effect of teacher question on concept map component score: increasing (+), no effect (0), and decreasing (-)

Based on the Manova test in Table 6, the expanded teacher's questions significantly affect the students' concept map component scores at all stages of PjBL (<0.05). Further testing was conducted to reveal gaps between the control and experimental group in each stage of PjBL using the LSD test.

The statistical analysis showed a significant effect of the expanded teacher question on the score of students' concept map components in the control and experimentation groups in all PjBL stages. Significant improvement can be clearly observed in the Valid relationship and Crosslink components in all PjBL stages. The other components of concept map were categorized as increased, no effect and decreased (Table 7). Additionally, Table 7 shows the PjBL stages in which it is easiest for the concept map scores of the students to increase using the expanded teacher question.

Effect of expanded teacher question on PjBL stages

Learning activities in the PjBL stages are student interactions with expanded teacher questions. The changes that occur because of the expanded teacher questions are increases, no effect, and decreases. Table 6 shows the resulting gap in the LSD test interpretation to determine the effect of expanded questions on students' concept map components in the PjBL stage.

The LSD test result between the control and experimental group in Table 6 shows all concept map components at all PjBL stage. As shown in Table 7, in deciding stage, all concept map component increased except example component. Three concept map components increased during the searching stage of PjBL (valid relationship, crosslink, and specific example), and three components has not affected (hierarchy, branching, pattern). The concept map component in the planning stage was classified into three cases: increased (valid relationship, crosslink, pattern), no effect (hierarchy, branching) and decreased (specific example). All concept map components except valid relationship and crosslink are decreased in the evaluating stage.

Based on data analysis, there are two perspectives. First, the concept map component and the expanded teacher questions in PjBL can result in increased, no effect and decreased concept map components. Second, the PjBL stages have different responses to expanded teacher questions to produce different concept map outcomes.

Discussion

The effect of the teacher's question on the concept map component quality

Using the expanded teacher questions in the PjBL stages can result in three different categories of student concept map quality: increased, no effect, and decreased (Table 7). Concept map quality is calculated based on the link of a significant component as a valid relationship (Gowin & Novak, 1984; Kinchin, 2000; Kinchin et al., 2000; Liu et al., 2005; Maker & Zimmerman, 2020; Novak, 1990). All concept map components are valid relationship as propositions (Zimmerman et al., 2011) except the pattern component. The concept map is a graphic built from valid relationship links (Nesbit & Adesope, 2006). The valid relationship link in the concept map component shows the organization of knowledge, which is one of the cognitive outcomes of the learning process (Bell, 2010; Canas et al., 2015, 2017; Kinchin, 2019; Kinchin et al., 2000, 2019; Taheri et al., 2016), so the quality of concept map ultimately depends on valid relationship.

The results showed that the expanded teacher questioning at the stage of PjBL increased concept map component quality by 63.3%, had no effect on 16.67% and decreased the quality by 20% (Table 6). The link quality of concept map components improved in all PjBL stages, such as valid relationship and crosslink. The pattern component increased in the planning, presenting and deciding PjBL stages. The concept map components hierarchy and branching increased in the presenting and deciding stages. At the same time, the example component increased only in the searching and deciding stages. The expanded teacher questions in the PjBL stages varied to produce meaningful links in the concept map component except in the valid relationship and crosslink component links.

Expanded teacher question to valid relationship and crosslink

Valid relationship and crosslink are two concept map components whose link scores increase in all stages of PjBL with expanded teacher questions. Valid relationship is a relationship of concepts through meaningful links (Kinchin, 2000; Kinchin et al., 2000; Novak et al., 1983, 1984; Reiska et al., 2018; Zimmerman et al., 2011) that are propositions (Novak et al., 1984; Reiska et al., 2018; Zimmerman et al., 2011). Crosslink is valid relationship that has links in different hierarchies (Novak et al., 1984; Zimmerman et al., 2011). A concept map is a graphic (Nesbit & Adesope, 2006; Sharma, 2007) that is composed of propositions and has the components valid relationship, crosslink, branching, hierarchy and pattern and example (Canas & Reiska, 2018; Kinchin, 2000; Kinchin et al., 2000; Liu et al., 2005; Novak et al., 1983, 1984; Zimmerman et al., 2011).

An expanded teacher question is a more detailed question that serves to recall students' prior knowledge (Cañas et al., 2017). Prior knowledge plays a role in improving the links between concepts compiled by students (Liu et al., 2005). Meaningful valid relationship links between concepts are prepositions (Zimmerman et al., 2011). Thus, the expanded teacher questions in all PjBL stages improve students' understandings, which is seen from the increasing components of valid relationship and crosslink. Students' improved understanding of concepts based on increasing prepositions such as valid relationship and crosslink is the quality of the student's concept map.

Expanded teacher questions are a more focused instructional approach (Correia & Aguiar, 2019) because questioning improves thinking processes (Chin, 2006, 2007; Forster & Liu et al., 2005; Nappi, 2017; Osborne, 2014; Penny, 2020). The expanded teacher question in all PjBL stages is an instructional approach that is more focused on constructing valid relationship and crosslink components.

Meanwhile, the link that connects the different hierarchies and a meaningful proposition on concept map is crosslink. The links in different hierarchies show students' deeper thinking ability, greater complexity, and better organization of the topic being studied (Kinchin, 2000; Kinchin et al., 2000). Thus, crosslink, in the case of the *Marchantiophyta* topic, refers to the ability of students to organize *Marchantiophyta* characteristics into a cluster in a specific hierarchy. Based on the meaning of links on crosslinks in concept map, the presence of crosslinks is a better thinking indicator. Reiska et al. (2018) state that crosslink is an indicator of HOTs. Thus, the expanded teacher questions used in the PjBL stages play a role in improving students' thought processes through the ability to organize the characteristics of the genus *Marchantiophyta* in a hierarchy.

Based on justification and calculation, the score for the crosslink component is 10 points for a link (Maker & Zimmerman, 2020; Novak et al., 1984). Crosslink has a significant role in the total scores because the links are different (Maker & Zimmerman, 2020; Novak et al., 1984). Based on the links between concepts on different hierarchies, those are better than the improved quality of concept map. The crosslink component shows improvement in all stages of the PjBL, which means that expanded teacher questioning is an instruction that is more focused on improving concept map quality. Unfortunately, the increase in links between valid relationship and crosslink, which resulted in changes in concept map quality caused by expanded teacher questions at all PjBL stages, had an unequal effect on other concept map component links.

The links of the other concept map components can stagnate and decrease, thus requiring an assessment of other factors. The factor that affects the quality of concept map related to instruction, which is more focused on the form of the expanded teacher questions, is teacher competence. Teacher competences are interacting and communicating (Hindman et al., 2019) and applying Technological Pedagogical Content Knowledge (TPACK) (Harris & Hofer, 2011; Mishra, 2019).

TPACK related to the expanded teacher questioning is pedagogy (Correia & Aguiar, 2019; Harris & Hofer, 2011; Koehler et al., 2011, 2013; Mishra, 2019). Pedagogy is a complicated matter because it involves students' external and internal factors. External factors are related to government policies regarding the knowledge represented in the curriculum at the previous education level, which is prior knowledge. Meanwhile, prior knowledge is needed for students to build links to meaningful learning (Canas et al., 2015; Reiska et al., 2018). Thus, the quality of concept map in the topic of *Marchantiophyta* cannot be separated from students' prior knowledge and the teachers' competence to assess prior knowledge.

Bergan-Roller et al. (2018) stated that meaningful learning is when students can connect their prior knowledge with a particular topic. Meanwhile, teachers' knowledge and competence, especially expanded teacher questions, determine the quality of the concept map. Variations in student prior knowledge and teacher competences using expanded teacher questions in the PjBL stages cause the link constructions that students build to link the components. Thus, even though valid relationship and crosslink are concept map components that increase at all stages of PjBL, several other concept map components are stagnant and decreasing.

Expanded teacher question to pattern

Pattern is a concept map component that increases in planning, presenting, and deciding stages of PjBL. Pattern is a component that is a concept map structure (Gowin & Novak, 1984; Hay, 2007; Novak et al., 1984; Ummah et al., 2019). Pattern is a component that supports concept map structures in the form of radius, net, and chain (Gowin & Novak, 1984; Hay et al., 2008; Kinchin, 2000; Kinchin et al., 2000; Liu et al., 2005). The increase in the pattern component in the planning, presenting, and deciding stages is due to a change in the structure of all links in the valid relationship, crosslink, branching, and hierarchy components (Liu et al., 2005). The concept map structure shows the depth of the topic studied (Kinchin, 2000; Kinchin et al., 2000). Thus, the expanded teacher question in the PjBL stages affects the depth of the topic studied.

However, changes in the structure pattern of concept map that is built from valid relationship, branching, hierarchy, and example (Liu et al., 2005; Tan et al., 2017) have meaning in link changes in all concept map components. The changing structure of concept map has implications for the number of links between concepts in concept map components. The links between concepts in the concept map components are constructed from the relevant prior knowledge (Cañas et al., 2017). Thus, expanded teacher questions as more focused instructions can change the thought process through the number of links in the concept map component that change the depth of the topic being studied. Finally, pattern is a concept map structure that changes as a result of modifications in the thinking process through instruction, which is more focused on the form of expanded teacher questions in the planning, presenting, and deciding stages.

Expanded teacher question to hierarchy and branching

Hierarchy and branching are concept map components that increased only in the presenting and deciding stages of PjBL. Hierarchy shows many levels of concept map that students construct. Hierarchy visualizes students' skills to organize general concepts into specific concepts (Novak et al., 1984; Schroeder et al., 2018). Hierarchy can be established if students group the same characteristic at a certain level. Meanwhile, branching is a branch that shows students' ability to distinguish the characteristics of *Marchantiophyta* (Borda et al., 2009). Branching is the effect of the student's ability to organize a feature of *Marchantiophyta*. Thus, the concept map components in the form of hierarchy and branching on the topic of *Marchantiophyta* are related. Branching is a grouping of the same *Marchantiophyta* characteristics at the same level, while hierarchy indicates the student's ability to group different levels of the topic of *Marchantiophyta*.

Marchantiophyta is one of the topics used to study classification in the plant world that has a genus to species. This species is an example of the topic of *Marchantiophyta*. Hierarchy denotes a level that refers to the level at the genus to species level (Glime, 2006). Components hierarchy and branching at all PjBL stages have the same link change pattern, meaning that components hierarchy and branching are two concept map components in the topic of *Marchantiophyta* that are interrelated. Thus, the expanded teacher question in the presenting and deciding PjBL stages changed the organization of the *Marchantiophyta* characteristics at the level of its classification.

Expanded teacher question to specific example

Example is the smallest part of the concept map unit that shows an example. An example of component example on the topic of *Marchantiophyta* is a species in the genus *Marchantiophyta*. Component example in concept map is the smallest part of *Marchantiophyta*, which is a species. Thus, the link showing the example component in concept map is the student's ability to find the most specific explanation (Anohina-Naumeca, 2016) or species found in the surrounding environment as the smallest part of a concept map.

Example is the concept map component that increases only in the searching and deciding stages. Example is the link of the concept map component that decreased the most in the PjBL stage. Example increases in the searching and deciding stages. Relating to the example component link as an example of the species that have experienced the most decline or the most difficulty to increase is since *Marchantiophyta* is a topic that aims to classify plants ranging from the genus to species level (Glime, 2006), which is a wide distribution location (Baker, 1883). The widespread nature of plants makes it difficult to detect their existence in the environment around students. Limited existence in the environment around student life affects the construction of knowledge that requires observable phenomena/data (Gunckel, 2010). Thus, the problematic increase in component example is due to the limitation of the existence of those species belonging to the genus *Marchantiophyta*.

The limitations of the species of *Marchantiophyta* in the environment are not a major problem since the source of knowledge from the references allows it to be used. However, the main problem that needs to be solved by students is "What is the classification of *Marchantiophyta* of life?" Based on the main question, the position and location in life become very natural. If it is not found in life, it is not written in example in the concept map built by the student.

The effect of expanded teacher question on each PjBL stages

The PjBL stages have different responses to expanded teacher questions. The response of the PjBL stages that accommodate the improvement of concept map quality through more focused instructional use in the form of expanded teacher questions in the PjBl stage from the best to the lowest is found in the 4th, 3rd, 1st, 2nd and 5th PjBL stages. Thus, the variation of the response from the instructional focus in the form of an expanded teacher question to build a concept map component link is the result of a combination of the cognitive activities of students in the PjBL stages and the expanded teacher questions.

PjBL uses open-ended questions that are adjusted to the stage of cognitive activity of students in the different PjBL stages (Turgut, 2008). The main question and standard in the PjBL stages is instructional design (Joyce et al., 2008). The expanded teacher question in the PjBL stages is a more focused instructional approach (Correia & Aguiar, 2019) because it is an extension of the standard questioning that becomes a bridge of thinking (Zheng & Wang, 2019), which plays a role in reducing the memory load in solving problems (Aguiar et al., 2019; Correia & Aguiar, 2019).

Instructional questions that are more focused in the form of expanded teacher questions in the planning stage are included in predictive questioning and inference questions. The searching stage used a combination of probing, inference, and predictive question types. The presenting and deciding PjBL stages use knowledge transfer and reflective questions. The last stage of PjBL used diagnostic and reflective questions (Walsh & Sattes, 2011). Expanded teacher questions adjusted to cognitive activity in the PjBL stages become the basis for differentiating expanded teacher questions at each stage of PjBL. Differences in expanded teacher questions result in variations in the response of links between concepts in the concept map component.

The 4th PjBL stage accommodates the improvement of all concept map component links. Deciding the study group stage, the method of collecting data and data analysis is the most responsive PjBL stage to change the student's thought process. PjBL stages that show students' cognitive activity through collaboration with their group are known as CPS (Griffin & Care, 2014), which entails cooperation between members to obtain data and analyze data, organize ideas and solutions (Razzouk & Shute, 2012), and build authentic artifacts (McCabe, 2011; Nesbit & Adesope, 2006).

Student CPS activities are carried out by sharing experiences, prior knowledge, and ideas to produce authentic learning outcomes in the form of concept map (Bell, 2010; Helle et al., 2006; Hung et al., 2008; Krajcik & Blumenfeld, 2006; Solomon, 2003; Tsybulsky et al., 2020). The topic is "How is the classification of *Marchanthiophyta* of life". The deciding stage is the core of PjBL because concept map component links are optimal for all concept map component links.

However, the deciding stage is a learning process activity that improves the quality of learning through cognitive and social aspects (Goldman et al., 2020; Scoular & Care, 2018) through student cooperation activities in CPS. Griffin and Care (2014) and Zheng and Wang (2019) state that cooperation between students in groups improves students' critical thinking skills. At the same time, critical thinking is included in HOTs. Thus, the instructional approach that focuses on expanded teacher questions in the deciding stage results in increased student thinking processes and social skills.

Instead, the evaluating stage is to evaluate the data, conclude, and present the project in class and discussion. It is a less responsive stage for link-building concept map components other than valid relationship and crosslink. The last stage of an instructional design is usually a monitoring activity for mastery of the topic being studied (Joyce et al., 2008), which is an understanding of the classification of *Marchanthiophyta*. Meanwhile, concept map about genus *Marchanthiophyta* is a graphic (Nesbit & Adesope, 2006) as a learning outcome (Bell, 2010; Tsybulsky et al., 2020) using PjBL, which is accompanied by a more focused instructional approach in the form of expanded teacher questions.

Concept map students about the genus *Marchantiophyta*, and all the links between concepts in all components, are identical to the material (Canas & Reiska, 2018; Liu et al., 2005). Thus, the last stage of the PjBL focuses on expanded teacher questioning, not as a part of the student constructing the concept map component link but monitoring the student's understanding so that the concept map component other than valid relationship and crosslink decreases.

An expanded teacher question is a type of question that serves as a thinking bridge for students. The breadth and depth of questions are adjusted to the learning conditions to provide space for students' thinking processes. Through expanded teacher questions, students are encouraged to do CPS as a vital part of learning to share ideas, experiences, and prior knowledge needed to build concept map. Future research should explore the various types of expanded teacher questions and their impact on students' CPS.

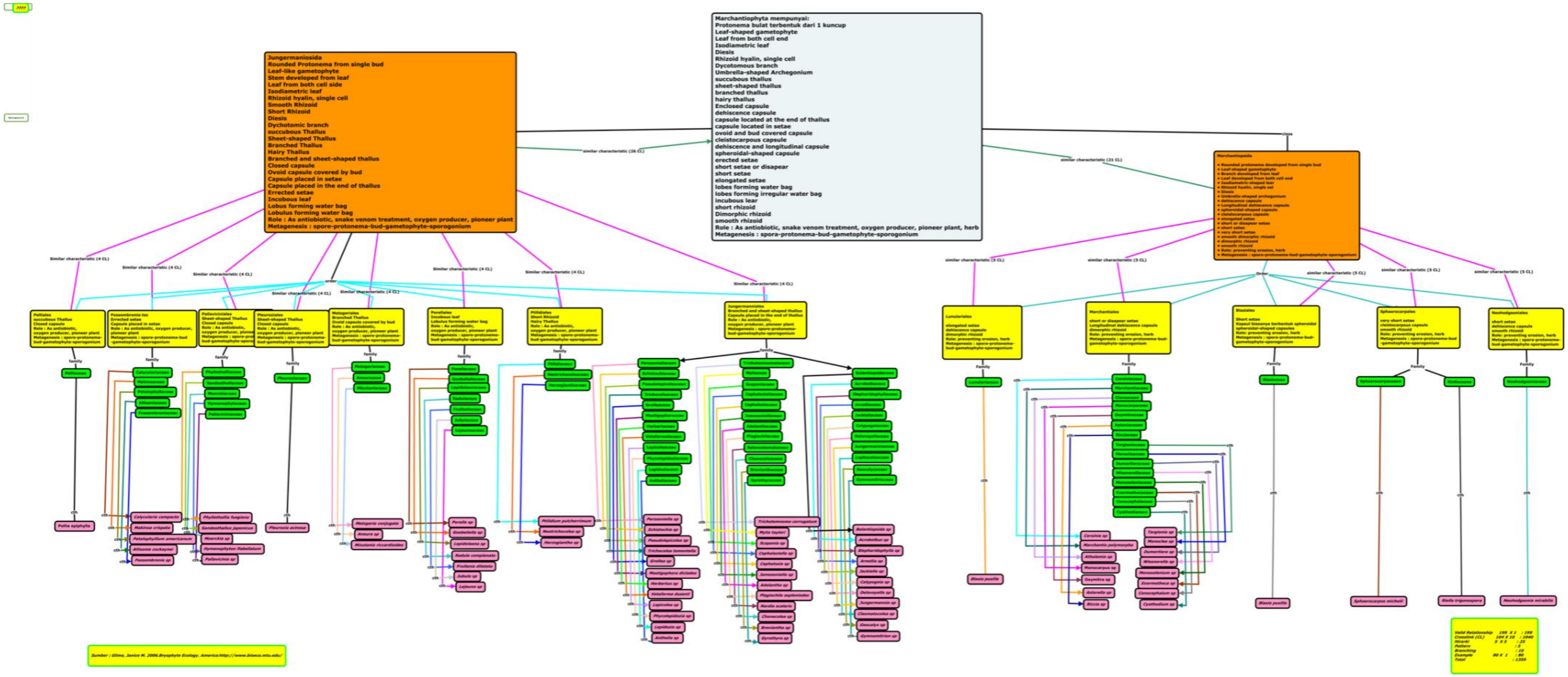
Conclusions

The quality of the concept map is determined by meaningful links between all components referred to as propositions that are valid relationship. The increase in valid relationship and crosslink at all stages shows that the quality of concept map is improved by using expanded teacher questions at all PjBL stages. The increased scores of valid relationship and crosslink indicate a better thinking process. It is identified from the concept map structure that shows a deeper mastery of the concept of the *Marchantiophyta* topic as pattern, but the links supporting the hierarchy and branching components in the classification of *Marchantiophyta* topics have the same pattern of change in the PjBL stage. The variation in links on concept map components in the PjBL stage is not an indicator of decreasing concept map quality because the concept map quality supported by concept map components may decrease or stagnate in certain concept map component links. The improvement of concept map quality through a more focused instructional process with expanded teacher questions changed the thinking process in all PjBL stages because of increasing valid relationship and crosslink in all PjBL stages. Changes in better thinking processes followed changes in social skills due to CPS activities, thereby increasing all concept map component links to decide on study groups and methods of data collection and analysis. The improvement of the concept map component score indicates that the deciding stage is the most critical stage for building concept maps.

The limitation of this study is that the expanded teacher question cannot be generalized to all learning models. Further study is needed regarding the expanded teacher question on other learning models to determine the impact on the concept map.

Appendix

Sample model of expert concept map for *Marchantiophyta* topic



Abbreviations

PjBL: Project-based learning; HOTs: Higher-order thinking skills; CPS: Collaborative problem solving; FGD: Focused group discussion; LSD: Least significant difference; TPACK: Technological pedagogical content knowledge.

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Authors' contributions

SW developed the framework and methods of the study. CAP conducted the data analysis. NH collected the data. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author, SW, upon reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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