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Development of metacognitive skills on the implementation of EAQD-PC models-learning journals in biology learning

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Abstract*:* Metacognitive skills are important because they help people develop an understanding of effective strategies. This skill also helps improve one's critical thinking and creative thinking so as to be able to overcome problems in everyday life. The purpose of this research is to train students' metacognitive skills through biology learning using the EAQD-PC learning model (acronym of exploring, analyzing, questioning, defining-peer coaching) which is integrated learning journals (LJ). This research was conducted at the University of Muhammadiyah Bone, South Sulawesi, Indonesia. Using a quantitative research design, 43 students were taught by EAQD-PC-LJ. Metacognitive skills were tested with an essay test three times. Previous essay tests were validated by expert raters and tested on previous batches of students to measure empirical validity and reliability. All tests are valid and reliable. The results of the treatment showed an improvement in students' metacognitive skills through three tests. The findings of this study prove that EAQD-PC-LJ is effectively used to improve students' metacognitive skills through the learning process. Learning journals have an important role as a tool to train students' mastery of concepts and knowledge.

Keywords: EAQD-PC model; learning journal; metacognitive skills

Introduction

People who are able to survive and thrive in the era of knowledge globalization are those who have the 21st century skills, such as critical thinking and creative thinking as a process of metacognition (Dwyer, et al, 2014). Metacognitive skills are the most important life skills for everyone including students to learn effectively (Singla, 2023). These skills, help them be more strategic and find faster problem solving in completing difficult coursework, such as abstract and complex biology content. Students in the era of knowledge globalization must have metacognitive regulation skills such as learning plans, self-monitoring (information management strategies, understanding management strategies and debugging strategies) and self-evaluation (Moritz & Lysaker, 2018). It can also help them sort out information and find suitable jobs in the era of free markets and knowledge globalization (Prasojo & Adinugraha, 2023; Cretu, 2017). Many students do not undertake the development of these skills before being encouraged (Santrock, 2018) and guided by lecturers (Putra, et al., 2024).

It is important to train students' metacognitive skills because they correlate with critical thinking skills (Semerci & Elaldı, 2014). So that it can increase student creativity in using innovative learning strategies (Ramdani, et al., 2021). Metacognitive skills help students know what they already and don't know, as well as help monitor and organize their own learning (Perry, et al., 2018). Elaboration, organization, repetition, and self-questioning skills are important in studying abstract and complex biology, but students do not take them into account (Nurmi, et. al, 2022). Therefore, students must be trained in critical thinking and creative thinking skills so that they have these skills (good metacognitive skills) (Wilis, et al., 2023). Thus, metacognition must be integrated into curricular components and learning strategies (Pradhan & Das, 2021).

Many previous studies have been conducted to improve students' metacognitive skills. This can be an effective teaching strategy to help students develop and control their own learning process (Singla, 2023). The results of research by Asy'ari, et al., (2022) illustrate that students' metacognition awareness is still in the category of quite good (1.33 < MA≥ 2.33) and low (MA ≤ 1.33). The results found that students' metacognitive awareness in 4 (four) schools in the Central Lombok region showed 6.15% in the very good category; 32.31% in the good category; 51.15% is categorized as quite good, 10.39% is categorized as bad. Students' overall metacognition awareness on each indicator was in the poor category with an average percentage of students' metacognitive awareness of 35.66%. These results illustrate that teachers have difficulty directing the student learning process and take a long time to train students' metacognitive awareness (Sukaisih & Muhali, 2014). The results showed: 1) The development of metacognitive abilities of students of the Department of Biology Education has not been optimal, which develops new metacognitive knowledge, especially aspects of declarative knowledge, 2) The age of students does not correlate with the development of metacognitive abilities, but there is a tendency that this variable contributes to aspects of metacognitive regulation 3) the variable of interest (study program) also has no impact on the metacognitive development of students, but partially, Biology Study Program students have better procedural knowledge, on the other hand, Biology Education Study Program students have better conditional knowledge (Paidi, et al, 2013).

The goal of undergraduate education is to educate individuals to know if they can perform tasks and be responsible (Cho & Kim, 2020). Students' consciousness and metacognition are still in the low category. This has an impact on their interest and motivation to learn. Thus, metacognition must be integrated into learning, especially metacognitive regulation known as control which refers to a person deliberately directing his thinking (Miller, 2017). This is expected to encourage students to plan, monitor and evaluate their own learning and learn independently. The implementation of the EAQD-PC integrated learning journal in this study can meet these expectations and train students to become metacognitively skilled in independent learning.

The goal of undergraduate education is to educate individuals knowing whether they can perform a task or tasks on their own, to know how to successfully solve a task or problem, who knows how to bring the problem to a conclusion, and for who knows which information should be used functionally in what problem situations, in other words, individuals who know what to do (Keliat, et al., 2021). Metacognitive processes use functional information in different ways in solving problems. Therefore, it is necessary to develop metacognitive skills to help students learn independently. When they try to become independent learners, they use metacognitive thinking and using information important (Djudin, 2018). The purpose of this research is to train students' metacognitive skills through biology learning using the EAQD-PC learning model (acronym of exploring, analyzing, questioning, defining-peer coaching) which is integrated learning journals (LJ).

Method

Research Design

This research is a quantitative design that aims to train students' metacognitive skills in biology learning for biology education students. The sample of this study used one class and 43 students studying with EAQD-PC-JB. The research was conducted for one semester at the University of Muhammadiyah Bone on Plant Physiology material semester 3 of 2022/2023. Learning plans have been created with Exploring, analyzing, questioning, defining and peer coaching (EAQD-PC) learning combined with learning journals. The semester learning plan meets the national foundation of higher education. In simple terms, the learning plan includes: learning materials, graduate learning outcomes and course learning outcomes (CPL and CPMK), learning experiences, assessments (criteria and forms, indicators), learning material modules and slides. The validity of RPS is determined by conducting an expert assessment consisting of instructional and technical reviews (Putra, et al., 2024).

We test students starting at the third meeting and continuing at the eighth meeting to ensure the learning process. In this case, as a study-to-study test that acts as a formative test. This formative assessment serves as a source of information for researchers, whether learning to train students learn to learn (metacognitive skills) in an exploratory, analytical self-inquiry-driven manner to generate understanding. If not, then lecturers must continue to train and provide examples or modeling so that students achieve learning independence and get their achievements. The first exploratory material is the relationship of water with plants which is divided into the nature of water and the importance of water to plants, fusion diffusion and osmosis, both transpiration, guttation and evaporation. The second part is soil as a source of nutrients, the role of microorganisms on the effectiveness of nutrient absorption carried out in one EAQD-PC learning cycle.

Research Subjects and Research Instruments

The subjects of the study were 43 third-semester students of the Department of Biology Education, Universitas Muhammadiyah Bone (UNIM Bone), South Sulawesi, Indonesia. Classes are selected by random sampling. All students involved in the study have expressed their willingness to become participants. This research has obtained permission from the city education office. The metacognition awareness integrated essay test is used to assess students' metacognitive skills. The essay test is accompanied by an inventory metacognition awareness indicator (MAI) which refers to planning, monitoring, and evaluation (Schraw & Dennison, 1994; Amin, et al., 2019). The essay test is prepared objectively with Plant Physiology material including: The relationship of water with plants; transpiration, guttation and evaporation; roots, soil and nutrient uptake; conservation of energy in photosynthesis (light reaction and dark reaction); allocation, relocation and distribution of photosynthetic products; cellular respiration (Rubric can be seen in Table 1).

Table 1. Metacognitive Skills Assessment Rubric

Indicator	score
Answers are written in the redaction of one's own sentences precisely, logically, systematically, analytically, elaboratively and argumentatively as a result of carefully planned exploration	4
Answers are written in the redaction of one's own sentences in an imprecise, logical, systematic, analytical, less elaborative and less argumentative manner	3
Answers are written in their own sentence redactions but are less precise, logical, systematic, less analytical, elaborative and argumentative as a result of in-depth exploration	2
Answers are written not in the redaction of the sentence itself even though it is precise, logical, systematic	1
No answer	0

Adapted from Schraw and Dennison (1994); and Amin, et al (2019)

The essay questions are equipped with an answer key to check the students' answers. Student answers are scored 0-4. Empirical validity and reliability tests of the instrument were carried out through small scale trials on 27 students of the first semester biology education study program at UNIM Bone. The Pearson Bivariate Test has been used to measure test validity. The results of the empirical validity test show valid questions with values of 0.459-738 greater than those in table r 0.437 based on the 0.05 sig test thus all questions are valid. The reliability of the question is also declared reliable based on the Crombach coefficient, the reliability is 0.785, this indicates that the test instrument is reliable (reliable).

Data Collection and Data Analysis

Before treatment, students are taught how to learn to learn exploratorily, analytically, using cognitive strategies (to know) and metacognitive strategies (to monitor) using self-questioning. The first session of learning Plant Physiology using EAQD-PC while giving examples of learning exploratory-analytical learning. The second session learns to document the material in a study journal which is then presented in front of the class. This session is carried out for 50 minutes, then doing peer coaching exercises (in pairs) and finally presenting in front of the class. The test was conducted for evaluation and proved that the learning process with the EAQD-PC model integrated learning journal went according to plan. Answer sheets are corrected and scored with reference to answer key sheets and metacognitive skill assessment indicators. The score given ranges from 0-4. Next, the data is changed to interval scale data. Descriptive statistical analysis techniques are used for data analysis, with a gain score formula to see improvements in students' metacognitive skills.

Results and Discussion

Development of EAQD-PC integrated Learning Journal

Development of EAQD-PC learning tools integrated learning journals to initiate and train the development of students' metacognitive skills. Initial analysis is conducted to identify problems and what it takes for students to become independent learners effectively. This is done to be the basis for making the right learning design design. Learning journals (LJ) are integrated into the first step of the EAQD-PC learning model, which is to orient students to learn by exploring and directly creating learning journals from the results of their respective explorations. Learning journals are created from the results of each stage of learning. The results of developing learning tools and instruments are obtained through validation sheets. The learning path with the EAQD-PC model can be seen in Figure 1.
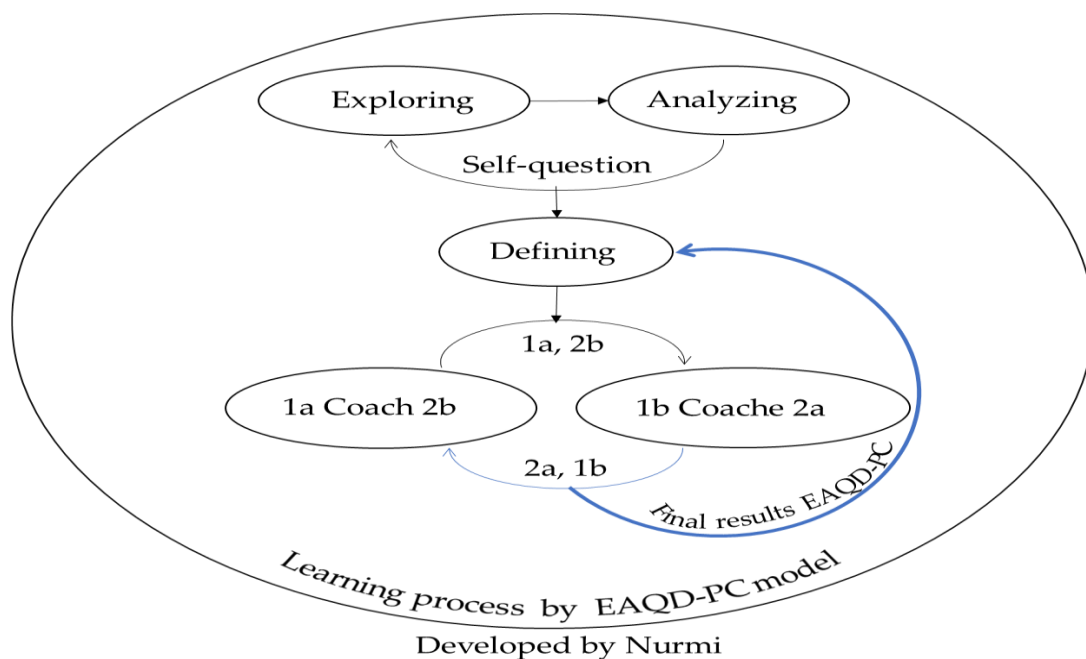
Figure 1. Learning process with EAQD-PC model: First stage: students are encouraged to explore after being given an introduction to learning material, Second stage: analyzing the results of exploration with self-questions (what, why, when, how long and how to do it) which is the third stage; The fourth stage produces a definition of concepts obtained from the first to the third stage; The final stage is peer coaching, at this stage each student trains himself (1a positions himself as the coach and 1b as the coached). This coaching process is carried out by students twice (first coaching themselves, second coaching by fellow friends) the results of each stage are written as a learning journal and at each edited and last edit after the second peer coaching.

The validity of the EAQD-PC-JB instrument to develop students' metacognitive skills, can be seen in the Table 2.

Table 2. EAQD-PC-JB Instrument Validity for This Research

No.	Learning Tools and Materials Plant Physiology	Validity Score	Criteria
1	Semester Learning Plan (RPS)	4,0	Very Valid
2	Learning Modules	3,97	Very Valid
3	Student Worksheets (LKM)	4,0	Very Valid

Based on Table 2, all teaching tools and materials are on valid criteria. RPS, learning modules and student worksheets can be used in learning to develop students' metacognitive skills in biology learning.

Student Metacognitive Skills Profile

The implementation of the EAQD-PC-JB model was carried out in three cycles of 16 meetings. Each cycle of the cycle is carried out four meetings and one formative test. This formative test aims to find out what aspects of metacognitive skills students have achieved after undergoing one phase of EAQD-PC-JB learning. This process is one of the efforts to support the improvement and development of the quality of the learning process. Educational research is expected to find models or strategies or learning methods that are effective in equipping students with 21st century life skills. A 21st century skill that greatly supports the independence of one's life is metacognitive regulation or better known as metacognitive skills, where EAQD-PC is one of the right learning models to train and develop students' metacognitive skills. The learning journal supports and strengthens the implementation of the learning model used in this study. The integration of learning journals into the EAQD-PC model was applied throughout the learning in this study. Data on students' metacognitive skills can be seen in Figure 2.
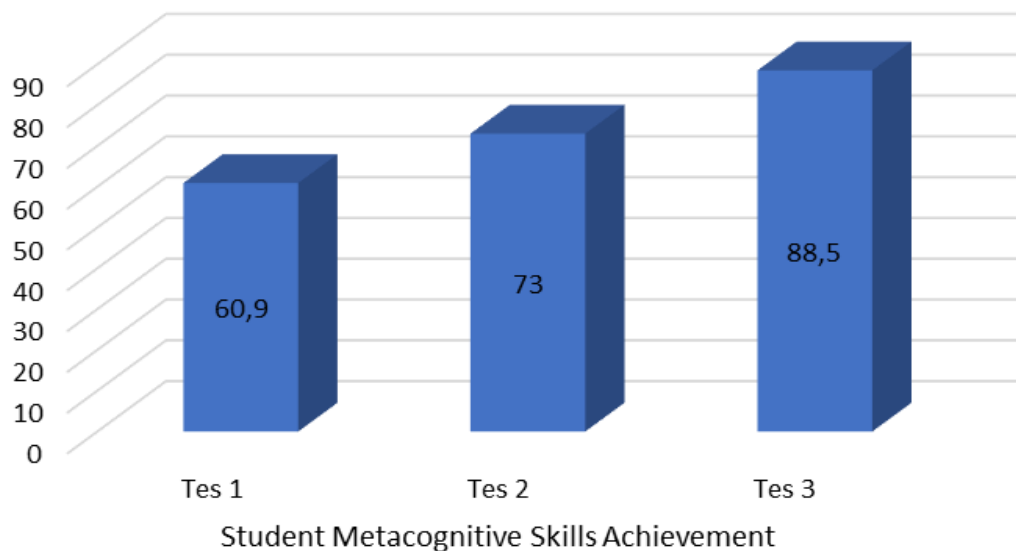
Figure 2. Student Metacognitive Skills Achievement

Figure 2 shows that college students' metacognitive skills improve over time. This data was obtained from the first test with a value of 60.9, in the second test increased after going through further learning with a score of 73, then in the third stage of learning they became more trained in strategic learning so that in the third test their score increased to 88.5. This, illustrates that the model used in this study is effectively used to train students' metacognitive skills.

Student Response to EAQD-PC and Learning Journal

Students' response about their learning motivation using the EAQD-PC learning model and Learning Journal (JB). Their response was taken by asking them to fill out some questionnaire questions. A summary of student response questionnaires can be seen in the Table 3.

Table 3 Student Response to EAQD-PC & Learning Journal

No.	Assessed Aspects	Percentage (%)
1	EAQD-PC	89.29
2	Metacognitive Skills	92.57
3	Learning Journal	97.07
	Average value	92.98

There are several questions asked in the questionnaire, namely EAQD-PC and learning journals, metacognitive skills (self-regulation), learning journals assisted by understanding management strategies. In general, students respond positively and enthusiastically to learning with EAQD-PC. This is shown in the students' response with an average score of 92.98%. Here researchers show some positive responses of students in learning with EAQD-PC assisted learning journals, for example: "*Learning exploratory-analytically with the EAQD-PC model assisted by JB was confused at first, but after being given examples several times, I began to understand and finally I felt engrossed in learning and most importantly this not only guided us to be engrossed in learning but also trained in creative thinking*" *Student 1, "*Learning using EAQD-PC is the most exciting and challenging is when advancing presentations with peer coaching because we have to ask critical questions*" student 2, "*I didn't like exploratory learning at first because I didn't like to read for a long time, then it was written, read again written again, but because this was mandatory then I kept trying to do it and it turned out that finally I realized that learning does have to be this way*" student 3.

However, there are also students who give negative responses, especially students who are bored because of the influence and impression of conventional learning.

"*At first I was interested but tired of writing and reading (lazy to read exploratively)*" *student 4.

Integration of Learning Journal into Exploring, Analyzing, Questioning, Defining-Peer Coaching (EAQD-PC & LJ)

This study examines the effectiveness of EAQD-PC assisted by learning journals in studying biology courses (which are complex). Learning journals and EAQD-PC are integrated in this research to help students improve their learning experience from the results of their exploration (first stage) and the analysis stage together with the questioning stage helps students build reflective thinking. This learning journal is a tool to extend memory and improve learning experiences in the learning process exploratively and analytically. Research on the use of learning journals has been conducted by Jado (2015). However, Jado integrates learning journals (LJ) with self-regulated learning (SRL) and reflective thinking (RT). This research is different from Jado which integrates LJ with self-regulation and reflective thinking, whereas it integrates LJ with learning models. To prove the importance of LJ, we visualized a comparison of LJ-SRL, RT and EAQD-PC integrated learning journals into a Table 4.

Table 4. LJ to EAQD-PC Integration Comparison

No.	Reference	Implementation of learning journals
1	Jado, 2015	Learning journals are created through self-organized learning and reflective thinking without being integrated with a learning model but introducing facilitation of student understanding and conceptualization of relevant learning. Learning journals are used as a tool to record thoughts, reflections, feelings, personal opinions and hopes or fears from experiences during the educational period.
2	Current study	1. Students explore, analyze, use self-questions, so as to produce defining about concepts and make journal presentations learning from each activity. 2. Identify what they already and don't know based on the first stage of activity used to revise the learning journal. 3. Based on activity experiences in numbers 1 and 2 students exercise metacognitive regulation of how they plan, monitor and evaluate their learning independently over time. 4. Students identify and evaluate learning strategies that fit their style.

We implement this integration into semester lesson plans and student worksheets that have been integrated with EAQD-PC to help students practice metacognitive skills. This allows students to have other 21st century skills, such as critical and creative thinking. The process of writing a learning journal accompanies each stage of the EAQD process which is carried out in approximately 45 minutes. Next, their peer coaching stage is done within the next 45 minutes. The enthusiasm of students is very good, but not every class meeting they can maximize because of the many obstacles that cannot be avoided. Although learning journals help students be more reflective and independent in learning (Blaschke & Umuc, 2010), But not all students are aware. Conscious students are always enthusiastic, tend to always be more prepared and active self-study for each class meeting (Growth, 2021). This proactive approach builds a learning space where every student is given the opportunity to develop his or her metacognitive skills.

Impact of EAQD-PC and Learning Journal on Metacognitive Skills

Based on the results of research data analysis, there was a significant improvement in students' metacognitive skills after learning using the EAQD-PC learning model integrated learning journals. This means that there is an influence of the learning journal-assisted EAQD-PC learning model on students' metacognitive skills. Based on the results of the analysis of metacognitive skills of students in experimental classes (EAQD-PC assisted by learning journals) higher than those who only use EAQD-PC alone. EAQD-PC is assisted by a learning journal to teach and provide opportunities for students to learn how to study effectively, the indicators trained are exploring and analyzing using self-questioning of each concept explored (cognitive strategies to know and metacognitive strategies to monitor understanding) (Schraw & Moshman, 1995; Schraw, 1998). The results showed that students were able to self-regulate to learn independently by using metacognitive skills. Students already know what their abilities are, know what they already and don't know. They already use think aloud in exploratory and analytical learning. The findings of this study prove that the integration of EAQD-PC with LJ can improve students' metacognitive skills (Keliat, et al., 2021; Ariyati, et al., 2024; Wilis, et al., 2023). Other research links metacognitive skills to self-regulated learning training (Dignath, et al., 2008).

Metacognitive performance is a skill about organizing, monitoring and controlling one's own thinking as a mental activity that leads people to think higher order and successfully find solutions to problems (Miller, 2017). EAQD-PC combined with learning journals consistently trains students' metacognitive skills. The EAQD-PC model and integrated learning journals train students to learn strategically, critically and creatively so as to provide them with meaningful learning experiences. Metacognitive thinking skills can only be achieved through intensive practice facilitated and with professional trainers (lecturers). Why doesn't our education world see and adopt what is done in the world of sports in educating and training athletes with strict discipline, preparing their respective teams to win games. Why don't educators adopt how soccer players who get hard and intensive training from professional coaches so that they are able to compete with extraordinary skill, intelligence and compactness so as to win the game. The hope of winning the game becomes a challenge and a reason that encourages training very hard and intensively with professional coaches who are paid well. Spector (2016) states the same thing that personalized learning and learning environments that support experiential learning and focus on cognitive processes improve thinking skills (intelligence). Educational institutions, such as schools or campuses for higher education are the most appropriate environment to train students' metacognitive skills, provided that designed with thing aloud culture under the guidance of lecturers (Nurmayani, 2020; Semerci & Batdi, 2015).

The EAQD-PC learning model is a model based on metacognitive strategies (Nurmi, et al., 2022). EAQD-PC trains students to be independent learners because each stage represents a metacognitive strategy, exploring (digging deeper exploring), analyzing means examining information or concepts methodically to obtain explanations and interpretations. Questions have a dual function, first as a cognitive strategy i.e. asking to know, second as a metacognitive strategy i.e. asking questions to monitor their progress (Clark, et al., 2018); help students reflect on their learning experience (Tanner K. D., 2012; King, 1991). Defining is training students to make definitions from the understanding obtained from the previous three stages (exploring, analyzing, and questioning). Results from The previous four stages are developed through peer coaching for feedback and mutual learning (Hornby & Greaves, 2022) and the results of each stage are recorded in a study journal. Many studies have proven the important role of metacognitive skills for problem solving (Güner & Erbay, 2021). Metacognitive skills encourage students to know what they don't yet know, help us plan task completion, monitor progress toward goal achievement and check comprehension (Colbert, et al., 2014). Students who have metacognitive skills are able to recognize their own cognitive abilities, direct their learning independently, evaluate their performance, understand what causes their successes and failures and learn new strategies (Quigley, 2018).

The Role of Learning Journals on the EAQD-PC Model

it was concluded that EAQD-PC integrated learning journals can improve students' metacognitive skills. An example of a student study journal can be seen in Figure 3. Learning journals as a tool used to help students document the results of their exploration and analysis. It is also used to evaluate when and how they are productive in learning, and to engage in critical thinking (Pusparini & Kurniasih, 2020). Learning journals encourage students to be more reflective and action-oriented in their learning. It also helps them realize how to develop their learning experience (Sudirman, et al., 2021). The effectiveness of higher education is measured by critical thinking, reflective, and lifelong self-study skills of its graduates (Blaschke & Umuc, 2010). Learning journals encourage reflective experiences in practice preparing students for lifelong learning in the future. For this reason, educators must prepare students to develop the ability to learn in new and unfamiliar contexts (Akdeniz, et al., 2016).

Writing a learning journal in learning with EAQD-PC provides opportunities for students to develop metacognitive skills to be more optimal because they can understand and direct their own learning process. The revision process, which requires critical thinking about the review and use of strategies for specific tasks presents an ideal opportunity to develop students' metacognitive awareness (Langford, 2015). Writing a learning journal encourages them to explore and analyze by thinking hard using self-questions to be able to produce definitions of the concepts read. The limitations of the architecture of the human mind, especially short-term memory, are the reason for the need for additional learning tools to help information processing train memory: working memory, short-term memory, and long-term memory work according to their respective tasks (MacArthur & Graham, 2016). Students should have knowledge and awareness of strategies such as mnemonic use exercises, content organization, all of which can be mobilized during learning (Colbert, et al., 2014).
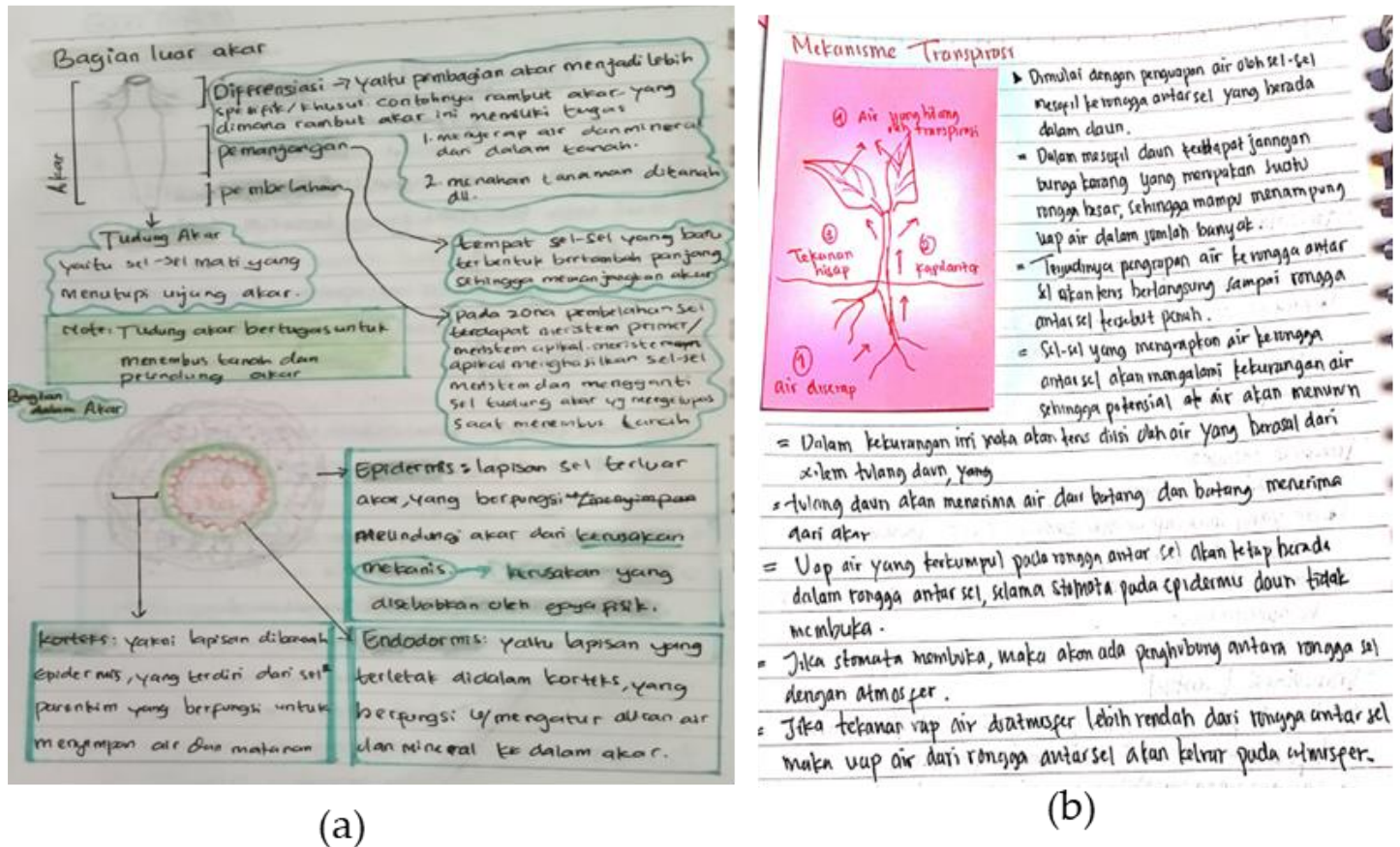
Figure 3. Student learning journals that describe their line of thinking about the process of transpiration through leaves, xylem vessels as water channels that are absorbed from the soil by the roots to meet the demands of needs in the leaves. Figure (a) Students draw root organs and transport vessels. Figure (b) drawing and elaborating the mechanism of transpiration.

Conclusion

The result of this study was an improvement in students' metacognitive skills. These findings suggest that EAQD-PC integrated learning journals can train and improve students' metacognitive skills during the learning process and in the process of writing their learning journals. Improvement of metacognitive skills occurs in the learning process because the EAQD-PC model is integrated in learning journals consistently and continuously trains students' exploratory, analytical, (self-questioned) thinking skills. Exploratory and analytical learning that is carried out continuously encourages them to continuously revise their learning journals. In addition, the EAQD-PC integrated learning journal trains students to realize what they already and do not know from the learning content they learn. EAQD-PC integrated j trains students self-monitoring skills. Learning journals help students monitor and evaluate their own progress. This integrative model also acts as a tool to solve learning difficulties. EAQD-PC helps students identify their competency development after they have repeatedly presented study journals.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

N. Nurmi: Study design, data collection, statistical analysis, preparation of manuscript; **H. Susilo:** Corresponding Author, Study design and data collection; **I. Ibrohim:** Study design and data collection; **S. Suhadi:** Data analysis, Preparation of manuscript, proof reading, and submission of manuscript.

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