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Representation Skills of Students with Different Ability Levels when Learning Using the LCMR Model

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Abstract

The current study aimed to assess the representation skills of biology students with varying degrees of academic ability when they learn using the Learning Cycle Multiple Representation (LCMR) model. The study employed a quasi-experimental design with a pretest-posttest control group, at March to August 2020 at Universitas Pendidikan Mandalika and Universitas Nahdlatul Wathan in Mataram, Indonesia. The study involved 62 sixth-semester students from the Department of Biology Education. The data were collected using eleven essay questions on Plant Physiology. Before administration, the essay questions were subjected to a validity and reliability check. ANCOVA was used to analyze the data at a 5% significance level. The analysis results showed that: a) there was a significant difference in representation skills between students learning using LCMR and those engaged in Learning Cycle (LC); b) students with high ability levels performed better than students with low ability levels in terms of representation skills; c) the interaction between learning model and academic ability levels affected students' representation skills, where the highest score of representation skills was reported by LCMR students with high academic ability, followed by LCMR students with low academic ability, LC students with high academic ability, and LC students with low academic ability. These findings imply that adding MR to the LC teaching model can improve the representation skills of students with varying degrees of academic ability compared with the LC teaching model alone.

Keywords: Academic ability, LCMR, Representation skills

Introduction

Representation skills are vital for learners in the current era of the industrial revolution 4.0. Representation skills are the ability to present information without eliminating the initial information from an object into another form of representation, this can be seen in a person's skills in drawing, making graphs, making tables, and elaborating objects to be simpler so that they can be understood well (Prain & Tytler, 2012); therefore, these skills need to be empowered. These skills assist learners in effectively recording and responding to sensory information, which will be subsequently processed in the brain and seen as an action known as internal representation (Carolan et al., 2008). Representation skills are also defined as expressing, describing, and symbolizing an object in graphic forms, such as graphs, drawings, diagrams, formulas, and others, referred to as external representations (Ainsworth, 2018; Tsui & Treagust, 2013). Representation skills assist learners in comprehending scientific knowledge from a variety of sources. Therefore, representation skills must be developed in every learner at all levels of education.

Representation skills are used to produce, use, reflect, interpret, and explain the fundamentals of an item, process, or mechanism of an entity and translate internal representations into external representations (Kozma & Russell, 2005). Modelling concrete objects in the real world into abstract concepts or symbols are referred to as representation skills. Representation skills include repeating the same concepts in different forms, such as verbal, graphic, and number modes, or expressing the same idea in different formulas (Ainsworth, 2018; Prain & Tytler, 2012).

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University students need representation skills to understand scientific information from various learning sources, such as textbooks, scientific papers, and other internet-based sources (Ainsworth, 2018; Prain & Tytler, 2012). With this information, learners are anticipated to create complex visualizations (Hwang et al., 2007; Kozma, 2003). Someone with good representation skills is distinguished by their capacity to supply others with concrete, efficient, and easily understandable information (Ainsworth, 2006; Schnotz, 2014). Information given through representations can improve the transferability of particular skills to new settings (Prain & Tytler, 2012; Sutopo et al., 2020; Tsui & Treagust, 2013).

According to Anderson et al. (2013), understanding a representation necessitates the following skills. The first step is to read the attributes and elements of a representation. The ability to assess the strengths, limitations, and quality of an external representation style comes next. Interpreting and using an external representation to solve a problem are the third skills. The following skill required is altering an external representation spatially to interpret and communicate a notion. The fifth skill is building external representations to explain concepts or solve issues. The sixth step is to use horizontal translations to translate concepts (Horizontal Translation across Mode/HTM). While translating concepts, a vertical translation (Vertical Translation across Level/VTL) is used to describe multiple organizational levels and their complexity. To comprehend a representation, a person must also envision the order of magnitude, relative size, and scale and translate concepts utilizing representations from different domains (Horizontal Translation across Domain/HTD).

Several research findings indicate that representation skills in college students are not fully developed. These students are still passively compiling representations of complex biological material (Hwang et al., 2007). The ability of these pupils to represent science concepts in other, more understandable forms is still rated as poor (Farida et al., 2010; Utami et al., 2019). Furthermore, university students struggle to generate representations in pictures or graphics for the provided tasks, impacting their learning outcomes (Sumarno et al., 2016). Students with poor representation skills find comprehending and depicting scientific subjects difficult. They cannot provide full information-rich in symbolism, iconography, and words at the macro, micro, and symbolic levels (Tang et al., 2014). Furthermore, they cannot express their ideas and thoughts using photos, graphics, and other symbols (Eilam et al., 2014).

Students' representation skills can be trained by involving them in developing representations (Tsui & Treagust, 2013). In higher education, students' representation skills are developed by creating and discussing concepts about representation. College students should be allowed to expand their knowledge and abilities in representation (Prain et al., 2009)but representational issues entailed in this understanding have not been investigated in depth. This study explored three students' engagement with science concepts relating to evaporation through various representational modes, such as diagrams, verbal accounts, gestures, and captioned drawings. This engagement entailed students (a. To be successful in science education, college students need to understand the link between biology concepts and other scientific domains (Rau, 2017).

Academic ability is significantly related to representation skills (Carroll, 2015). Academic ability is defined as the level of skill demonstrated in educational activities (Laura, 2021). Another school of thought holds that academic ability refers to a student's level of knowledge about a subject. Academic ability is capital for gaining a broader and more nuanced understanding of a concept (Semerci & Batdi, 2015). Academic ability is classified into three levels: high, medium, and low (Visser et al., 2018).

Learning activities must be designed according to student learning characteristics to close the achievement gap between students with upper and lower abilities (Prayitno et al., 2015). Several researchers, including Leasa and Corebima (2016), Noviyanti et al. (Noviyanti et al., 2019), and Maharani et al. (2020), have distinguished research class groups based on their academic ability. Groups of pupils with lower academic ability continue to struggle with mastering the learning material (Rahmat & Chanunan, 2018; Visser et al., 2018). The diverse learning characteristics of students must be accommodated by introducing novel learning strategies, such as multi-representation strategies.

Multi-representation (MR) learning is an approach to achieving learning objectives by utilizing a variety of representations (Hwang et al., 2007). These diverse representations may take the shape of macroscopic, microscopic, symbolic, formulaic, visual, or linguistic representations that reflect students' comprehension of a given concept (Carolan et al., 2008). According to Kozma (2003), modern technology enables students to visualize and improve their comprehension by integrating numerous interpretations into the classroom. Students in higher education generate science concepts through representations suited to their roles, enabling them to interpret, find, assert, process, and construct knowledge (Prain & Tytler, 2012). Organizing knowledge through numerous representations also improves learning quality, as university students build their representations using prior knowledge and information from books or the Internet (Verhoeff et al., 2013).

Biology education uses MR to aid students in developing mental models or internal representations of concepts (Treagust & Tsui, 2013). Tytler and Prain (2012) define MR as a science learning process in which students are trained to express the same topic or process in various ways, including verbal, graphic, and numerical. Additionally, multi-representation can aid pupils' reasoning when comprehending complex topics (Sumarno et al., 2018).

According to Ainsworth (Ainsworth, 2008a), MR can be particularly beneficial when learning complicated new concepts. MR is a component of cognitive development processes, as the utilization of several types of representation is one of the features of human intelligence (Eilam et al., 2014). Students can use and manipulate MR in various ways, which improves their comprehension (Wong et al., 2011). Multi representational strategies can help students develop their competence, tenacity, critical thinking, and representational skills (Carolan et al., 2008). Multi-representation involves students in a thinking process (Anderson et al., 2013). Clément and Castéra (2013) explain that students do not create their representation models but instead use pre-existing ones, one of which being Learning Cycle 5E.

The Learning Cycle 5E (LC) is a constructivist-based learning model in which students are taught to build new ideas on top of their existing ones (Belapurkar, 2017; Namgyel & Bharaphan, 2017). The LC process comprises five stages, beginning with "E," namely engagement, exploration, explanation, elaboration, and evaluation (Belapurkar, 2017; Ong et al., 2018). Each stage has tasks that might help pupils develop their ability to construct knowledge. This instructional model enables students to learn in real life by empowering them to take ownership of their education, learn by experience, and transfer knowledge to others (Bıyıklı & Yagcı, 2015).

LC assists educators in facilitating efficient learning (Duran & Duran, 2004). This paradigm, which is based on structural methods and cognitive psychology, can be utilized in science education to increase the quality of student practise (Bybee et al., 2006). LC enables educators to conduct a series of relevant activities to develop the critical thinking skills of university students (Bevevino et al., 1999). Additionally, the utilization of LC can assist students in understanding science topics, correcting inaccurate or insufficient knowledge, delving deeper into concepts, and adapting classroom learning to their daily lives (Açisli et al., 2011; Özbek et al., 2012). Campbell (2006) asserts that the 5E learning cycle in the classroom promotes constructivism, conceptual transformation, and inquiry learning.

While LC has numerous advantages, it has one disadvantage: the absence of teacher oversight during several stages of learning (Snajdr, 2011). As a counterbalance to this LC's deficiency, multi-representation is an option. More precisely, it is explained that during the exploration phase, the lecturer can assign students to activities or procedures (Bell & Odom, 2012). These activities assist students in conducting investigations and enhancing their capacity for information exploration. The learning by MR can be used with the LC phases, beginning with the second E, exploration.

Plant Physiology is a subfield of botany concerned with studying how plants live (Hopkins & Hüner, 2008). Plant Physiology is the study of the physiological processes of plants throughout their life cycle (Taíz & Zeiger, 2010). Plant Physiology is distinguished by its abundance of information in illustrations, visuals, symbols, and words. As a result, Plant Physiology instruction must be organized around a constructive learning approach that supports students' psychomotor skills, including representation skills. As a result, it is preferable to include representational learning activities that align with the learning objectives of the Plant Physiology material during the exploration phase of MR. At this stage, college students will be trained to use MR strategies to meet the predetermined learning indicators.

According to the description above, this study combined Learning Cycle (LC) and Multiple Representation (MR) to form Learning Cycle Multiple Representation (LCMR) to aid students in acquiring complicated biological concepts (Ainsworth, 2008a; Sumarno et al., 2018), such as Plant Physiology. As a result, it is necessary to examine the effect of the LCMR model on students' representation skills in biology. This study was aimed to determine the impact of the LCMR model on the representation skills of university students with varying levels of academic ability compared with the LC model alone. The hypotheses of this study are: there is a difference in students' representation skills as a result of the implementation of a particular learning model in the classroom; there is a difference in students' representation skills as a result of academic ability; and there is a difference in students' representation skills as a result of the interaction between the learning model and academic ability

Method

Research Design

This study used a quasi-experimental pretest-posttest only control group design, using the 2 x 2 factorial (Table 1). The treatment consisted of 2 types of learning called factor A, namely the Learning Cycle Multiple Representation/LCMR (A1)

Table 1: Factorial 2x2 quasi-experimental pretest-posttest only control group design

	Learning Model (A)	
Academic ability (B)	*LCMR (A1)*	*LC (A2)*
High (B1)	A1B1	A2B1
Low (B2)	A1B2	A2B2

Note:
A1B1 : High academic ability LCMR model
A1B2 : Low academic ability LCMR model
A2B1 : High academic ability LC model
A2B2 : Low academic ability LC model

model and the Learning Cycle/LC (A2) model. Furthermore, as a moderating variable, academic ability is referred to as factor B, namely high academic ability (B1) and low academic ability (B2). The dependent variable in this study is the ability of representation.

Participants

The present study involved 62 biology education students in semester 6 at Universitas Pendidikan Mandalika and Universitas Nahdlatul Wathan Mataram, West Nusa Tenggara, Indonesia. The experiment was conducted in the even semester of the 2019/2020 academic year. Participants were randomly assigned to an experimental and a control group. The experimental group consisted of students from Universitas Pendidikan Mandalika exposed to LCMR (Learning Cycle Multiple Representation). In contrast, the control group consisted of students from Universitas Nahdlatul Wathan who were exposed to LC (Learning Cycle) learning.

A test was used to measure the participants' academic ability. The examination consisted of five essay questions in general biology. The participants' test scores were ranked from highest to lowest. Individuals were divided into two groups based on their test scores: those with high and low academic abilities. There were four groups of treatment: LCMR with a high level of academic ability, LCMR with a low level of academic ability, LC with a high level of academic ability, and LC with a low level of academic ability.

Data Collection Tools

The participants' representation skills were measured using an instrument adapted from Anderson et al., (2013). The instrument contained nine indicators and 11 essay questions on Plant Physiology (Appendix B1). Prior to the use, the instrument had been tested for validity (construct and empirical) and reliability. Two experts from Universitas Negeri Malang, Indonesia, participated in the construct validation: a lecturer with a doctoral degree in educational technology and a professor title in biology education. The appropriateness of material with the assessment rubric, the production of the assessment rubric, the layout of the questions, and the use of language are aspects of the instrument's evaluation. The average construct validity score is 4.27 (valid), while the average reliability score is 91.68 (highly reliable).

Meanwhile, the instrument's empirical validation was conducted by administering a representation-skills test to 32 students in semesters 6 and 8 from the Department of Biology Education, Universitas Pendidikan Mandalika. They have studied plant physiology in the previous semesters. Students who took the test had been told that they would be asked to answer questions that were suitable for their ability level. The test lasted two sessions of 45-minute each in a classroom. The results showed a strong correlation between each test item and the total score, where the correlation coefficient falls within the valid category (0.36-0.65). In addition, Cohen's Kappa analysis showed that the instrument's reliability was high, with correlation coefficients between 0.429 and 0.683.

The rubric used to score the participants' test answers is the representation ability rubric from Hwang et al. (2007), which was modified by Lengkana et al. (2020)which is the selected technique randomly. The research instrument used the pretest- posttest to know the students' mastery concepts and representation skills improvement and questionnaires to identify students' learning styles. The design used was a nonequivalent pretest-posttest control group design. Data of students' concepts mastery and representation skills in the form of pretest-posttest and n-gain analyzed using ANCOVA and Least Significant Difference Test (LSD, which has five levels of the score (1-5): very good (5), good (4), fair (3), poor (2), and very poor (1). Before using the rubric, we did an intra rater assessment, in which two raters analyzed student answers one at a time. Then, the findings of the two raters' assessments were averaged.

Research Procedure

The research stages for the experimental class followed step 5E in the LC, which consists of engagement, exploration, explanation, elaboration, and evaluation. The engagement stage contains activities that help students connect their prior knowledge with the material to be learned. Students can develop concepts by completing investigations, laboratory activities, or examining questions during the exploration stage. The explanation stage directs students' attention by demonstrating the outcomes of the exploration stage's actions. Then, students participate in additional activities in the elaboration stage, such as receiving feedback from instructors and other students on the results of prior activities. The evaluation step allows students to assess their accomplishments concerning the learning objectives.

The MR strategy is placed in the exploration, explanation, and elaboration steps of the LC model, giving it the name LCMR. Students are guided through the phases of learning by compiling representations, beginning with drawing, explaining drawings, assembling diagrams, graphs, and connecting representations with one another, as part of the MR strategy. Appendix A1 shows an example of a learning activity involving LCMR and transpiration content. Student worksheets aid students through the representation activity activities.

The research stages in the control class refer to the 5E steps of the LC model. However, students in the control group also received training in compiling representations during the exploration stage. The activity to train representation skills is also carried out in the control class, based on the characteristics of plant physiology material, which is rich in pictures, diagrams, symbols, graphs, and image interpretation. Exercises for compiling representations provided for the control group can be found on student worksheets.

Data Analysis

The data were classified into three categories: student representation skill scores based on the learning model, student representation skill scores based on academic ability, and student representation skill scores based on the interaction between the learning model and academic ability. The data analysis used is descriptive statistics and parametric statistics. Descriptive statistical technique to describe the representation ability data presented in graphical form. Parametric statistical analysis technique to test the data representation ability using two way ANCOVA at a 5% level of significance.

Findings

The results of data analysis using ANCOVA at a significance level of 5% are presented in Table 2. The statistical analysis (Table 2) showed that there was a significant difference in students' representation skills due to the implementation of the learning model, with a significance value of 0.00 (p-value < 0.05). Besides, it was also found that student representation skills differed significantly among groups with different academic abilities (a significance value of 0.00, p-value < 0.05). Similarly, based on the interaction between the learning model and academic ability, the treatment groups reported different scores on representation skills, with a significance value of 0.01 (p-value < 0.05). The following sections contain detailed explanations of the differences in students' representation skills based on the learning model, academic ability, and the interaction between the learning model and academic ability.

Student Representation Skills Based on the Learning Model

Figure 1 presents boxplots describing student representation skills based on the learning model. It further shows that students in the LCMR (Learning Cycle Multiple Representation) groups achieved a higher mean score than students in the LC (Learning Cycle) group. Quartile 2 for LCMR was 83.33, while quartile 2 for LC was 56.67. Based on the data shown in Figure 1, it can be concluded that the LCMR group differed significantly from the LC group, so further analysis on students' academic ability was conducted. The data on student representation skills based on academic ability are depicted in Figure 2. Table 3 displays the results of the LSD test on student representation skills based on the learning model. The LSD notations indicate that the mean score obtained by the LCMR students (79.26) was considerably higher than that achieved by the LC students (61.43).

Student Representation Skills Based on Academic Ability

Figure 2 demonstrates boxplots representing student representation skills based on academic ability data. The data indicate that the representation skills of students with high academic ability are higher than those of students with low academic ability. Quartile 2 for students with high academic ability was 71.67, while for students with low academic ability was 56.67. Table 4 presents the results of the LSD test on student representation skills based on academic ability. The LSD notations indicate that the mean score obtained by students with high academic ability (73.49) was significantly different from that of students with a low academic ability (67.19).

Student Representation Skills Based on the Interaction Between the Learning Model and Academic Ability

Figure 3 shows boxplots delineating student representation skills based on the interaction between the learning model and academic ability. The highest score for Quartile 2 was reported by the LCMR students with the high academic ability (86.67), followed by the LCMR students with the low academic ability (80.00), the LC students with a high academic ability (64.17), and the LC students with a low academic ability (50.83).

Table 1 summarizes the results of the LSD test on student representation skills based on the interaction between the learning model and academic ability. Based on the LSD

Fig. 1: Boxplots showing the difference in student representation skills based on the learning model

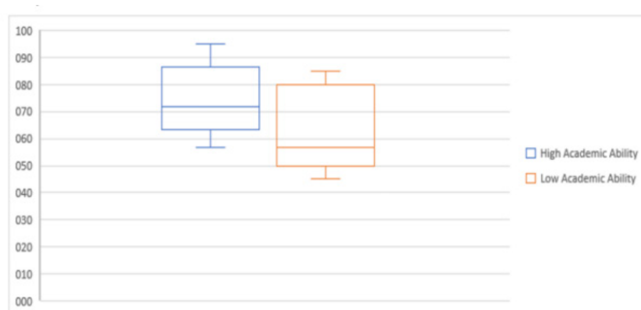


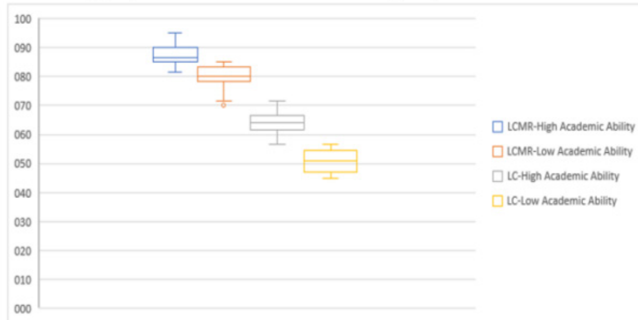
Fig. 2: Boxplots showing the difference in student representation skills based on academic ability.

notations, it can be concluded that the LCMR students obtained the highest mean score for representation skills compared to other treatment groups. Sequentially, representation skills from the highest to the lowest are reported by: the LCMR students with high academic ability, the LCMR students with low academic ability, the LC students with high academic ability, and the LC students with low academic ability.

Discussion

Student Representation Skills based on the Learning

Learning Cycle Multiple Representation (LCMR) is a constructivist learning model that combines Learning Cycle 5E and the Multiple Representation strategy. LCMR is created by incorporating multiple representations into Learning Cycle 5E's exploration, explanation, and elaboration stage. The combination of LC and MR has been shown to be effective in guiding pupils toward achieving predetermined learning objectives. Data presented in Table 2 show a difference in student representation skills based on the learning model



learning model and academic ability.

Table 2: The results of ANCOVA on Student Representation Skills

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Corrected Model	12618.45a	4	3154.61	249.65	.00	.95
Intercept	1500.51	1	1500.51	118.75	.00	.68
Pre_Representation	239.00	1	239.00	18.91	.00	.25
Group	933.77	1	933.77	73.90	.00	.57
Academic	260.65	1	260.65	20.63	.00	.27
Model * Academic	82.20	1	82.20	6.51	.01	.10
Error	720.26	57	12.64			
Total	317605.56	62				
Corrected Total	13338.71	61				

Table 3: The Results of the LSD test on Student Representation Skills based on the Learning Model

		Mean			
No.	*Group*	*Pretest*	*Posttest*	*Mean Score*	*LSD Notation*
1.	LCMR	45.17	83.44	79.26	a
2.	LC	29.95	57.50	61.43	b

Table 4: The Results of the LSD test on Student Representation Skills based on Academic Ability

		Mean			
No	*Academic*	*Pretest*	*Posttest*	*Mean Score*	*LSD Notation*
1.	High	41.61	75.54	73.49	a
2.	Low	33.01	64.57	67.19	b

Table 5: The Results of the LSD Test on Student Representation Skills based on the Interaction between the Learning Model and Academic Ability

		Mean			
No.	*Interaction*	*Pretest*	*Posttest*	*Mean Score*	*LSD Notation*
1.	LCMR High Academic Ability	49.33	87.67	81.25	a
2.	LCMR Low Academic Ability	41.00	79.22	77.26	b
3.	LC High Academic Ability	34.38	64.17	65.73	c
4.	LC Low Academic Ability	25.52	50.83	57.12	d

implemented in the classroom, where the LCMR students performed better than the LC students. Furthermore, the results of the LSD test in Table 2 indicate that the mean score achieved by the LCMR students (79.26) was significantly different from that obtained by the LC students (61.43).

The students' mean score demonstrates the success of LCMR in enhancing students' representation skills. This finding is consistent with previous LCMR research across disciplines and in different contexts. Multi Representation contributes to the Learning Cycle (LC) by providing students with complementary information (Ainsworth, 2008a). Additionally, multi-representation directs students toward a more in-depth examination of a subject (Jong & Meij, 2012). Individuals can use MR to investigate their way of thinking to increase their comprehension of a topic and convey their thoughts in novel ways (Ainsworth, 2018). The pedagogical functions of MR include the following: completing learning processes (tasks, individual differences, and strategies) (Eilam et al., 2014; Rau, 2017); becoming complementary information (differentiating information, shared information); reducing misinterpretation through recognition of the inherent; and constructing knowledge (abstraction, extension, relations) (Ainsworth, 2006). A study demonstrates that multi-representation can help students understand college when confronted with complex biology information (Sumarno et al., 2018; Tsui & Treagust, 2013) and enhance their science concept knowledge (Kozma, 2003).

Through a diversified and systematic learning process, LCMR provides students with a unique learning experience (Nitz et al., 2014). Multiple Representation (MR) is critical in completing student comprehension, for example, by completing assignments, highlighting individual differences (representation selection), and adopting performance-enhancing tactics (Anderson et al., 2013). MR gives students additional information about a biological phenomenon by utilizing graphs, tables, equations, and illustrations. Since individual preferences for representation vary, the representation can be modified to provide information according to the user's interests (Ainsworth, 2018). Additionally, MR acts as a means of presenting a simple system to students in higher education, facilitating the learning process (Jong & Meij, 2012), and assisting students in strengthening their critical thinking skills (Sumarno et al., 2016)so it needs to be investigated how the conception of inter-level interacting. It requires a complex system of reasoning in order to obtain an understanding of how the various components, behaviors and interactions that occur in the system or between systems. The implications of this requires learning models to treat complex systems reasoning ability. The learning model of multiple representation supported argumentation (MRSA.

Additionally, LC has numerous benefits to the classroom: it promotes constructivism-based learning, conceptual development, and inquiry learning (Campbell, 2006). LC assists educators in developing a higher-quality learning process (Duran & Duran, 2004) and enhancing practice quality through structural approaches and cognitive psychology (Bybee et al., 2006). Also, in developing students' thinking abilities (Bevevino et al., 1999), guiding students as they learn science concepts, and correcting incorrect or incomplete knowledge. Besides, LC assists students in delving deeper into science subjects and applying what they learn in school to their daily life (Açisli et al., 2011; Özbek et al., 2012).

Student Representation Skills based on Academic Ability

Students with strong academic ability have superior representation skills than students with a low academic ability (Figure 2). The mean score of representation skills obtained by students with high academic ability (73.49) is higher than those with low (67.19). According to the findings of this study, there are disparities in conceptual mastery between students with high and low academic ability (Husni et al., 2019), and academic ability has a substantial association with the metacognitive skills of students, including representation skills (Akunne & Anyanmene, 2021). Similarly, in general knowledge and mental representation, students with strong academic ability have superior representation skills to those with a low academic ability (Carroll, 2015).

Academic ability is defined as competence attained during the educational process (Laura, 2021). Academic abilities are classified into high, average, and low (Visser et al., 2018). Due to the unequal distribution of academic abilities, students are classified as having high or low academic abilities (Ismirawati et al., 2018). Academic ability classification is beneficial for narrowing the skills gap between individuals with high and poor academic abilities (Prayitno et al., 2015). The classification is done so that groupings of students with high academic ability and those with low academic ability do not have a great deal of ability in common. By assessing students' academic ability, constructivist learning can help to improve the quality of their learning (Semerci & Batdi, 2015).

Students with high academic ability have better higher-order thinking skills (Lee et al., 2002). Individuals with superior academic ability demonstrate excellent conduct and study habits compared to individuals with a poor academic ability (Mahanal et al., 2019; Sarwar et al., 2009)Indonesia. The sample consisted of 134 students from two separate schools which represented different academic abilities (high and low. Behaviour and study habits are also related to students' ability to manage their study time effectively. Compared to genetic variables, the background of a student's academic ability has a more significant influence on the student's academic performance (Visser et al., 2018).

Student Representation Skills based on the Interaction Between the Learning Model and Academic Ability

The corrected mean scores of representation skills from four treatment groups are depicted in Table 5. The highest mean score of representation skills was obtained by the LCMR students with a high academic ability (81.25), followed by the LCMR students with the low academic ability (77.25), the LC students with the high academic ability (65.73), and the LC students with the low academic ability (57.12).

The findings of this study indicate that students who have been educated to apply the LCMR model can compose a variety of representations in biology learning, most notably for plant physiology. According to Ainsworth (2006), plant physiology has three levels of representation. The three levels of representation are as follows: macroscopic, which is real and contains visible and tangible matter; (sub) microscopic, which is real but invisible and consists of particulate levels that can be used to explain abstract phenomena such as the movement of electrons, molecules, particles (ions), or atoms, electric current, and the structure of haemoglobin. The final level is the symbolic level, which includes image representation, algebra, and computer representations of microscopic (sub) representation (animation, simulation, and visualization of other forms). Students can reach these levels of representation with the assistance of educators, whose responsibility is to support students in compiling their representations. Students are expected to develop their conceptual understanding and critical thinking abilities through these activities (Prain & Tytler, 2012).

Combining the Learning Cycle (LC) and Multiple Representation (MR) effectively guides university students toward more excellent proficiency in representation. LC and the MR strategy have significantly contributed to student competency improvement. As a constructivist-based learning methodology, the Learning Cycle (LC) facilitates students' active production of new knowledge (Belapurkar, 2017; Seven et al., 2017). The application of LC can assist students in comprehending problems and natural phenomena while also fostering the development of critical thinking skills and scientific attitudes (Ulaş et al., 2012). Additionally, the LC enables educators and students to construct new information and experiences from pre-existing knowledge and experiences (Belapurkar, 2017).

Multiple Representation (MR) in this study can provide unique benefits when one learns complex material. The study findings are in line with previous studies on MR, which are explained as follows. Multiple Representation (MR) can assist students in identifying the impacts of a process, predict results, sort material, clarify ideas, organise data, explain a topic's relationship, and describe the causes (Carolan et al., 2008). It is believed that MR has a positive relationship with higher-order thinking skills (Tajudin & Chinnappan, 2016). Structured representations can be one of the learning aids that can help students enhance their ability to think critically, motivate, and focus (Al-Samarraie et al., 2013). Multiple Representation (MR) can also help reduce misinterpretation of a phenomenon by identifying the underlying features of representation. For instance, when students learn to use MR, they improve their perception of a familiar image. Additionally, Multiple Representation (MR) contributes to developing deep understanding by abstracting, extending, and associating (connecting) scientific materials (Jaber & BouJaoude, 2012; Sunyono et al., 2015; Sunyono & Meristin, 2018).

The findings also indicate that MR can enhance students' comprehension of scientific concepts. Similarly, some experts also discovered that MR is a strategy for describing scientific concepts (interpretation); generating representations (construction); identifying, describing, and analyzing the characteristics of the representation; and relating and explaining the connection between numerous representations (Abdurrahman et al., 2011; Kozma & Russell, 2005). Similarly,

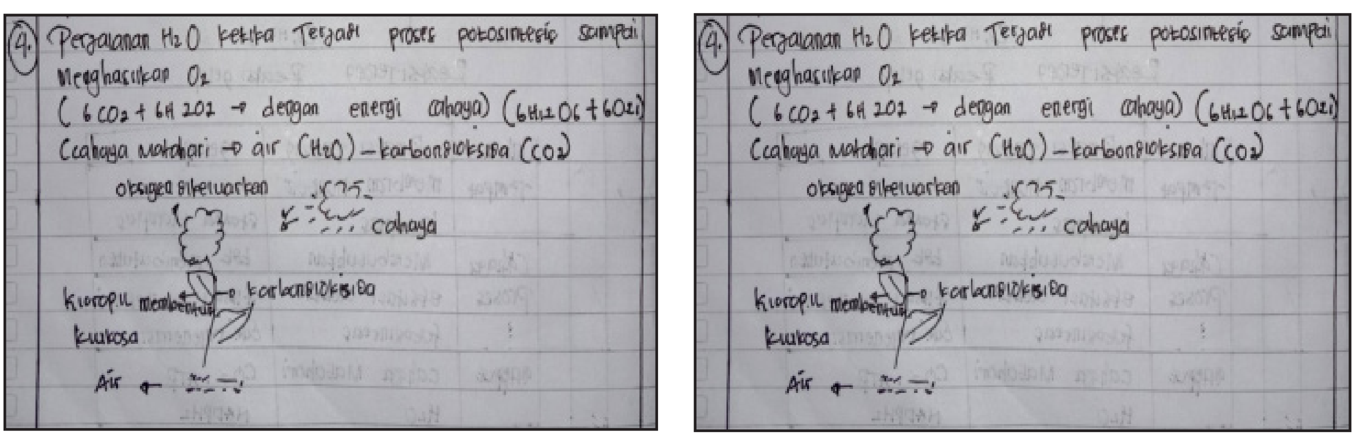


Fig. 4: Examples of Student Responses: (a) Student response (initial M) from the LC and low academic ability group; (b) student response (initial AAA) from the LCMR and high academic ability group.

Tang et al. (2014) found that MR interprets and explains scientific ideas or concepts using analogies, verbal statements, written texts, diagrams, graphs, and simulations.

The interplay of academic ability and learning models (LCMR) has been shown to help close the representation skills gap between students with and without high academic abilities. This is indicated by the mean scores presented in Table 5, which confirmed that the mean score achieved by the LCMR-low ability group was higher than that obtained by the LC-high ability group. Multi Representation would assist students with low academic ability in systematically organizing representations systematically (Ainsworth, 2008b; Waldrip et al., 2010), allowing them to elaborate on scientific concepts in the form of image

Academic ability and LCMR interact to support students' representation skills, particularly accuracy, elaboration ability, and the ability to communicate reasons (Hwang et al., 2007; Wong et al., 2011). The use of vertical multi-representation learning has improved students' higher-order thinking skills (Sari et al., 2021). Knowledge acquisition entails horizontal, transverse, and cross-domain translations that describe concepts at multiple levels of biological organization and in various representational ways (Schönborn & Bögeholz, 2009). Students' cognitive abilities improve due to media-based instruction in horizontal mode representation (Tindani et al., 2021). Constructivist learning can be used to enhance representational skills (Hwang et al., 2007; Lengkana et al., 2020; Sikumbang et al., 2020).

Prain and Tytler (2012) showed how MR could aid in science learning and assist students in developing their representational skills. Students can build representational skills through interactive learning (Farida, 2009); one such strategy is the MR strategy (Ainsworth, 1999). Furthermore, it was noted that when integrated with other learning models, such as the 5E learning cycle, MR can maximize student learning outcomes (Treagust & Tsui, 2013). The learning outcomes in question are the competencies that students must acquire. The competencies discussed in this study are representation skills.

Additionally, the connection between academic ability and the Learning Cycle (LC) schedules learning events so that students can gradually develop a comprehension of a concept (Ong et al., 2018). The Learning Cycle (LC) has been shown to significantly boost student learning outcomes and motivation (Ulaş et al., 2012). Additionally, LC (Faizin et al., 2018) can help students develop a more scientific mindset. Similarly, LC (Sen & Oskay, 2016; Wafirah et al., 2016) can enhance one's self-esteem and scientific attitude. On the other hand, pupils' conceptual understanding can be significantly improved through various representations (Fatmaryanti et al., 2019). The Learning Cycle (LC) is consistent with multi-representation, empowering students to reconstruct a concept in alternative ways (Kozma & Russell, 2005).

Figure 4 illustrates student responses to a question about photosynthesis in plant leaves at the macroscopic, microscopic, and symbolic levels. The two images depict distinct responses; 4a represents the response of a student with the initial "M" who is a member of the LC group and has low academic competence. Meanwhile, Figure 4b represents a student's response with the letters "AAA" who is a member of the LCMR group and possesses exceptional academic competence. These responses demonstrate the students' capacity for vertical translation (Vertical Translation across Level/VTL) (fourth indicator).

According to Figure 4, the two students' response patterns differ significantly. As illustrated in Figure 4a, the LC student drew images of how H_2O is formed when absorbed in the soil to form O_2 and then ejected through the leaves. Furthermore, the student included the chemical process. However, question 4 essentially asks participants to describe the process of leaf change, as illustrated by students in Figure 4b. As shown in Figure 4b, the student was able to construct a representative form of the H_2O's trip through the leaf till the production of O_2. The macro image of the leaves is excellent, as are the symbols used to illustrate the direction of movement. Additionally, the LCMR student described well microscopic photos of the inside of the leaf, including stomata, grana, thylakoids, and plasma membrane. Additionally, the student skillfully recorded the symbols utilized in the reaction process, such as arrows and signs of light absorption.

This research was divided into stages that correspond to the steps of the 5E Learning Cycle, namely engagement, exploration, explanation, elaboration, and evaluation (Belapurkar, 2017; Ong et al., 2018). The engagement stage consisted of activities designed to teach general information and facts about Plant Physiology and was allowed to perform investigations, discussions, and tasks during the exploration stage. The explanation stage included exercises for presenting the exploration findings to the class. The students confirmed and obtained new information about the content throughout the elaboration stage. They worked on practice questions and prepared the following subject during the evaluation stage.

At the engagement stage, the students were invited to identify key concepts. At the planning stage, the lecturer defines important concepts or major ideas for a topic to anticipate the representations students will construct as they expand their understanding and are regarded as evidence of learning. Additionally, the exploration stage emphasized the development of the form and function of different representations. The professor and students examined the function and purpose of previously compiled representations. For instance, when students work with graphs, they should be asked why they are utilized in science. Thus, the instructor can help students learn about the many forms of representations and their use as tools for explaining natural phenomena. Students must construct a sequence of representations to explore and explain their concepts, extend these ideas to new circumstances, and combine representations in meaningful ways. They must be pushed and encouraged to organize representation as a mode of expression to achieve clear, defensible, and adaptable knowledge.

The elaboration stage is where the student and instructor compare their perceptions of the prepared form of representation. The explanation stage is a more advanced step of elaboration in which the students explain the type of representation they developed via a simple presentation. The elaboration assignment required the students to record and send their explanations over the WhatsApp group. Finally, during the evaluation step, the students were asked questions about the material. They were assigned to conduct a library analysis linked to the material addressed the following week as homework. The responses to the questions and the findings of the library analysis were gathered via WhatsApp one day before the course began.

External representations created by students in this research include descriptions of various ideas in different sentences, drawings of various physiological processes in plants, and tables illustrating the variations between processes that occur horizontally in plants. The results of this research are consistent with previous findings in many different disciplines and contexts, which are described as follows. Instructions with MR guide students in problem-solving (Ainsworth, 1999; Opfermann et al., 2017; Schönborn & Bögeholz, 2009), provide students with complementary information (Ainsworth, 2008a; Eilam et al., 2014; Rau, 2017), build student knowledge (Ainsworth, 2006; Treagust & Tsui, 2013), facilitate learning (Carolan et al., 2008; Jong & Meij, 2012; Kozma & Russell, 2005), and develop student concepts (Kozma, 2003; Prain & Tytler, 2012; Tsui & Treagust, 2013). The use of MR has been known to be effective in helping students in different learning contexts, such as in chemistry (Farida et al., 2010), biology (Sikumbang et al., 2020; Sumarno et al., 2018; Tindani et al., 2021), physics (Abdurrahman et al., 2011), and mathematics (Hwang et al., 2007). Meanwhile, the LC model can put students in a situation where they can share with and help each other to achieve learning goals (Seven et al., 2017). The combination of LC and MR results in improving the representation skills of students with low ability, if compared to the effect of the LC model alone on the representation skills of students with low ability. This can happen because MR complements the shortcomings of LC application by guiding students in creating a systematic representation (Ainsworth, 2008b; Waldrip et al., 2010). The effectiveness of a student's education is inextricably linked to their ability to understand external representations (Anderson et al., 2013; Wong et al., 2011). As a result, it may be asserted that many representations can benefit from learning science (Clément & Castéra, 2013; Nitz et al., 2014).

Conclusion

The statistical analysis showed a difference in student representation skills based on the learning model. The LCMR students performed better than the LC students in representation skills. As indicated by the LSD test results, the mean score of representation skills obtained by the LCMR students was higher than that achieved by the LC students. LCMR provides a new learning experience for students. LCMR is made up of the Learning Cycle (LC), a constructivist model capable of offering conceptual transformation, improving cognitive quality, training thinking abilities, and guiding students through learning science topics. LCMR also contains a Multiple Representation (MR) strategy, a learning approach for completing information and processes, reducing misinterpretation, and constructing knowledge. Students can study science concepts in-depth and apply what they have learned in their daily life with LCMR. As a result, the LCMR model can help students enhance their representation skills. As a result, the LCMR model can help students enhance their representations skills when compared to the LC model alone.

Besides, the representation skills of students with varying levels of academic ability also differed significantly. The mean score obtained by the high-ability students was higher than that found in the low-ability group. The classification of college students into high and low academic abilities is due to the unequal distribution of academic abilities in high schools. Academic ability classification is useful for bridging students' science process skills gap between groups with high academic abilities and groups with low academic abilities. Students with higher academic abilities have more vital higher-order thinking skills, behaviour, study habits, and time management skills than students with lower academic abilities. As a result, college students who excel academically also excel in representation skills.

In addition, the interaction between the learning model and academic ability had a different effect on student representation skills. Based on the LSD notations, the highest mean score of representation skills was found in the LCMR and high ability group, followed by the LCMR and low ability group, LC and high ability group, and LC and low ability group. These findings indicate that LCMR can improve the representation skills of Biology students with different levels of academic ability above the skills in LC alone. The classification of college students into high and low academic abilities is due to the unequal distribution of academic abilities in high schools. Academic ability classification helps bridge students' science process skills gap between groups with high academic abilities and groups with low academic abilities. Students with higher academic abilities have stronger higher-order thinking skills, behaviour, study habits, and time management skills than students with lower academic abilities. As a result, college students who excel academically also excel in representation skills.

Limitation

This study contains limitations, most notably in the portion of the subject involving university students. There is still a need for further research on various areas, particularly for junior high and senior high school pupils. Additionally, this research is restricted to the examination of plant physiology. As a result, additional research is expected to examine other biological materials to form thorough findings.

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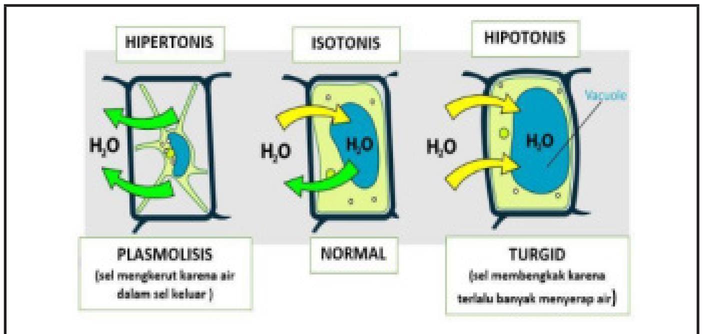
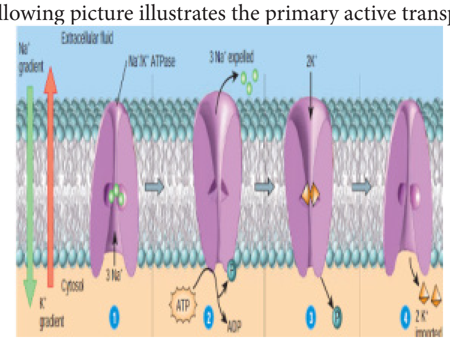
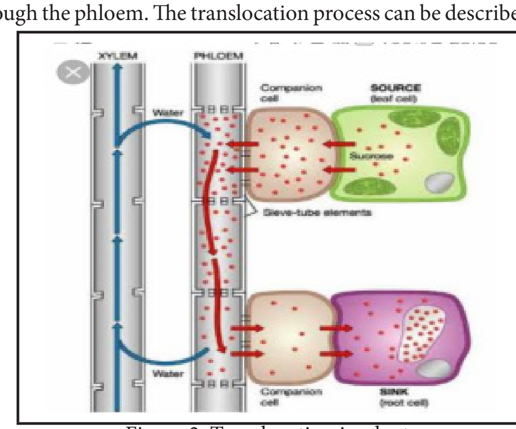
Appendix

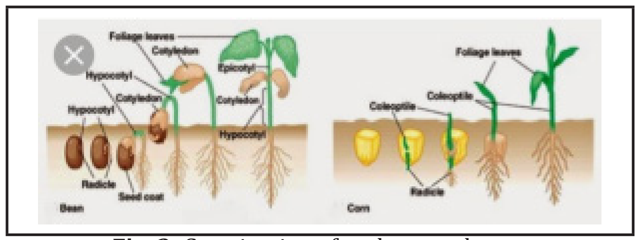
Table A1. Examples of Student Activities in LCMR Classroom

Learning Activities	
Lecturer	*Student*
Engage (10')	
a. Create and stimulate students' interest and curiosity by asking, "What is the name of the part of the leaf that functions as the entry and exit point for CO_2 and H_2O?" b. Provide a meaningful context for learning by accommodating various student answers to the previous question c. Ask questions for the practice of inquiry and science, namely about plant transpiration d. Express students' ideas and beliefs regarding learning objecti-ves.	a. Have a high curiosity regarding the question given by the lecturer, by providing appropriate answers. b. Pay attention to the answers of their classmates. c. Pay attention to the question posed before carrying out investiga-tions on plant transpiration. d. Express ideas to achieve learning objectives
Explore (45')	
a. Provide a learning experience about a phenomenon, such as plant transpiration shown in the Student Worksheet b. Guide students in conducting investigations on: □ the location and shape of stomata on leaves through macro-scopic images □ how stomata work in helping to regulate the rate of transpira-tion at the macroscopic and microscopic levels □ mechanisms of opening and closing stomata through pictures and verbal stimulus □ the stimulus for opening and closing stomata microscopically and symbolically □ effects of transpiration on leaf wilting and temperature verbally □ adaptations that reduce verbal evaporative water loss c. Help students focus on determining the form and function of the Multi Representation (MR) to be used	a. Read about plant transpiration provided on the Student Worksheet b. Use the Worksheet as guidance to conduct practicum activities c. Perform investigations on: □ the location and shape of stomata on leaves through macroscopic images □ how stomata work in helping to regulate the rate of transpiration at the macroscopic and microscopic levels □ mechanisms of opening and closing stomata through pictures and verbal stimulus □ the stimulus for opening and closing stomata microscopically and symbolically □ effects of transpiration on leaf wilting and temperature verbally □ adaptations that reduce verbal evaporative water loss d. Focus on determining the Multi Representation (MR) form and function to be used.
Explain (45')	
a. Ask each group to re-examine the results of the investigations they have done in the exploration stage. b. Ask each group in turn to present the results of their discussion c. Compare different explanations produced by the students d. Review the scientific explanations provided by the students	a. Prepare the investigation results. b. Present the results of the investigations alternately c. Answer questions from the lecturer or other groups d. Complement each other's answers
Elaborate (25')	
a. Ask students one or two questions to explore their understand-ing of the topic being discussed b. Explain concepts that students have not understood regarding plant transpiration c. Reconstruct and extend explanations using different models, such as written language, diagrams and graphs, and mathematics	a. Answer the questions presented by referring to the teaching mate-rials recommended by the lecturer b. Ask concepts that are not understood. c. Discuss the representations made with the lecturer
Evaluate (10')	
a. Provide opportunities for students to review their understand-ing and skills b. Provide proof for changes in student understanding and skills c. Give assignments, particularly library analysis on photosynthe-sis, which should be submitted one day before the following lecture schedule	a. Collaboratively reflect with classmates on the outcomes of the prepared representations b. Receive evidence of changes in understanding and skills c. Prepare to perform homework in the form of a photosynthe-sis library analysis

Appendix B. Representation Test Indicators and Questions on Plant Physiology

Table B1. Representation Test Indicators and Questions on Plant Physiology

Question Number	Plant Physiology subtopics	Indicators of Representation Skills	Questions
1	Osmotic potential and water potential of plant cells	Read the attributes and elements that indicate a representation	Look at the following picture.  Explain the response of plant cells to different solution conditions, as shown in the picture above!
2	Solute Transport	Interpret and use representations to solve problems	The following picture illustrates the primary active transport.  Figure 1: primary active transport process Describe each process you identified from the image above, using the appropriate concepts, principles and theories!
3	Photosynthesis	Translate concepts using Horizontal Translation across Mode (HTM)	In photosynthesis, there are light reactions and dark reactions. Present the difference between light reactions and dark reactions in photosynthesis using pictures, tables, and diagrams!
4	Transpiration	Translate concepts using Vertical Translation across Level (VTL)	Explain the journey of H2O when photosynthesis occurs to produce O2. Describe the physiological processes in this event/phenomenon at the macroscopic, microscopic, molecular, and symbolic levels.
5	Transport and translocation of nutrients and minerals that occur in the plant's body	Interpret and use representations to solve problems	Translocation is the movement of dissolved materials (food materials) in all plant parts through the phloem. The translocation process can be described as follows.  Figure 2: Translocation in plants

			Questions: a. Why does the number of dots at the top (leaf cells) increase after moving to the left? b. Why does the number of dots on the bottom (phloem) increase after moving to the right?
6	Respiration	Translate concepts using Horizontal Translation across Domain (HTD)	Respiration in plants goes through several stages. Explain these stages using the basic principles of respiration in different domains!
7	Cell wall: structure, formation, and production	Construct representations to explain concepts	Nutrients influence an increase in plant height as a result of plant metabolism. Explain the role of metabolism in plants.
8	Signal transduction	Visualize order of magnitude, relative measure, and scale	Signal transduction is a sequential change in the form of a signal, from an extracellular signal to a response in communication between cells. The goal is for cells to understand their surroundings and react to them. Describe the signal transduction process in cells!
9	Growth and Development	Translate concepts using Horizontal Translation across Mode (HTM)	Look at the following illustration.  **Fig. 3:** Germination of soybean and corn. Explain the difference between epigeal and hypogeal germination using tables and diagrams!
10	Hormones	Translate concepts using Horizontal Translation across Domain (HTD)	Explain how abscisic acid works in the process of dormancy and leaf shedding. The explanation is expected to use the basic principles of the hormone ABA in a different domain!
11	Plant Movements	Construct representations to explain concepts	Draw a concept map representation to explain the division of motion in plants!