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ARTICLE

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Exploration of critical thinking and self-regulated learning in online learning during the COVID-19 pandemic

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Abstract

An in-depth analysis of today's online biochemistry learning is required to ensure better learning in the future. As a skill that students need to enter the world of work, critical thinking remains a goal in higher education. To develop critical thinking, students need to self-regulate by developing their self-regulated learning (SRL). This study aims to analyze students' critical thinking and SRL during online biochemistry learning. The research sample comprises 54 University of Mataram students. The data on critical thinking and SRL were gathered using tests and questionnaires. Supporting data were collected from observations on the Moodle platform, which was used as a learning tool during the learning process, and free-response data. The results revealed low average scores for three components of the students' critical thinking in online biochemistry learning, namely hypothesis testing, developing conclusions and argument analysis. Among the indicators, metacognitive skill had the highest average score and help seeking had the lowest average score in the SRL measurement. Students' low critical thinking in online biochemistry learning may be caused by a lack of student–student interaction.

KEYWORDS

critical thinking, learner–learner interaction, online learning, self-regulation

1 | INTRODUCTION

The COVID-19 pandemic has prompted changes in many fields, including education. The closure of schools and universities in a bid to prevent the spread of COVID-19 has altered the learning process.[1,2] Where learning initially took place face-to-face, it is now conducted online.[3]

Online learning demands innovation capable of training students to become accustomed to critical thinking.[1] There are many challenges linked to the transition to this type of learning process, including uninteresting learning, the development of anxiety and students sometimes feeling stressed.[4–6] The government and experts in the field of education need to play an active role in identifying ways of ensuring that online learning can be conducted effectively.

Biochemistry is one of the courses held online at the University of Mataram. The challenge involves providing interesting learning at the same time as developing students' critical thinking skills.[7–10] Several studies have reported innovation in teaching methods to ensure effective biochemistry learning and increase student motivation. The use of problem-solving methods, discussions and a combination of the two has been shown to increase student activity.[11–13] Case-based learning, especially COVID-19 cases, can also increase student interest.[14,15] Exploratory experiments can overcome the difficulties of conducting online laboratory work.[6,16] Such work

can also be undertaken using virtual laboratories and online simulations.[17,18]

Critical thinking is defined as a set of thinking skills that include the ability to analyze, think reflectively and reasonably, analyze arguments and evaluate an argument well in order to hold a position in the face of existing opinions.[19–22] Higher education requires the development of critical thinking skills to enable students to adapt to various changes.[23] In addition, critical thinking has become demanded in the world of work as one of the key skills required by students.[24–26] Students with well-developed critical thinking skills typically find it easier to adapt to changes in the world of work that often accompany changing times.[27]

Several researchers have reported on critical thinking indicators, which are usually measured as part of the learning process in universities, and then used these to develop research instruments. Instruments for measuring critical thinking use indicators of analysis, evaluation, inference, deduction, induction, formulating assumptions, and testing arguments.[28,29] A recent study developed a critical thinking instrument for chemistry students using the indicators of making assumptions, developing hypotheses, hypotheses testing, making conclusions, and analyzing arguments.[30] Aside from a written test, critical thinking can also be measured through the preparation of scientific writing. Hoyo[31] developed a critical thinking rubric similar to that developed by York Technical College with indicators following Bloom's taxonomy, namely synthesis, knowledge and evaluation, analysis, knowledge and application, understanding, and evaluation.

A learning process strategy is required if it is to achieve its goals. This strategy is known as self-regulated learning (SRL) and it is important that students are trained in this skill.[32] Students with good SRL can manage themselves to plan and evaluate their learning process. In addition, SRL can increase motivation and help in selecting an environment that can support the learning process.[33]

SRL is influenced by three main factors, namely self-confidence, motivation and goals. Self-confidence is related to an individual's belief about their ability to learn and practice skills. Motivation relates to things that can drive individuals to achieve their goals.[34] Self-confidence and motivation are in turn related to self-regulation, which can affect student academic achievement.[22,35,36]

The implementation of online learning is ongoing but needs to be analyzed in depth. Analysis must focus not only on student perceptions of online learning but also its influence on learning outcomes.[6] The results of the analysis can thus be considered within the process of improving learning and producing innovations in effective teaching methods in the context of the COVID-19 pandemic.

Recent studies on online learning have reported student perceptions linked to the implementation of half-semester learning.[13] Until now, however, there has been no widespread reporting of analysis related to critical thinking and SRL during the implementation of online biochemistry learning. This study therefore attempts to analyze students' critical thinking and SRL during online biochemistry learning. The results of this study are expected to produce recommendations and encourage innovations that can improve online biochemistry learning in the future.

2 | METHODS

2.1 | Situation analysis

Online biochemistry learning was in place for two semesters. The topics of protein, nucleic acids, and viruses were discussed during the first semester, which ran from January to May, while the second semester, from July to November, contained the topics of carbohydrates and lipids. During the first semester, as the initial stage in online learning, the students needed time to adapt to the changes in how their learning was being delivered. This semester was therefore a phase of transitioning from face-to-face to online learning. The implementation of online learning in the following semester showed that the students had adjusted to the online learning and evaluation process, thus making it easier for them to follow the learning process.

Online biochemistry learning was carried out for 150 min per week for 12 weeks. The online scenarios included:

1. The lecturer explained the mechanisms and methods used during online learning. The students were able to provide mutually agreed suggestions and input, which also applied to the assessment to be carried out.
2. Learning was carried out using the Moodle platform as a program recommended by the university. This contains various features that facilitate lecturers in giving lectures, including attendance, "material pockets," "task bags," discussion forums, meet-ups and elements for carrying out assessments. Before the start of a lecture, the students registered using an email address. The platform recorded all student activities during lectures.
3. Every week the lecturer gave students assignments based on studying the material in the "material bag" and the students were asked to develop their own

TABLE 1 Demographic data of the sample ($N = 54$)

Background	Subtotal	
	N	%
Gender		
Male	8	14.8
Female	46	85.2
Age		
21	12	22.2
22	42	77.8

materials with the references they had. Through discussion forums and meetings, the lecturer and students discussed topics that they had not yet fully understood. At the end of the lesson, the lecturer and students created a summary, which was uploaded to the Moodle discussion forum.

4. In each lesson, the lecturer contextualized the concept explained to the surrounding environment and the current pandemic conditions. For example, the lecturer explained the importance of washing hands with soap to prevent the transmission of COVID-19 because soap helps to dissolve the lipid bilayer that composes the viral capsid. This example was thus used to explain the properties of lipids. The use of examples linked to the surrounding conditions can increase student interest.[15]
5. The lecturer set structured assignments that students had to complete and upload to the "task bag." The lecturer provided feedback on each assignment and the students could ask questions related to assignments that had not been understood.
6. Assessment was carried out using critical thinking questions that measured the students' critical thinking skills.

2.2 | Sample

The research sample comprised Mataram University students in Mataram City, West Nusa Tenggara Province, totaling 54 students from a population of 87 students. All of the students were enrolled on a biochemistry course and had undertaken two semesters of online biochemistry learning. The students were 21 and 22 years of age; the demographic data are shown in Table 1.

2.3 | Data collection techniques

Data collection began at the start of the second semester of online biochemistry lectures. The lectures during the first semester served as a transitional stage for students to adapt to the online learning process. Exploration was carried out on two variables, namely critical thinking and SRL. Data on critical thinking were collected using a written test uploaded to the Moodle platform. The respondents took the test against a time limit set in Moodle. The respondents' SRL data were obtained through a questionnaire. Observations were also made during lectures via the student activities recorded in Moodle.

2.4 | Data collection instrument

The research data were collected using two instruments, namely critical thinking instruments and SRL. The critical thinking instrument was developed following the Danzhak et al.[30] procedure and contained five critical thinking indicators: making assumptions, developing hypotheses, testing hypotheses, developing conclusions, and analyzing arguments (Appendix S1). Each indicator develops into four questions from scientific articles.[30,37,38] A Forum group discussion (FGD) consisting of 10 experts and practitioners from three universities in Indonesia analyzed these questions. Their assessment of each item calculated the value of V Aiken and Interclass Correlation Coefficients (ICC). The result of content validity showed the value of V Aiken between 0.75 and 0.92 with a high-validity category. The reliability value (ICC) is 0.642, concluding that critical thinking questions have good content reliability. The instrument was tested on respondents ($N = 85$) to measure the validity and reliability of the instrument construct. The test questions on respondents showed a Cronbach's alpha of 0.72 and a Pearson correlation value (r) between 0.375 and 0.919 ($p < 0.05$), so the questions had good construct reliability and validity.

The SRL questionnaire was developed based on Jansen et al.[39] The SRL components of this questionnaire comprised metacognitive skills, time management, environmental structuring, persistence, and help seeking. Each component was developed into several statements (Appendix S1). The responses for each item were presented on a 7-point Likert scale, ranging from not at all true for me (=1) to very true for me (=7). The questionnaire was tested for validity and reliability using the Aiken and ICC indices. The results showed that the instrument was valid and reliable and could thus be used as a data collection instrument.

2.5 | Data analysis technique

The critical thinking and SRL data were tabulated and averaged for each component. Free-response data

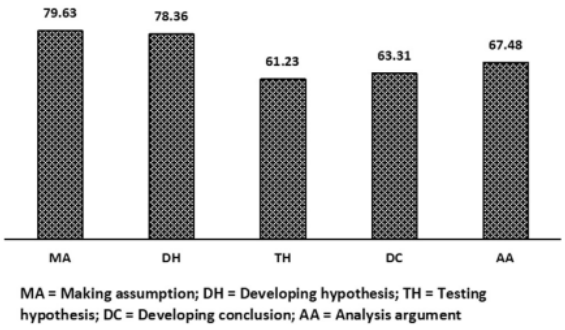

FIGURE 1 Average scores for the components of students' critical thinking in online biochemistry learning

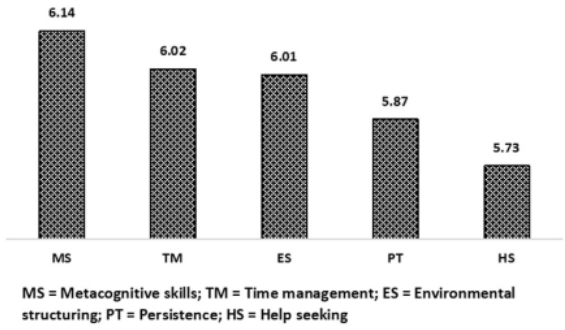

FIGURE 2 Averages for the components of student SRL in online biochemistry learning

combined with the observational results were used as supporting data to explain the students' critical thinking and SRL during online biochemistry lectures.

3 | RESULT AND DISCUSSION

3.1 | Students' critical thinking in online biochemistry lectures

The average scores for critical thinking varied across the five components. The highest scores were for making assumptions and developing hypotheses, at 79.63 (SD = 0.864) and 78.36 (SD = 0.719), respectively. The other three components, namely hypothesis testing, developing conclusions and argument analysis had average scores of 61.23 (SD = 0.72), 63.31 (SD = 0.746) and 67.48 (SD = 0.687), respectively. This shows that the three components overall had low average values (Figure 1).

3.2 | Students' self-regulated learning in online biochemistry lectures

For student SRL, metacognitive skills received the highest average score, with help seeking on the lowest average score, at 6.14 (SD = 0.71) and 5.73 (SD = 0.84), respectively. Time management, environmental structuring, and persistence had average values of 6.02 (SD = 0.7), 6.01 (SD = 0.706), and 5.87 (SD = 0.79), respectively. The averages for the five SRL indicators are shown in Figure 2.

The following six statements in the SRL questionnaire received the lowest average scores:

1. I find it difficult to follow the study schedule in online lectures.
2. I find a comfortable place to study during online lectures.
3. When my mind is not focused on online lectures, I try to stay concentrated.
4. When I do not understand the material in an online lecture, I ask a friend for help to explain it.
5. I share problems with classmates during online lectures so that we can solve them together.
6. I communicate with my classmates regarding conducting online lectures.

4 | DISCUSSION

Observation of the students' activities on the Moodle platform revealed a lack of interaction between the students during the learning process. They interacted more with the content than with their fellow students, which may potentially explain their low average critical thinking score.

Making assumptions can improve students' problem-solving and analytical skills. Looking at the pattern of student answers, those with high scores on making assumptions also tend to have high values for developing hypotheses and analyzing arguments. The results of this study are in line with Fortus,[40] who showed that making assumptions helped students both understand the problem and analyze solutions to the problem. Hypothesis development is based on the ability to make reasonable assumptions so that students who can make assumptions also tend to be able to develop hypotheses.[41,42]

Hypothesis testing had the lowest average score among the components of critical thinking. This is in line with Saeger[42] and Vallecillos,[43] who noted that the students in their study found the testing of hypotheses difficult. This relates not only to interpreting statistical data but also to determining whether deductions are reasonable or unreasonable. The inability of students to answer

questions in the category of testing a hypothesis affects their ability to answer questions in the category of developing conclusions. This is also evident in the low average score for developing conclusions on critical thinking questions in this study.

The low average scores for hypotheses testing, developing conclusions and analyzing arguments share similarities with difficulty in compiling scientific writing. The preparation of conclusions, introductions and discussions is a highly complex part of scientific writing. Students will thus find it difficult to compile these three sections as they relate to hypothesis testing and argument analysis.[44,45] Based on Bloom's taxonomy, hypothesis testing, conclusion development and argument analysis are part of creating and evaluating and as such are some of the most complex elements of scientific writing.[46] This raises concerns regarding the implementation of learning at the university level as part of 21st century educational goals.[23,47]

The researchers linked the low average score for students' critical thinking in online biochemistry learning with student activities on the Moodle platform. The observation results show that the students only used the platform to download lecture materials and upload the assignments set by the lecturer. Around 9.26%–18.5% of students provide feedback on lectures' assessments per week. Only a few students responded to the feedback provided by the lecturer on each assignment. The students never used the discussion forum feature as a way of interacting with other students (0%). Student visits to the Moodle platform were limited to lecture hours. Visiting time at Moodle is only about 1–2 h per week.

The effectiveness of online learning is influenced by several factors, including the type of method, interaction and academic support. An interactive method that can stimulate students to think independently is recommended in online learning. Student–student, student–lecturer, and student–content interaction are all crucial factors in increasing online learning activities. Academic support plays an important role in providing support facilities for the implementation of online learning.[48–51]

We employed a method aimed at stimulating students' interest in participating in online biochemistry learning through the use of facts and cases that occur in the surrounding environment.[15] The university also supported the implementation of online learning by providing programs that make it easier for lecturers and students to access it. The low score for students' critical thinking is possible because of the students' low level of interaction in the learning process. According to Hussin et al.,[52] student–student interaction plays a key role in improving their critical thinking during online learning. This interaction can be in the form of online discussions or peer tutorials to stimulate students to exchange ideas as a trigger for the development of critical thinking.[53–55]

There is a more pressing need to develop students' SRL in online learning due to the higher level of student autonomy compared to face-to-face learning.[56,57] However, the obstacles encountered during learning can sometimes reduce their motivation to learn in a context where motivation plays an important role in the development of student SRL.[58,59]

SRL is developed over three phases, namely the planning, performance, and assessment phases.[60] Looking at the analysis of the SRL statement with the lowest average score, students experience obstacles in the planning and performance phases. The challenges that students face during the planning stage are shown by their difficulty following the lecture schedule and not finding a comfortable place in which to study. Meanwhile, maintaining concentration and the three statements featuring the help seeking indicators indicate difficulties at the performance stage. The planning phase can affect the performance phase, so students need to establish a good learning strategy for themselves in order to achieve the desired learning goals.[61,62]

Lack of contact with students is one of the weaknesses of online learning.[63] In this study, SRL analysis on the help seeking indicator is a form of student interaction with other students. The previously discussed observations on the Moodle platform also reveal that the platform's discussion forum was not used for student–student interaction. This lack of student–student interaction indicates a lack of peer support, which can reduce student motivation.[64]

The students' responses through free-response data revealed complaints in several areas. A majority of students stated that they preferred face-to-face to online learning. The reasons for this varied, including more assignments, poor internet connectivity, and less interaction between friends meaning they could not discuss things and ask for help. Twenty-five percent of students gave a positive response, namely that they liked online learning because they had more time to explore assignments.

Student responses related to online learning have been reported by previous research. Poor internet connectivity and having too many tasks create high levels of emotion and stress that hinder online learning.[65] Many teaching methods remain limited to traditional learning, where students are only expected to memorize information that is posted, with no requirement to understand the deeper meaning behind the concepts being studied.[66]

There is a need for innovation in learning methods in order to make learning more fun. This study used case-based learning, which was positively received by the students because they felt that biochemistry was close to

their lives.[15] The students were able to make suggestions for things that could be integrated with the laboratory work and carried out at home using materials they had to hand. In the context of the current pandemic, the provision of virtual lab simulations is an option in the implementation of laboratory work.[17,18] However, virtual labs are not conducive to the development of students' creativity; therefore, it is necessary to design experiments that can be conducted at home as a means of generating simple data that can then be linked with the concepts of biochemistry being taught.[16] According to Hsu and Rowland-Goldsmith,[6] students prefer exploratory experiments because they are more interesting and provide opportunities for learning from the experimental results they obtain.

The students' responses related to the lack of interaction with friends during online learning highlight an obstacle to the development of critical thinking. Cao et al.[5] identified five types of interaction in online learning: learner–interface interaction, where learners can access learning information online; learner–self interaction, where students can monitor their learning progress through reflection, facilitated by online learning; learner–content interaction, where learners can access learning materials/content in online learning; learner–instructor interaction, where learners can interact with instructors through online learning facilities; and learner–learner interaction, where learners can interact with other learners. Of these five types, learner–learner interaction has a stronger effect than the other interactions.[52] Interaction with peers is reported to affect student motivation and thus has a direct impact on the development of critical thinking skills.[67] SRL is also a dominant factor in influencing students' critical thinking skills.[68] However, despite analyzing various factors that affect critical thinking skills, there is a need for further research and analysis on the factors that influence critical thinking during online biochemistry learning.

5 | CONCLUSION

Three components of students' critical thinking in online biochemistry learning had low average scores, namely hypothesis testing, developing conclusions and argument analysis. SRL recorded low average scores on six statements: I find it difficult to follow the study schedule in online lectures; I found a comfortable place to study during online lectures; When my mind is not focused on online lectures, I try to stay concentrated; When I do not understand the material in an online lecture, I ask a friend for help to explain it; I share problems with classmates during online lectures so we can solve them together; and I communicate with my classmates regarding carrying out lectures. Observations on the implementation of online lectures revealed a lack of student–student interaction, raising the possibility that this is the reason for the students' low level of critical thinking in online biochemistry learning.

This study puts forward the following recommendations:

1. The implementation of online biochemistry learning can employ case-based learning combined with laboratory work that can be carried out at home so that students can practice their analytical skills as part of developing critical thinking.
2. Lecturers need to develop scenarios that can trigger student–student interaction in order to develop students' SRL during online biochemistry learning.

6 | RESEARCH LIMITATIONS

This research has not been able to link critical thinking and self-regulated learning strongly. We know that online learning has complexities in the process, such as internet reliability, distraction at home, etc. Further studies to the discussion about online instruction should acknowledge these are confounding factors.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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