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# Teacher and Student's Expectation towards Biochemistry STEM-based Module in Promoting Critical Thinking and Creativity

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**Abstract:** This research aims to describe the expectations of teachers and students towards STEM-based Biochemistry modules in promoting critical thinking and creativity. An interdisciplinary approach and appropriate learning module involving elements of Science, Technology, Engineering, and Mathematics (STEM) integrated into the Engineering Design Process (EDP) are deemed to improve student learning experiences through problem-solving activities in the real world. This study used a qualitative descriptive method through a survey. The subject is teachers of Biochemistry courses and students who have taken Biochemistry courses and fill out the survey voluntarily. Research data were collected through questionnaires and analyzed using descriptive analysis. The results showed that teachers and students expect the modules need to include contextual materials and integrate the elements of Science, Technology, Engineering, and Mathematics, and the presentation of learning materials should be interactive and attractive. This research will be a reference in developing STEM-based Biochemistry teaching materials that can develop students' critical thinking skills and creativity.

**Keywords:** Biochemistry; Critical thinking; Creativity; STEM-based Module

## Introduction

21st century skills such as critical thinking and creativity are essential skills in today's world. The rapid evolution of technology in the 21st century has changed the workforce's needs and made the problems increasingly more complex. Solving real-world problems that are not fragmented requires cross-disciplinary skills (Arlinwibowo et al., 2020). Critical thinking and creativity play a significant role in complex problem-solving activities. While critical thinking is a synthetic process that allows a person to formulate and evaluate their own beliefs (Ulum et al., 2019), creativity is reflected in understanding, approaches, perspectives, and new ways of understanding things (Aini et al., 2020). Critical thinking is an intellectual process that allows students to assess their reasoning when making decisions and drawing appropriate conclusions (Daryanes et al., 2023). Moreover, critical thinking will help individuals analyze and evaluate problems. In addition, critical thinking skills are required to explore possible solutions during problem-solving, evaluate consistency between alternatives during the decision-making process, or predict the outcome of a decision (Savran-Gencer & Dogan, 2020). Creativity is considered a solution to many urgent global issues because solutions to those problems require new approaches (Zhbanova, 2018). The complexity of multidisciplinary global problems requires critical thinking and creativity that integrates various cconcept of Science, Technology, Engineering, and Mathematics (STEM).

STEM is an interdisciplinary approach that integrates Science, Technology, Engineering, and Mathematics. More specifically, STEM integration involves students' participation in engineering design to develop relevant technology through the integration and mathematical implementation or science in meaningful learning (Moore & Smith, 2014). STEM help

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learners apply their knowledge from various disciplines to create a new product. Therefore, STEM is one of the most important approaches to developing creativity (Bozkurt Altan & Tan, 2021). STEM learning is a strategy to improve the quality of graduates and make them ready to give solutions to community problems. Integrating science, technology, engineering, and mathematics (STEM) allows students to use their acquired skills in the real world and thus provides students with meaningful learning. Through engineering integration, students are aware of their role and existence in the community and can implement the engineering design process (EDP) to find solutions for real-world problems (Hidayah et al., 2019). Engineering design process (EDP) is one of the training methodologies used to support critical thingking skills. Reflective thinking is required in EDP to make better decisions in completing tasks given by the teacher (Putra, 2023)

According to Hafiz et al. (2019) EDP in STEM learning applications is a pedagogical strategy that directs students to a series of steps to generate the most effective solutions. These steps are tested repeatedly and correctly according to mathematical and scientific concepts. The results of an earlier review by Winarno et al. (2020) revealed that EDP is one of the learning models used to integrate STEM approaches in addition to Problem Based Learning and Project-Based Learning. One of the challenging factors in the implementation of STEM learning is teachers' readiness in designing STEM learning, including preparing appropriate teaching materials. This is in line with the results of SEAMEO QITEP research in 2016, which argues that teaching materials are one of the important elements that need to be considered in implementing STEM in Indonesia (Utami et al., 2020).

Teaching materials play a pivotal role in the teaching and learning process. Teaching materials are any collection of materials or learning content systematically arranged and used by teachers and students in the learning process (Widayanti et al., 2019). The utilization of teaching materials is a key component of putting education into reality. Because of the teaching materials, the teacher will have an easier time delivering lessons, and students will be more cooperative and find learning easier (Zan et al., 2023). Quality teaching resources must follow the intended curriculum, the development of science and technology, and bridge learning so that specified competencies can be achieved (Munthe et al., 2020). In order to meet the skills required in the 21st century, such as critical thinking and creativity, teachers need to be more creative in developing the learning process, one of which is by making innovations in the development of teaching materials in Biochemistry courses.

Biochemistry is the study of the chemical composition of living organisms, the structure, and characteristics of their constituent substances, and the transformation of such substances within living organisms. The abstract concepts which require higher-order thinking and a very limited time to deliver material are a few of many obstacles in biochemical learning. In addition, Biochemistry is a study that integrates knowledge and methods from various science disciplines using a real synthesis approach (Butnariu & Sarac, 2018). With that being said, Biochemistry plays a vital role in producing multidisciplinary solutions to complex real-world problems (Hardy et al., 2021). Therefore, teaching materials that correspond to biochemical characteristics are indispensable. STEM approaches that are interdisciplinary are aligned with the characteristics of Biochemistry so that they can become a reference in the development of teaching materials. Teaching materials are expected to provide opportunities for students to expand and deepen their knowledge and understanding through scientific explanations of real-world phenomena, which can hone students' skills.

STEM-based teaching materials are fundamentally different from common teaching materials. STEM-based teaching materials highlight the process of exploration and design that encourages active learning and makes it easier for students to understand the material. STEM-based teaching is guided by the Engineering Design Process (EDP) as the main focus in the problem-solving approach through thinking, designing, creating, and testing (Utami et al., 2020).

There are some recent studies concerning the development of chemical and biochemical teaching. For instance, the research by Munthe et al. (2020) successfully developed an e-module with a discovery learning model on valid and useable protein material. Another study by Pratiwi et al. (2020) has developed STEM-based project-based learning chemical teaching materials that are proven to be valid and practical for learning. Penelitian However, information related to the development of STEM-based Biochemistry teaching materials which integrate Engineering Design Process (EDP) activities is so far still limited. Accordingly, more in-depth research on the development of STEM-based Biochemistry teaching materials containing Engineering Design Process (EDP) activities is needed.

According to Hidayah et al., 2019, there are three crucial components in the teaching and learning process, namely teachers, learners, and teaching materials. Teachers and students will use teaching materials in the learning process (Widayanti et al., 2019). Teaching materials should be able to provide clear instructions for students to understand them. In addition, learning will be more effective if teachers are equipped with proper

teaching materials (Pratiwi et al., 2020). Therefore, the development of teaching materials should be based on the needs of teachers and students. By so doing, students will obtain the teaching materials that are an excellent match to their needs and be able to achieve the expected competencies, critical thinking skills, and creativity.

Three research questions that are the main focus of this research are: What are the teachers' expectations towards STEM-based Biochemistry module in promoting critical thinking and creativity?; What are the students' expectations towards STEM-based Biochemistry module in promoting critical thinking and creativity? and What do teachers and students have in common regarding their expectation towards STEM-based Biochemistry module in promoting critical thinking and creativity? This research aims to know the expectations of teachers and students towards STEM-based Biochemistry modules in promoting critical thinking and creativity.

## Method

The descriptive research was used in this study. A total of 9 Biochemistry lecturer and 64 students who have taken Biochemistry courses were involved as the research respondents. The sampling technique used was purposive sampling by giving questionnaire to the Biochemistry lecturer and the students from Biology Education and Science Education Program. The questionnaire instruments was used to determine the teachers' and students' expectations towards STEM-based Biochemistry modules. The questionnaire use scale ranges from 1 (strongly disagree), 2 (disagree), 3 (agree), and 4 (strongly agree) and include 13 statements for teachers and six statements for students. The instrument used has been validated by three experts with the average validation score was 93.7%. The respondent data used are presented in Table 1.

Research data were analyzed descriptively**.** The data analysis technique was carried out with the steps of discarding irrelevant data, presenting data in the form of diagrams, and drawing further verification or conclusions based on the analysis as shown in figure 1.

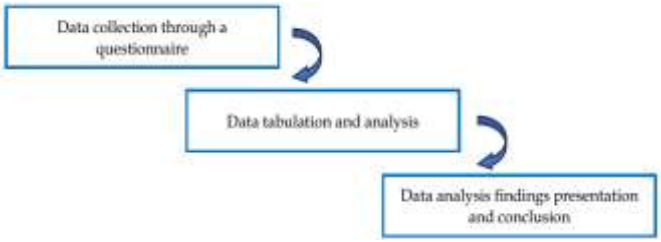


**Figure 1.** Research flowchart

**Table 1**. The Respondents Profile

| Respondents | Variable | Category | Quantity | Percentage (%) |
|---|---|---|---|---|
| Teacher | Gender | Male | 3 | 33.33 |
| | | Female | 6 | 66.67 |
| | Education | Master | 6 | 66.67 |
| | | Doctoral | 3 | 33.33 |
| | Teaching experience (years) | ≤ 10 | 3 | 66.67 |
| | | >10 | 6 | 33.33 |
| | Department | Biology education | 8 | 88.89 |
| | | Science education | 1 | 11.11 |
| Student | Semester | 3rd Semester | 16 | 25.00 |
| | | 5th Semester | 26 | 40.62 |
| | | 7th Semester | 22 | 34.38 |
| | Department | Biology education | 50 | 78.13 |
| | | Science education | 14 | 21.87 |

## Result and Discussion

The research results consist of the analysis of teachers' and students' expectations on Biochemistry STEM-based learning materials, which allow the development of students' critical thinking and creativity and their similarities. The result of the analysis is as follows.

**Table 2**. Result of the Teacher Expectation

| Statement | Percentage of category (%) | | | |
|---|---|---|---|---|
| | Strongly agree | Agree | Disagree | Strongly disagree |
| 1. Biochemistry learning materials should be designed based on the finding of the research so that they are relevant to the recent development of knowledge and technology | 89 | 11 | 0 | 0 |
| 2. Biochemistry learning materials should include contextual problems and instructions for problem-solving activities | 78 | 22 | 0 | 0 |

| Statement | | Percentage of category (%) | | | |
|---|---|---|---|---|---|
| | | Strongly agree | Agree | Disagree | Strongly disagree |
| 3. | Students will easily understand biochemistry learning material if it contains more theoretical discussion than practical materials such as experimental design activities | 11 | 11 | 56 | 22 |
| 4. | Biochemistry learning materials ideally involve problem-solving collaborative activities | 89 | 11 | 0 | 0 |
| 5. | Biochemistry learning materials should be aligned with the course learning outcomes (CPMK) and 21st century learning demand | 89 | 11 | 0 | 0 |
| 6. | To develop students' critical thinking and creativity, Biochemistry learning materials contain only factual knowledge without other conceptual, procedural, and metacognitive knowledge | 11 | 11 | 11 | 67 |
| 7. | Biochemistry learning materials need to be equipped with the technological feature, engineering, and mathematics to develop 21st-century skill | 67 | 33 | 0 | 0 |
| 8. | Biochemistry learning materials ideally lead to repeated testing activities and design improvement | 56 | 44 | 0 | 0 |
| 9. | Biochemistry learning materials delivered with a monodisciplinary approach lead to the development of critical thinking and creativity in problem-solving | 23 | 33 | 33 | 11 |
| 10. | Biochemistry learning materials formed into several units of learning activities make it students hard to study independently. | 44 | 44 | 12 | 0 |
| 11. | Biochemistry learning materials are ideally designed with language instruction that is clear, simple, and relevant to the Indonesian Spelling General Guidelines (PUEBI) | 67 | 33 | 0 | 0 |
| 12. | Biochemistry learning materials are ideally presented interactively through flipbook, video, pictures, and IT-based assessment feature to make students easily grasp the material | 78 | 22 | 0 | 0 |
| 13. | Biochemistry learning materials are ideally presented with an attractive layout design | 56 | 33 | 11 | 0 |

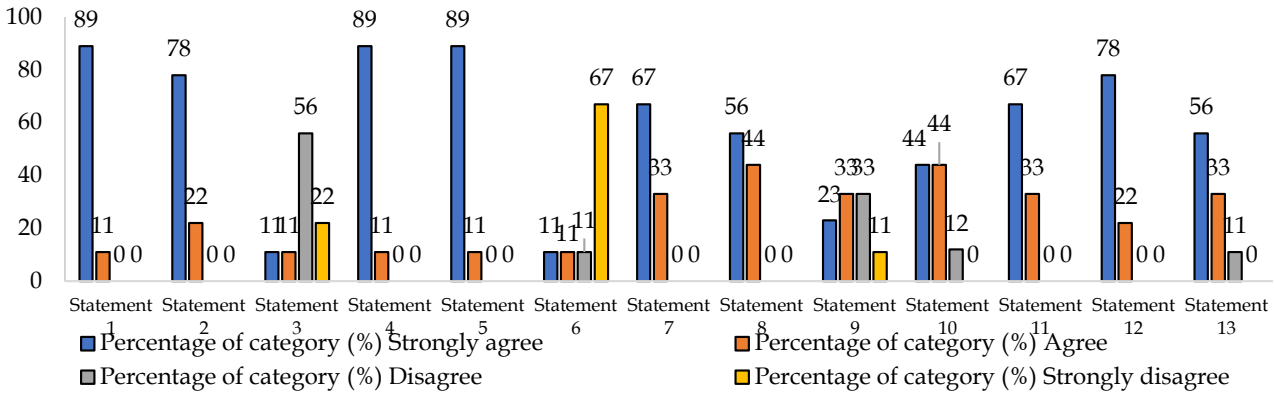


**Figure 2.** Results of the teacher expectation

According to Table 2 and Figure 2, the Biochemistry teaching materials that teachers expected are designed based on the research result because it is relevant to the development of science and technology. In addition, all respondents (teachers) also strongly agree with the idea of presenting teaching materials that provide daily contextual problems and direct students to problem-solving activities. They argue that the presentation of contextual issues is very relevant to the needs of the competitive 21st century. Through problem-solving activities, students will be trained to think critically and creatively. As many as 80% of teachers also believe that teaching materials equipped with designing an experiment will make students understand the material easily because designing activities or designing an experiment for solving problems will lead students to think critically and creatively. It is also supported by the opinion of teachers who expect the existence of

technological features (utilization of tools and materials), engineering (design activities or design experiments), and mathematics (mathematical calculations) in biochemical teaching materials, particularly in protein structure.

The expectations of respondents (teachers) are in line with the results of research (Putri et al., 2020), which shows that providing students with challenging and complex real-world problems through the STEM approach has been proven to increase students' creativity. STEM implementation through assigning students with challenging task projects encourages students to convey many formulations of ideas (fluency), provide a range of ideas to solve problems from the perspective of other disciplines (flexibility), and formulate a complete prototype design that is unique and different from other groups (originality). In addition, some stages, including problem-defining (define), problem analysis (learn), and planning/designing solutions (plan) in teaching materials, have proven to be able to strengthen students' critical thinking skills (Ulum et al., 2019).

In the aspect of the ideal Biochemical teaching material presentation, 44.4% of teachers strongly agree that the teaching materials presented in the units of learning activities will enable students to learn independently. In line with the opinion of Asrizal et al., (2023), stated that modules are educational resources prepared by teachers to make it easier for students to learn independently. According to Munthe et al., (2020), the module delivered ultimately and systematically allows learners to learn with or without teachers' assistance depending on their respective learning speeds.

In addition, all respondents also expect interactive teaching materials such as in the form of flipbooks, images, videos, as well as technology-based assessment features. According to Ula et al., (2023), flipbooks have the advantage of being able to provide a flip effect module (flippable pages). Flipbooks are also relatively simple to create, and the display module can be in the form of text and images, as well as video and audio supporting content. With the presentation of interactive teaching materials, teachers hope that student learning motivation will increase. In addition, interactive teaching materials require certain input from the user in text, graphics, animated images, simulation and video., Interactive multimedia applications are commonly designed to show specific results and provide feedback quickly (Pricilia et al., 2020).

**Table 3**. Result of the Students Expectation

| Statement | | Percentage of category (%) | | | |
|---|---|---|---|---|---|
| | | Strongly agree | Agree | Disagree | Strongly disagree |
| 1. | Biochemistry learning materials consist of dominant theoretical materials without applicable samples make me easily grasp the materials and train me to think critically and become creative | 20 | 42 | 34 | 4 |
| 2. | Biochemistry learning materials leading to experimental design activities make me motivated in solving problems | 29 | 67 | 3 | 1 |
| 3. | I need Biochemistry learning materials that are able to encourage me to learn independently | 52 | 43 | 5 | 0 |
| 4. | I need Biochemistry learning materials with clear, simple, and communicative language | 72 | 28 | 0 | 0 |
| 5. | Interactive learning materials in the form of flipbooks, video, pictures, and IT-based assessment features are easier and more practical to study | 54 | 42 | 2 | 2 |
| 6. | I become more motivated to study with Biochemistry learning materials which are presented with an interactive layout design. | 48 | 48 | 4 | 0 |

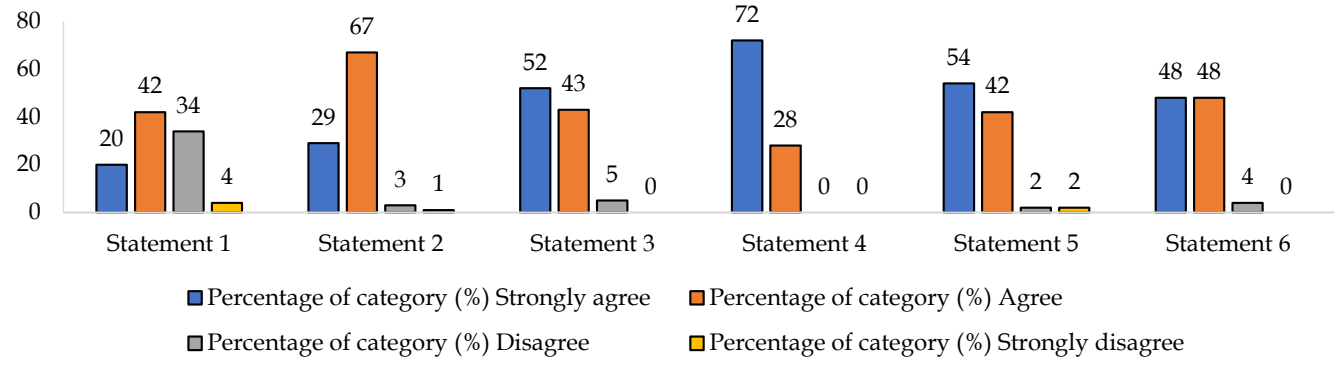


**Figure 3.** Results of the student's expectation

Table 3 and Figure 3 shows that the Biochemistry learning material that students expect is the one that contain directions to perform experimental design activities. 67% of the students agree with the design activities in their learning which promote problem-solving (statement 2). Students argue that the activity of designing experiments makes them more motivated to learn. In addition, students also expect biochemical teaching materials containing theoretical material presentations and more practical examples that can make them easily understand the material and train them to think critically and become creative. Students also expect an interactive presentation of Biochemistry teaching materials, for example, in the form of flipbooks, images, videos, and IT-based assessment features will develop their critical thinking skills and creativity.

This assertion is supported by the result of the study (Lok & Hamzah, 2021), which reports students' positive experiences using digital technology such as 3D animation and multimedia. They argue that these media provide them with a better understanding of the abstract concept of chemistry. In addition, other research from Osman et al. (2020) also suggests that using an interactive platform such as MyKimDG in game design projects can help improve students' understanding of chemistry material and develop their 21st century skills.

**Table 4.** The similarity between Teachers and Student Expectations Towards STEM-based Biochemistry Modules to Develop Critical Thinking and Creativity

| Aspects | Expectations of teachers and students |
|---|---|
| Design | Expecting teaching materials that lead to the activity of designing experiments to solve problems so as to train critical and creative thinking skills. In addition, they also desire the design of teaching materials in the form of units of learning activities that encourage students to learn independently |
| Content | Expecting biochemical teaching materials which contain not only theoretical material but also contextual problem-based applications |
| Presentation | Expecting the teaching materials to be in a clear, communicative, and simple language and using attractive layouts and designs. In addition, they also expect teaching materials that are packaged interactively, such as through videos, images, and IT-based assessment features |

Table 4 shows similarities related to the expectations of teachers and students towards STEM-based Biochemistry teaching materials to develop critical thinking skills and creativity. The similarities are related to aspects of design, content, and presentation. In the design aspect, both teachers and students expect biochemical teaching materials that lead to designing experiments to solve problems to train critical and creative thinking skills. Problem-solving activities are carried out on complex contextual issues related to biochemical materials.

This finding is in line with the characteristic of STEM, which emphasizes on design thinking process in problem-solving. According to Veerasinghan et al. (2021), design thinking uses sensitivity or mindset and methodology that a designer commonly uses to find an idea, solution, alternatives, and recommendations that suit stakeholders' expectations. Design thinking effectively promotes 21st-century learning in a complex interdisciplinary project in a holistic constructivist manner. As a holistic concept for designing cognition and learning, design thinking allows the students to successfully work in a multidisciplinary team to solve complex real-life problems.

In the aspect of content, both teachers and students expect biochemical teaching materials that contain a combination of theoretical (factual and conceptual) and applicable material (procedural & metacognitive). According to Kustiana et al. (2020), metacognitive refers to an individual's ability to regulate and control self-learning behavior. Metacognitive can help students become independent. While independent students are responsible for their learning progress, the implementation of STEM and learning can help them hone their higher-order thinking skills to help lead them to be creative, innovative, and responsible for themselves.

In the presentation aspect, teachers and students understand that STEM-based teaching materials can be packaged by utilizing multimedia, exciting designs and layouts, and clear and communicative language. According to Enawaty (2023), educational materials must now keep up with technological changes. Interactive multimedia-based teaching materials, such as e-modules, are one sort of teaching material that can facilitate today's digital generation's learning characteristics.

## Conclusion

Based on the findings of this study, teachers' expectations for STEM-Based Biochemistry modules that promote the development of critical thinking skills and creativity can be summarized as follows: the modules must include contextual materials and integrate elements of science, technology, engineering, and mathematics; there are problem-solving activities utilizing design thinking; and the presentation of

learning materials must be interactive and appealing. Students' expectations include: more applicable module content with contextual samples; design exercises in problem-solving; and dynamic and appealing learning material design. The survey also found commonalities in the expectations of teachers and students for STEM-based Biochemistry modules to foster critical thinking abilities and creativity in design, content, and presentations linked with STEM characteristics. This conclusion strongly suggests that STEM-based Biochemistry learning materials be developed to encourage students' critical thinking and creativity

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**Author Contributions**

All authors in this article contributed to the process of completing the research. Novy Eurika conceptualize the research idea, designed the study, collected the data and performed the experiments under the guidance of Suratno, Sutarto, and Jekti Prihatin as a supervision of the project, contributed to the literature review and provided critical feedback on the manuscript. All authors participated in the writing and revision of the manuscript.

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**Conflicts of Interest**

In this study all authors do not have a conflict of interest, because this research is independent research in which all funds spent during the research process use the researcher's personal funds. There are no other interests in this research, but researchers only want to contribute to advancing education by informing the findings in this research. So that it can provide more benefits to the reader."

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