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Article

The Multilevel Inquiry Approach to Achieving Meaningful Learning in Biochemistry Course[S]

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Abstract

Biochemistry learning in higher education not only aims to allow students to remember the concepts learned, but also to achieve meaningful learning. This study examines the implementation of the multilevel inquiry approach in order to achieve meaningful biochemistry learning. Such as approach begins with a structured inquiry, leading to a guided inquiry, and ending with an open inquiry on topics that are connected to each other. A posttest-only control group design was employed, with a total sample of 87 students taking biochemistry courses. The control class consisted of 43 students, with 44 students in the experimental class. The variables tested were learning outcomes, practical skills, and attitudes toward biochemistry, while the effect of the implementation of multilevel inquiry on these three variables was analyzed using multivariate analysis of variance (MANOVA). The results show that the class that applied the multilevel inquiry approach achieved higher scores in all three variables than the control class. The MANOVA test shows that the implementation of this approach has a positive effect on the three variables, which represent the cognitive, psychomotor, and affective domains, and that multilevel inquiry was able to foster meaningful learning in biochemistry courses. © 2019 International Union of Biochemistry and Molecular Biology, 00(00):1–10, 2019.

Keywords: *Attitudes toward biochemistry; biochemistry learning; inquiry; meaningful learning; practical skills*

Introduction

Biochemistry learning not only aims to help students to remember information and overcome misconceptions, but also to develop their conceptual understanding [1]. Learning is directed more at the activity of discovery and the development of thought processes, in order to train students to develop their cognitive, communicative, social, and moral domains, as well as their personalities and attitudes [2]. This can be achieved if the learning process is supported by material content, appropriate approaches and management of quality learning [3, 4].

Biochemistry is a field of science that has widespread applications. Biochemistry learning is related to living things, so the content delivered is of high interest [5]. However, interesting content is not always accompanied by successful learning practices; negative responses to biochemistry learning have been reported by several researchers [6, 7]. Therefore, it is important to conduct further studies to find solutions to such problems.

Certain problems have been found in the biochemistry learning process; for example, the complexity of visualization, the use of terms that are difficult for students to understand, content that is not relevant to students' lives, and the delivery of too much content in class are examples of problems faced by students in biochemistry classes [6, 8, 9]. Students' opinions that biochemistry learning is unpleasant and irrelevant to their careers and lives are important considerations in the learning process [10–12].

Like science learning, biochemistry includes laboratory work in the learning process. However, problems often faced by lecturers and students are that the practical content is not relevant to student life and that the topic of investigation is not integrated with other learning topics in the

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classroom [13, 14]. In addition, the common application of the cookbook laboratory is less effective in training students to think critically, learn practical skills, and develop relevant attitudes and motivations [15–17].

Inquiry is related to constructivist theory, which posits that the acquisition of knowledge by individuals begins with the formation of an individual's initial understanding. Furthermore, individuals actively build their own knowledge and connect new concepts to prior ones [18]. These prior concepts can help students construct further knowledge and make it easier for them to make connections between concepts learned and applications in the form of investigations [19].

The inquiry approach has been reported to enable the training of students' thinking and practical skills [20–22]. In addition, inquiry activities are known to be able to develop scientific attitudes and student motivation to learn [14]. Inquiry-based learning can also be applied to courses that involve laboratory work in the learning process.

The inquiry is divided into four levels, namely level 0 (verification), level 1 (structured inquiry), level 2 (guided inquiry), and level 3 (open inquiry) [23]. A description of the four levels is given in Table I. The use of inquiry and open inquiry has also been reported to be able to improve students' understanding of chemistry learning [24–26]. However, direct application of guided and open inquiry can make students uncomfortable, because they are used to conducting investigations with procedures provided by lecturers [27, 28]. Multilevel inquiry related to the research stages was studied by Kakisako *et al.* [29] in relation to the chemical properties of hard water. However, to date few research reports have investigated the application of tiered inquiry approaches to biochemistry learning in higher education.

Meaningful Learning

Meaningful learning is defined as learning which can encourage students to expand, modify, and develop information systematically, so that the concepts studied are relevant to long-term memory [30]. It can occur if students actively interact independently and collaboratively on meaningful tasks, so that they are practicing critical thinking and problem-solving skills [31].

Meaningful learning has three main requirements, as listed below [32, 33]:

1. Students must have the initial knowledge relevant to the placing and capturing of new knowledge.
2. Students should believe that the material to be learned is relevant to other knowledge and must contain significant concepts and propositions.
3. Students must consciously and deliberately choose to relate to any new knowledge and to develop their initial knowledge.

According to Grabe and Grabe [34] and Jonassen [35], meaningful learning comprises five dimensions, as shown in Table II. These five dimensions show that such learning will only occur if the learning provides an experience that requires students to relate knowledge to the three domains, namely the cognitive, psychomotor and affective [36].

Methods

Scenario

Multilevel inquiry involves structured inquiry, guided inquiry and open inquiry in tiered topics. In structured inquiry, students are given problems and procedures for obtaining data, but the way the data are interpreted is decided by them. Guided inquiry provides opportunities for students to construct procedures and methods for data analysis, but the problems are posed by the lecturer. On the other hand, open inquiry provides an opportunity for students to develop problems, procedures and problem solving themselves. The multilevel inquiry scenarios are listed in Table III.

Traditional laboratory approaches involve the following stages:

a. Students obtain explanation topic such as students in experiment class with the application of multilevel inquiry.

TABLE I *Levels of inquiry in chemistry laboratory experiments [23]*

Level	*Problem/Question*	*Procedure/Method*	*Solution*
0	Provided to student	Provided to student	Provided to student
1	Provided to student	Provided to student	Constructed by student
2	Provided to student	Constructed by student	Constructed by student
3	Constructed by student	Constructed by student	Constructed by student

TABLE II *Five dimensions of meaningful learning [34, 35]*

Dimensions	*Definition*
Active	Learners are organisms, which interact with the environment, in which they process their learning and monitor its process. Therefore, learners play dynamic roles in learning activities.
Authentic	Learning in authentic environments stimulates motivation, as learners accept learning tasks designed from the real world.
Constructive	Constructive learning means that learners integrate new ideas into their prior knowledge/experiences.
Cooperative	Working in a knowledge-building community makes it possible for learners to exploit each other's skills and provide social support and modeling for other learners.
Integrated	Content knowledge and technology should be integrated into teaching/learning processes with smooth and vivid applications.

b. They are given questions by the lecturer that must be answered through investigation activities.
c. They are given step-by-step investigation activities to conduct.
d. They follow the step-by-step investigation instructions.
e. They collect data and interpret them based on the lecturer's instructions.

For this study, implementation of the learning scenarios took place over 2–3 weeks for each level of inquiry. The learning process involved eight teaching assistants, who help the researchers to evaluate the students' performance. Before conducting the assessment, the teaching assistants attended a workshop, which included an explanation of the main and support activities they needed to undertake during the learning process. The main activities included the rules that must be followed by assistants and students; how to make practical skills assessment; how to communicate with students; how to use practical skills assessment instruments; how to observe student activities during learning; and how to analyze student reports. Support activities included cooperation with other teaching assistants if there were any problems or difficulties. After the workshop, the researchers presented their outcomes in the form of a summary teaching assistant job description.

TABLE III *Multilevel inquiry scenarios*

Level of inquiry	*Scenario*
Structured inquiry	a. Students were given an explanation of the structure, properties and qualitative analysis method of amino acids. b. They were given procedures for the qualitative analysis of amino acids employing Millon reaction, Hopkins-Cole reaction, the ninhydrin test, and the Biuret test. c. They conducted investigations in accordance with the procedures provided by the lecturer. d. They collected data and interpreted the results of their investigation.
Guided inquiry	a. Students were given an explanation of the structure, properties, and analysis method of protein in a sample. b. They were given the task of designing investigations to analyze the protein content of the sample by selecting one of the procedures studied. c. They implemented an initial investigation to obtain data and then interpreted the results.
Open inquiry	a. Students were given an explanation of enzymes as protein molecules. b. They were asked to devise an appropriate problem and to design investigations into the theme of "protease enzymes." c. They implemented an initial investigation to obtain data and then interpreted the results.

Implementation of each level of inquiry involved teamwork in groups. The selection of group members in the control and experiment classes was made using the results of the pre-intervention evaluation, which was categorized based on the percentage of student mastery. Three basic concept categories were employed, namely high, medium, and low (Table IV). Each group comprised 4–5 members, with students representing the high, medium, and low mastery categories in the same proportions. There was a total of 10 groups in each control and experimental class.

Research Design

The study used a posttest-only control group design consisting of two groups, an experimental group and a control group [38]. The experimental group followed a multilevel

TABLE IV Mastery category of prior concepts [37]

Percentage of concept mastery	Category
$66.67\% \leq X$	High
$33.33\% \leq X < 66.67\%$	Medium
$X < 33.33\%$	Low

$X = \frac{x}{n} \times 100\%$.
x = score.
n = total score.

inquiry approach, while the control group took a traditional laboratory approach. After the process, each group was given a final test. The sample comprised Universitas Mataram students taking Biochemistry courses, with a total sample of 87 students taken randomly from a population of 116. The control class consisted of 43 students, with 44 students in the experimental class.

Research Instruments

Three variables were measured, namely learning outcomes, practical skills, and attitudes toward biochemistry. The instrument used to measure the learning outcomes was a test based on four indicators: understanding the structure and properties of amino acids; understanding the structure and properties of proteins; understanding the action mechanism of enzyme; and understanding the factors that affect the workings of enzyme. Each indicator comprised two or three essay questions, with each question given a score according to the rubric developed. The learning outcomes were assessed based on the accuracy of the answers, analysis, and reasons given.

Practical skills were measured using a rubric consisting of three aspects: procedural skills, observation skills and interpretation skills. Procedural skills included the ability of students to plan the tools and materials to be used, to determine these, and to conduct work procedures. Observation skills were the ability of students to make observations, while interpretation skills included their ability to record and interpret the inquiry data. Each skill measured was based on simple reports compiled by the students and observations made by the teaching assistants. The report consisted of eight columns: lab work purposes, tools, materials, work procedures, observation, analysis, interpretation, and conclusion. The columns were filled in by the students in both groups and collected after the investigation had been completed. The practical skill scores were based on the number of criteria students were able to meet. If all the criteria were fulfilled appropriately, the highest score given was four. If none of criteria was met, the lowest score given was one. For example, the students were asked to indicate the objectives, tools, materials and stages of the investigation in the relevant column in the report. This information was associated with hands-on ability performance. The students who displayed performance that matched the criteria listed in the rubric obtained the maximum score.

Statements regarding attitudes toward biochemistry were modified from Cheung's [27] questionnaire. The original questionnaire only contained positive statements, while for this study negative statements were added to avoid data bias. Four categories were measured: liking for biochemistry theory lessons (LBTL); liking for biochemistry laboratory work (LBLW); evaluative beliefs about biochemistry (EBB); and behavioral tendencies in learning biochemistry (BTLB). Each category was developed into three positive and negative statements, with five answer choices: strongly agree, agree, neutral, disagree, strongly disagree. The students' attitude toward biochemistry was given the lowest score (1) for the strongly disagree answer, with the highest score (5) given for strongly agree with regard to positive statements. Conversely, for the negative statements the lowest score 1 was for the strongly agree answer and the highest score 5 was for the strongly disagree choice. The learning outcome tests, the rubric for scoring the tests, the practical skills rubric, and the questionnaires on attitude to biochemistry are provided as Supporting Information Appendix S1.

Two experts validated the content of each instrument, 1) employing the assessment categorizations of not relevant; 2) insufficiently relevant; 3) relevant; and 4) very relevant. The validity and reliability of the experts' assessment results were examined. The results of their validation showed that the indicators in the learning outcomes instrument, the practical skills rubric, and the attitudes toward biochemistry questionnaire were all valid. The Gregory index scores in these three areas were 0.8 (high), 0.78 (mediocare) and 0.75 (mediocare), respectively, while the reliability testing based on inter-rater reliability (IRR) showed IRR scores in the three instruments of 0.78–0.83 in the mediocare-high category [39]. Expert judgment analysis showed that the instruments were valid and reliable.

Data Analysis

The scores for each measured variable were collected and averaged. Student achievement scores were analyzed using multivariate analysis of variance (MANOVA), with support from SPSS 21 (IBM SPSS Statistic 21), to determine the effect of the implementation of multilevel inquiry on the three variables. Supporting Information Appendix S1 in the form of student suggestions and comments, and observation of students by the teaching assistants, were analyzed and described in general.

TABLE V *Pre-intervention evaluation scores*

Group	*N*	*Score average*	*SD*	p
Control	43	84.17	0.267	0.895
Experiment	44	83.98	0.269	

Results

Before the treatment, an evaluation phase was conducted using short answer questions (SAQ). The questions asked in the pre-intervention served as basic knowledge to understand the four indicators used (Supporting Information Appendix S1). For example, students needed to understand stereoisomers and the properties of carboxyl and amine groups to understand the structure of amino acids. The average pretest scores in the control and experimental classes were 84.17 and 83.98, respectively. The Levene test shows that the probability value higher than 0.05 meant that the pretest score variance before treatment between the control and experiment classes was the same. It can be concluded that the average pretest score before treatment did not differ significantly between the two classes (Table V).

The student learning outcomes in the multilevel inquiry approach showed higher average scores than the traditional laboratory work approach. The average score in the experimental class was 72.92 (SD = 6.64), while in the control class it was 59.125 (SD = 8.17). Analysis of each indicator obtained the same results; that is, the students who employed a multilevel inquiry approach achieved higher average scores than those who undertook traditional laboratory work ($p < 0.05$). The average scores of the four indicators achieved by the two groups of students are shown in Fig. 1.

In the class that took the multilevel inquiry approach, the students were able to answer the questions with fairly good explanations compared to the traditional laboratory work group. They were able to explain the relationship between amino acids and proteins based on the analytical techniques used in the laboratory; to explain the action mechanism of enzyme and the factors that affect their working; and to conduct laboratory tests on this action mechanism. The enzyme action mechanism was the indicator with the lowest achievement obtained by the students.

Practical skills show the ability of students to understand and conduct work procedures in the laboratory. The application of multilevel inquiry enabled this class to achieve higher practical skill scores (M = 77.7; SD = 7.54) than the one which conducted traditional laboratory work (M = 60.43; SD = 7.47). Each skill category measured showed higher results for the students who took the multilevel inquiry approach ($p < 0.05$) (Fig. 2).

The implementation of multilevel inquiry influenced the students' procedural skills. From the results of the analysis of the reports and the performance of students in the laboratory, those who applied multilevel inquiry showed the ability to achieve the purposes of the investigation, and to determine the tools and materials for the investigation in order and with care. They were also able to follow the investigation phase well and systematically without referring to the notes. The students who undertook traditional laboratory work did not fill out all the fields in the investigation report completely. In addition, according to the observations of the teaching assistants, in the laboratory the students were not able to systematically conduct the investigation phase and were often confused.

Observation skills showed higher scores in the class, which applied multilevel inquiry. Mastery of inquiry procedures had implications for students' ability to observe,

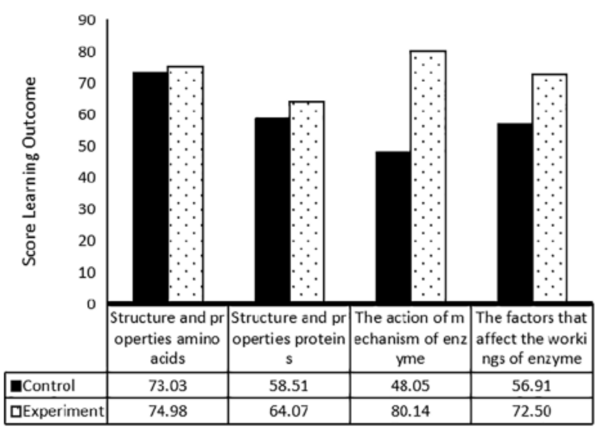


FIG 1 *Effect of multilevel inquiry on learning outcomes scores.*

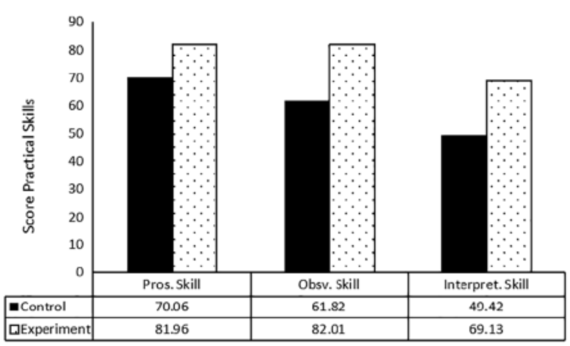
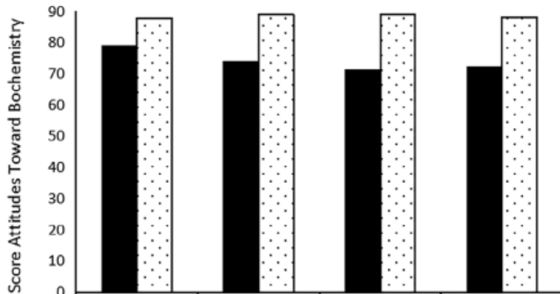


FIG 2 *Effect of multilevel inquiry on practical skills scores.*



	LBTL	LBLW	EBB	BTLB
■Control	78.76	73.80	71.01	71.94
□Experiment	87.73	88.79	88.79	88.03

FIG 3 *Effect of multilevel inquiry on attitudes toward biochemistry scores.*

record and collect data carefully and systematically, skills which were not found in the control class, where students were less thorough and systematic when conducting observations in the laboratory. This inaccuracy clearly affected the students, as shown by the interpretation of the results of the investigation. The incompleteness of the data meant students were unable to make appropriate analysis or to build arguments about the results of their investigations.

The biochemistry attitude scores in the multilevel inquiry class showed higher values than in the traditional laboratory work class, at 88.33 (SD = 3.07), compared to 73.88 (SD = 3.18) ($p < 0.05$). This was the case for all the attitude categories (Fig. 3).

In the class undertaking traditional laboratory work, the lowest attitude category was that of preference for biochemistry laboratory work and the tendency to study biochemistry. Students indicated they were "neutral" in response to the statement "doing biochemistry experiment is fun" and "If I had the chance, I would do a project in biochemistry." The scores in the preference category for liking biochemistry laboratory work and behavioral tendencies to learn biochemistry were 71.01 and 71.94, respectively.

Analysis of the relationship between the implementation of multilevel inquiry and learning outcomes, practical skills, and attitudes toward biochemistry was made using the MANOVA test. Box's test of the quality of covariance matrices shows an M test value of 2.219, an F test value of 0.356, and a significance level of 0.356. Values of significance levels higher than 0.05 indicate that the variance/covariance matrix of the dependent variables is the same. These test results fulfill the MANOVA assumption, so the analysis can be continued.

The next analysis was a multivariate test to ascertain whether the implementation of multilevel inquiry affected all three dependent variables. The test results show that the significance values for Pillai Trace, Wilk Lambda, Hotelling Trace and Roy's Largest Root were lower than 0.05, so it was concluded that in general there was a relationship between the implementation of multilevel inquiry and learning outcomes, practical skills, and attitudes toward biochemistry.

The following analysis was a test of between-subject effects to test the effect of multilevel inquiry implementation on each dependent variable. Previously, a Levene test was conducted to establish whether the MANOVA assumptions were fulfilled in the test. The significance of the three variables was greater than 0.05, which means that they had the same variance. This is consistent with the MANOVA assumptions, so the analysis could be continued.

The results of the test of between-subject effects show significance lower than 0.05 for the relationship between the implementation of multilevel inquiry and learning outcomes, practical skills, and attitudes toward biochemistry, which means that the implementation had an influence on the three variables (Table VI). The levels of adjusted R squared for learning outcomes, practical skills and attitudes toward biochemistry were 48.8, 57.5 and 84.5%, respectively.

Discussion

This research was designed to improve students' understanding by taking a multilevel inquiry approach to learning. Previous research has reported that such an approach is able to improve their understanding and problem-solving skills [24, 26, 40–44]. In addition to students, the approach can also provide experience for lecturers to develop learning materials and improve their teaching skills [45].

Multilevel inquiry was employed for several reasons. First, Universitas Mataram students have been using conventional learning and cookbook laboratories in investigation processes, so the inquiry approach is not yet familiar to them. Second, direct application of guided and open inquiry can make students uncomfortable, because they are accustomed to conducting investigations with procedures provided by lecturers [27, 28]. Third, the use of tiered approaches, starting from easy topics to ones that are difficult to report, can improve student skills in the investigation process [46, 47]. Fourth, tiered stages allow integration of topics and approaches, enabling students to connect together each stage of the investigation.

The first stage was the use of structured inquiry, which involved stages similar to conventional learning. The role of the lecturer was more evident in the process of learning and investigation, and students were given detailed investigation procedures, such as a cookbook laboratory. The structured inquiry approach is not always a bad method; even though it does not involve students very much, it can be used as a pre-investigation to train their readiness to face more severe investigative problems. Pre-investigation activities have been reported to be able to prepare students for planning subsequent investigations [48–51]. The cookbook laboratory at the

TABLE VI ***Manova analysis of the implementation of multilevel inquiry***

Source	*Dependent variable*	*Type III sum of square*	*df*	*Mean square*	*F*	*Sig.*
Corrected Model	Learning outcome	4138.79*	1	4138.795	74.775	0.000
	Practical skills	6483.175†	1	6483.175	114.966	0.000
	Attitudes	4545.484‡	1	4545.484	464.504	0.000
Intercept	Learning outcome	379182.941	1	379182.941	6850.651	0.000
	Practical skills	414943.025	1	414943.025	7358.204	0.000
	Attitudes	572207.298	1	572207.298	58473.933	0.000
Treat	Learning outcome	4138.795	1	4138.795	74.775	0.000
	Practical skills	6483.175	1	6483.175	114.966	0.000
	Attitudes	4545.484	1	4545.484	464.504	0.000
Error	Learning outcome	4704.742	85	55.350		
	Practical skills	4793.310	85	56.392		
	Attitudes	831.783	85	9.786		
Total	Learning outcome	388987.943	87			
	Practical skills	427467.689	87			
	Attitudes	578833.333	87			
Corrected Total	Learning outcome	8843.537	86			
	Practical skills	11276.485	86			
	Attitudes	5377.267	86			

**R squared= 0.468 (adjusted R squared = 0.462).*
†R squared = 0.575 (adjusted R squared = 0.570).
‡R squared = 0.845 (adjusted R squared = 0.843).

beginning of learning can improve student laboratory work skills in dealing with inquiry approaches [20].

The second stage was the use of guided inquiry, representing the beginning of student involvement in designing investigations. Students start to be trained to compile and prepare their own investigation processes independently; no detailed procedures are prepared by the instructor. Investigation design activities benefit students, increasing their ability to argue, increasing motivation, and helping to realize meaningful learning [48, 52, 53]. The ability of students to design investigations determines the success of these, and increases their responsibility and readiness to conduct investigations [54–56].

Inquiry design sharpens student skills in using instruments in the laboratory; helps implement planned procedures and record investigation data correctly; and aids analysis of investigative data, its systematic presentation, and subsequent interpretation [16, 57]. In addition, successful planning and implementation can increase students' confidence in conducting investigations [58, 59].

The next step was the implementation of open inquiry, which gives students the opportunity to determine problems, draw up a draft investigation, and interpret the data. In the group, which applied multilevel inquiry, the source of the enzyme studied was waste, such as that from pineapple and papaya. In contrast, in the class that applied the cookbook laboratory approach, the enzymes tested were determined by the lecturer and the students only followed the procedures in the laboratory work instructions. The draft inquiry prepared by the students was considered in advance through class discussions, which were intended to keep the investigation process conducted by the students under control [60]. The experience of structured and guided inquiry was demonstrated by students by linking previous investigations into the design of their own.

The processes that occurred in the inquiry approach included the following steps:

1. Students arranged their own questions. For example, the lecturer gave the students the task to draft a laboratory investigation with the theme "protease enzyme." The students began work by compiling questions related to the theme given; examples included "How can bromelin enzymes be isolated in pineapple?" and "Does temperature affect the activity of the bromelin enzyme from pineapple?" The questions developed by the students were written in the relevant column for the purpose of the investigation.
2. Students collected information to answer questions that have been developed. They developed a draft inquiry

based on information obtained from the literature. The results of the literature study led students to determine the tools, materials, and stages of work required to isolate the bromelin enzyme and to determine the effect of temperature on its activity. After the design of the investigation had been compiled, the students collected data and wrote down their observations in the observation column.

3. Students analyzed the information. The results of the observations produced led them to analyze the results of the investigation. For example, they found that bromelin enzyme activity decreased at temperatures above 60°C. The analysis written by the students showed that at temperatures above 60°C the enzyme protein denatured and lost its catalytic activity. The explanation of protein denaturation was connected with initial knowledge in previous discussions about the properties of proteins.
4. Students concluded the results of the inquiry in response to the questions they posed earlier. For example, temperature can affect the activity of the bromelin enzyme.

In the cookbook laboratory, students only followed laboratory work procedures that had been compiled in practical instructions. Each stage was not yet understood by the students; for example: Why does enzyme isolation use buffers when making crude enzyme? What is the function of TCA in measuring protease activity? This is in contrast to the experimental class, where the enzyme topic involved open inquiry, which demanded the independence of students in compiling investigation procedures and required them to learn and understand each stage needed in the investigation process.

The use of multilevel inquiry does not mean it is necessary to pay more attention than in the cookbook laboratory. Multilevel inquiry provides more opportunities for students to participate in the investigation process, with lecturers as facilitators. This is different from the cookbook laboratory, which only follows investigation procedures, without understanding the intent of each stage. The use of multilevel inquiry requires students to gradually design the investigation process independently.

The responsive analysis made by the students shows that the use of multilevel inquiry was satisfying for them. Some examples of the students' opinions are given below.

"The multilevel inquiry approach presents a challenge for me to make a better investigation plan. I am very happy if I succeed in the investigation process."

"During this time I was not happy to carry out an investigation in the laboratory because I did not understand every stage of the work given. However, through the multilevel inquiry approach, I slowly understood each stage of the investigation and felt interested in conducting an investigation."

Negative responses were also given by students:

"I still experience confusion in starting an investigation process because this approach is something new for me."

TABLE VII ***Meaningful learning in the multilevel inquiry approach***

Dimension	*Multilevel inquiry*
Active	Through multilevel inquiry, students are active in: a. compiling an inquiry design through a study of the literature. b. preparing the tools and materials needed for investigation. c. conducting investigations in accordance with the design they have arranged. d. collecting and analyzing the data, and drawing conclusions in accordance with the draft investigation that has been prepared.
Authentic	Through multilevel inquiry, students are given more opportunities in preparing the investigation process. The stage of designing a good inquiry process determines the success of the investigation process, which can increase student motivation.
Constructive	Multilevel inquiry helps students conduct investigations independently. Investigation at the level of structural inquiry gives students initial knowledge and experience for inquiry at the guided level. Investigation at the level of guided inquiry gives students the knowledge and experience for subsequent open inquiry.
Cooperative	The stage of designing an investigation makes all group members work well together in preparing the investigation process. The positive interdependence formed among group members aims to ensure the success of the investigation phase.
Integrated	Students at the open inquiry stage have the ability to isolate crude bromelin enzymes from pineapple waste. Analysis of each procedure designed by the students shows that they understand the stages of enzyme isolation.

Improved learning outcomes, practical skills, and attitudes toward biochemistry associated with the application of multilevel inquiry are shown by the responses given by the students. According to Cheung [34], successful inquiry can occur if students have belief, which can be built in four ways: experiencing success; observing success; building motivation; and verbal persuasion (the suggestion to believe that one can succeed). The implementation of multilevel inquiry increases students' motivation to start from the inquiry guide, strengthening their confidence to succeed in the next investigation. Feelings of pleasure when successful, or disappointment when not, can be sources of motivation to succeed in subsequent investigations [61–63].

Based on five dimensions that represent meaningful learning [34, 35], multilevel inquiry can achieve such learning on biochemistry courses. An explanation of five-dimensional meaningful learning in the multilevel inquiry approach is shown in Table VII.

Conclusion

The application of a multilevel inquiry approach can have a positive influence on learning outcomes, practical skills, and attitudes toward biochemistry in biochemical learning. Learning outcomes are part of the cognitive domain; practical skills part of the psychomotor domain; and attitudes toward biochemistry represent the affective domain. Strengthening the three variables that represent the three learning domains shows that the implementation of multilevel inquiry can achieve meaningful learning on biochemistry courses.

Limitations

There are several limitations to this study. First, a comparison is only made between classes implementing conventional learning and multilevel inquiry approaches. Second, the study has not used groups applying the four levels of inquiry, so the influence of the learning outcomes, practical skills, and attitudes toward biochemistry on each level of inquiry has not been covered in this research. The use at least three classes/year is recommended for future research.

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