RESEARCH ARTICLE

Hypothetical learning trajectory in microbiology course through argumentation-based inquiry learning

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Abstract: The application of effective teaching methods needs to be implemented to improve the quality of microbiology education which can empower important competencies in the current era. This study aims to analyze the application and trajectory of argumentation-based inquiry learning through the application of microbiology lectures. This research uses research design methods consisting of preliminary design steps, teaching experiments and retrospective analysis. The source of the data comes from student learning activities in argumentation-based inquiry learning implemented in microbiology courses. The results showed that the learning trajectory of Hypothetical Learning Trajectory (HLT) in microbiology lectures with an argumentation-based inquiry model was in accordance with the stages of student research ranging from determining research themes, compiling proposals, designing and implementing data collection, analyzing data, discussing research results, writing research reports to conducting scientific publications in journals. Students who carry out microbiology lectures using argumentation-based inquiry learning through the implementation of different research in the field of microbiology experience a similar learning trajectory so that a specific and distinctive set of Hypothetical Learning Trajectory (HLT) can be formulated.

Keywords: argumentation-based inquiry; hypothetical learning trajectory; inquiry learning; microbiology

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Introduction

Biology as part of science, provides support for the development of human civilization through science products, science processes and scientific attitudes (Arens & Glazko, 2022; Earla, 2015; Lickliter & Honeycutt, 2015). Knowledge and products of science are obtained through research and a series of experiments that are continuously developed and strengthened by scientists to obtain optimal benefits (Rodríguez-Vargas et al., 2020). Biology as a subject in schools should be applied and developed as scientists discover and develop biological concepts through research and experimentation (Borisenko et al., 2021; Satybekova et al., 2023). Microbiology learning is one of the important aspects in biology education given its significant role in the fields of medicine, pharmacy, biotechnology and the environment (Brockman et al., 2020; Muliadi, 2020).

Microbiology is one of the compulsory courses for students in the Tadris Biology Study Program which equips students with knowledge and skills in studying microorganisms as living things, and their roles for life \. Traditional lecture methods that are teacher-centered and less actively involve students are now starting to shift towards a more innovative, interactive and student-centered approach (Bull et al., 2020; Lall & Datta, 2021). Microbiology courses provide opportunities for students to learn theory and practice in getting to know the life of microorganisms through lecture activities carried out using various strategies and approaches, including using research-based lectures through argumentation-based inquiry learning (Fating et al., 2024). The steps of learning this argumentation-based inquiry are 1) Introducing inquiry problems and questions; 2) Formulate initial group arguments and hypotheses; 3) Design and carry out experiments; 4) Analyze data and formulate group arguments; 5) Conduct class argumentation sessions

by critiquing the arguments of other groups; 6) Make reports on research results and arguments; 7) Conduct peer review of reports; 8) Revise and evaluate reports (Sampson et al., 2011; Roviati, 2020).

Argumentation-based inquiry lectures are expected in addition to developing knowledge in the field of microbiology, also developing skills such as higher-order thinking skills, laboratory skills, science process skills, scientific argumentation skills and research skills (Taş et al., 2022; Rodríguez et al., 2019). In this context, argumentation-based inquiry learning is emerging as a promising pedagogical strategy, designed to enhance student engagement, critical thinking, and their argumentation and problem-solving skills (Rapanta & Felton, 2022; Memis & Akkas, 2020; Fakhriyah et al., 2021).

Argumentation-based inquiry learning activities have not been widely carried out in biology lectures. Though inquiry learning is known as a learning model that develops the ability to work scientifically which is an extension of the scientific method and is also considered as one of the superior cognitive models in science learning in schools (Saefi et al., 2023). Likewise, the linkage of inquiry in developing students' research skills (Dikilitaş & Bostancioglu, 2019) and research skills and creativity (Rodríguez et al., 2019). Meanwhile, argumentation is an important component in science learning by giving meaning to the learning process, considering that science is developed through the construction of knowledge and theories equipped with explanations and evidence that make it the knowledge believed today (Yilmaz et al., 2017). Argumentation in science learning is also applied to develop critical thinking skills, reasoning abilities, and understanding concepts (Roviati & Widodo, 2019). Furthermore, argumentation-based inquiry has also been examined for its contribution in developing formal reasoning skills and argumentation skills, science learning achievement, writing skills and science process skills (Acar & Patton, 2012; Demirbag & Gunel, 2014; Demircioglu & Ucar, 2015).

Hypothetical Learning Trajectory (HLT), an innovative approach that aims to plan and predict the learning process in students, so as to optimize learning outcomes, is a concept used in mathematics education and is now increasingly recognized in various disciplines as a tool for designing effective learning (Stevens, 2021; Simon, 2020; Berland & McNeill, 2010).This concept focuses on planning the expected learning path, starting from learning objectives, activities to be carried out, to predicting student responses and learning adjustment strategies (Simon, 2020). Through this approach, lecturers can design lecture sessions that not only facilitate academic knowledge, but also develop students' critical and argumentative thinking skills (Tritschler et al., 2019).

This concept was first introduced in the context of mathematics education by Douglas Clements in 1989 with the perspective of constructivist learning theory (Simon, 2020). However, since then, the concept of HLT has developed and is used as a valuable tool for guiding instructional design and assessment in various disciplines, including education, social sciences, and science (Alonzo & Elby, 2019; Clements & Sarama, 2020). At the core of the HLT concept is the understanding that each student has a unique learning journey, and as educators, we can design the "trajectory" of learning expected for them. Nevertheless, their potential in structuring microbiology education through Argumentation-based inquiry has not been thoroughly investigated. Most research on HLT has been conducted in mathematics or elementary science education (Duschl, 2019; Simon, 2020; Cardace et al., 2021), suggesting a need for more studies in the context of microbiology.

Key elements in the HLT concept include (1) Learning Objectives: Determining what students are expected to learn or achieve during the learning process; (2) Learning Activities: Design a set of activities that support the achievement of learning objectives. These activities can be discussions, experiments, assignments, or other interactions that allow students to be actively involved in the learning process; (3) Prediction of Student Response: Considers how students might respond or react to the designed learning activity, including possible difficulties or confusion they may face; and (4) Learning Adjustments: Planning strategies to overcome challenges or difficulties that students may face during the learning process. This could include providing additional assistance, simplifying materials, or providing additional resources (Baroody et al., 2022; Simon, 2020; Clements & Sarama, 2020; Sztajn et al., 2012).

By using the HLT concept, educators can more effectively plan and manage the learning process, as well as be more responsive to students' individual needs by helping to ensure that the learning experience is more directed and meaningful for each student, thus enabling them to achieve their learning potential optimally (Lantakay et al., 2023), but there is a lack of data specific to microbiology. In the context of microbiology lectures with an argumentation-based inquiry approach, HLT can help design challenging and enriching learning experiences, and enable the development of students' critical and argumentative thinking skills more effectively (Ammah-Tagoe et al., 2021). This research will provide empirical evidence on how argumentation-based inquiry approach, guided by HLT, affects students'

conceptual understanding and argumentation skills in microbiology.

Based on the description of the research background, it is known that it is important to analyze Hypothetical Learning Trajectories. Currently there are very few research results and information regarding Hypothetical Learning Trajectories, especially those applied to Microbiology lectures through argumentation-based inquiry learning. Therefore, this study aims to analyze *Hypothetical Learning Trajectories* in microbiology course through argumentation-based inquiry learning.

Method

The study used the design research method developed by Gravemeijer and Cobb, consisting of three stages of research, namely preliminary design, teaching experiment, and retrospective analysis. Design research is a research method that aims to develop a learning model in which there is collaboration between students and teachers or lecturers as researchers with the aim of improving the quality of learning (Gravemeijer & van Eerde, 2009);. Design research was selected as systematic and flexible method, aiming to improve teaching practice through analysis and iterative design, and also implementation that refers to collaboration between researchers and practitioners, with contextual-sensitive design principles and theories (Kusumaningsih et al., 2022).

In design research, there were two important aspects, namely Hypothetical Learning Trajectory (HLT) and Local Instruction Theory (LIT) (Yuliardi & Rosjanuardi, 2021). These two aspects were aimed and directed to the learning activities taken by students in their learning activities (Syafriandi et al., 2020), in this case it is argument-based inquiry learning.

The research was carried out at the Department of Biology Education, in a university in Cirebon, Indonesia and the research subjects were 4th semester students who study microbiology. Data collection was carried out during the stages of the lecture process, starting from preparing mini research proposals, argumentation-based inquiry research, to obtaining research results and writing research report articles.

The steps for argumentation-based inquiry learning are: 1) Introducing the research problem and inquiry questions by dividing students into groups of 2 and choosing a research topic in the field of microbiology to raise research questions; 2) Formulating initial group arguments and hypotheses explaining the reasons why they need to carry out their research and research hypotheses to prepare a research proposal; 3) Designing and carrying out experiments to obtain data to prove the hypothesis; 4) Analyzing data and formulating group arguments answer research questions; 5) Carrying out argumentation sessions by presenting the research findings and criticizing other groups' arguments; 6) Making a draft research report; 7) Conducting peer review of other groups' reports; 8) Revising and evaluating the reports according to reviewers' suggestions and submitting articles to journals according to their field of science. The discussion was carried out in accordance with the stages of research with the design research method. Retrospective analysis of this study was conducted in the form of HLT and LIT (Figure 1).

Results and Discussion

Application and learning trajectory in argumentation-based inquiry microbiology lectures

The results of this study showed that the learning trajectory of students during microbiology lectures using argumentation-based inquiry models is very important in helping students improve research skills through planning, implementing and writing research reports. Student research is carried out for 8 weeks, starting from group formation, selection of research themes, preparation of proposals, implementation of experiments / data collection, to preparation of reports. Research planning begins with students forming groups of 2 people and choosing research themes to research questions. In accordance with the characteristics of inquiry, students are given the freedom to choose research themes in the field of microbiology that suit their interests. Argumentation in this study also helps students in determining arguments and discussions with other groups to enrich and deepen understanding of the importance of each stage in research and how their research findings answer their research questions and curiosities. In this study, most students chose the theme of food microbiology and health microbiology, although there were also those who chose soil microbiology or agriculture. More fully research themes are presented in Table 1. Furthermore, students design and compile research proposals and carry out research as a form of data collection to answer investigation questions. Each stage of designing research themes and research proposals to draft research reports is collected and stored in Google Classroom assignments to facilitate examination and consultation during research. As a result, students can compile research reports in the form of articles submitted to various scientific journals according to the field of science as part of student introduction to scientific publications through journals. In more detail,

the results of this study are presented according to the stages of the research method. The titles of all articles can also be seen in Table 1.

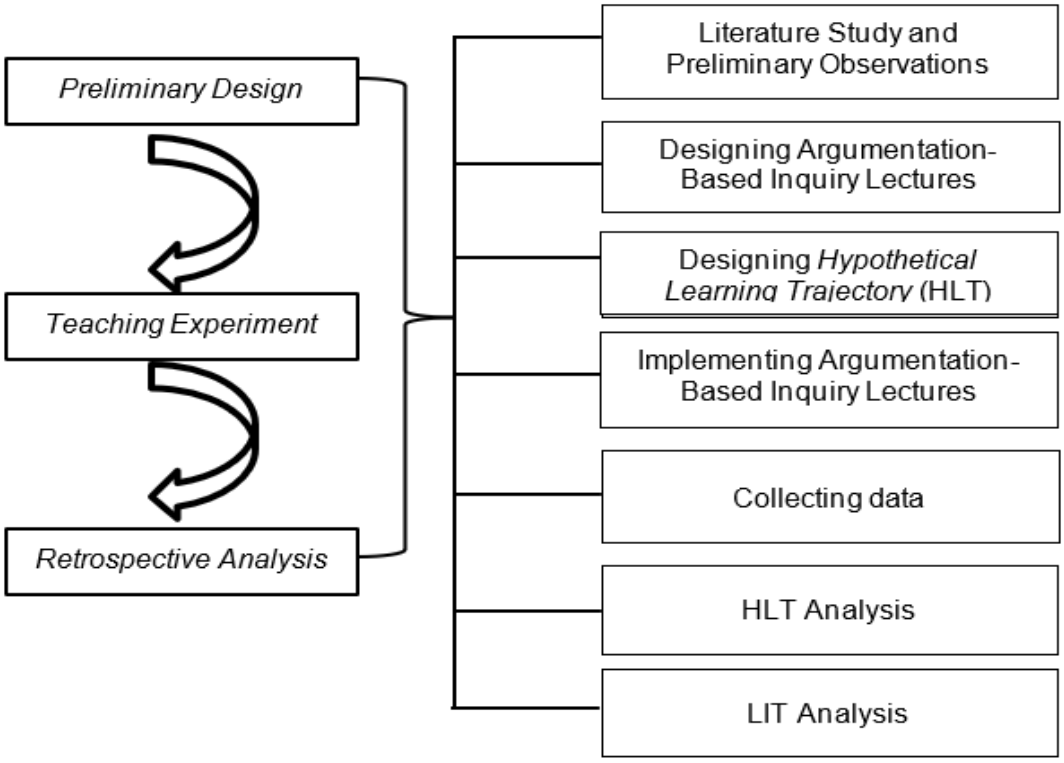


Figure 1. Research methods using research design

Preliminary design stage

At this stage, a literature study was carried out on argumentation-based inquiry learning (ABIL) as a basis for developing lecture designs applied to microbiology courses and on research skills used to develop rubric instruments for assessing research skills used in this study. The ABIL lecture activity tool applied to the microbiology course is also used to design the HLT presented in Figure 2.

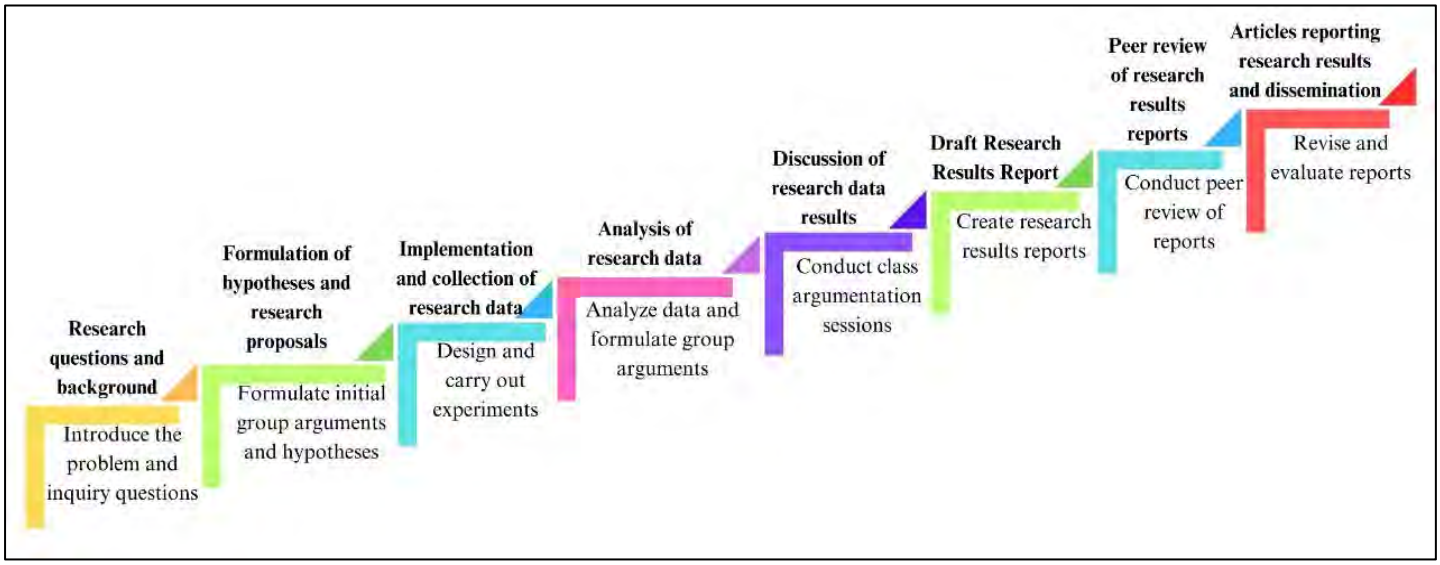


Figure 2. Hypothetical Learning Trajectory (HLT) design in microbiology lectures with argumentation-based inquiry model

Teaching experiment

At this stage, microbiology lecture activities using ABIL that have been designed at the preliminary design stage are carried out and observed. Assessment or data collection is carried out based on the syntax of the argumentation-based inquiry learning model and is adjusted to the basic competencies of research-based microbiology courses required by research-based RPS learning outcomes and the profile of graduates majoring in Tadris biology as research assistants. The implementation of microbiology lecture activities using this argumentation-based inquiry model begins with the division of student groups consisting of 2 people. Furthermore, each student group participated in the following argumentation-based inquiry learning steps: 1) Introduce inquiry issues and questions. At this stage, students produce research themes, research questions and problems behind the research topic viewer; 2) Formulate initial group arguments and hypotheses. At this stage, students produce a research proposal complete with hypotheses in accordance with the research theme and inquiry questions asked in the previous stage. At this stage, students also study literature from journals related to research themes and explain the reasons for the need for the research they choose; 3) Design and execute experiments. At this stage students produce experimental designs and carry them out for later data collection; 4) Analyze data and formulate group arguments. At this stage students produce data tabulations in the form of tables or graphs and data analysis to prove hypotheses and answer research investigation questions; 5) Conduct class argumentation sessions by critiquing the arguments of other groups. At this stage, each group of students presented the results of their research findings to answer the inquiry questions and was criticized by other groups. Here students try to question the arguments of other groups and defend their group arguments using research data and supporting theories; 6) Make reports on research results and arguments. At this stage students produce a draft of a complete research report.; 7) Conduct peer review of reports. At this stage students carry out peer review by reading and assessing other groups' reports and acting as reviewers who provide corrections and suggestions to reports that have been written by their friends; and 8) Revise and evaluate reports. At this stage, each student group produces a revised research report article based on corrections and suggestions from reviewers to then be submitted to national journals according to the field of study of science in each research theme. As proof of students carrying out assignments at this stage, students are asked to send copies of articles and screenshots of proof of submitting articles. The title of the research results of each group, the name of the compiler and the journal to which the article is submitted can be seen in Table 1.

Table 1. All research titles carried out by students in microbiology lectures are argumentation-based inquiry

No.	Research Title	Author (Initials)	Submitted to Journal
1.	The Effect of Differences in Wrapping Leaves on Sticky Rice Tape	RAM & FIRE	Journal of Food Technology
2.	The Effect of Alum Concentration on the Inhibition of Bacterial Growth	AA & RMY	Quagga: Journal of Education and Biology
3.	The Effect of Fermentation Time Differences on Yogurt Quality	AFS & SMS	Journal of Food Science and Technology (ITEPA)
4.	The Effect of Salt Concentration on Kimchi Quality	AFD & TCK	Food Technology Scientific Media
5.	Identification of Probiotic Bacteria in the Manufacture of Pickled Fermented Cucumber Products as Food Ingredients	DM & FMA	UMA Biological Scientific Journal (JIBIOMA)
6.	Identification of Lactic Acid Bacteria contained in Date Probiotic Drink (*Phoenix dactilyfera)*	DS & NR	Journal of Food Science and Technology (ITEPA)
7.	The Effect of Different Soaking Water on the Quality of Salted Mustard	RR & EIS	Journal of Agricultural Engineering Huna:
8.	Public Understanding of the Effect of a Healthy Lifestyle on the Risk of Influenza	FDN & HR	Journal of Pharmacy and Health
9.	The Effect of Different Sugar Concentrations on the Fermentation of The Kombucha	FPD & PA	Indigenous Biology: Journal of Education and Biological Sciences
10.	Identification of Tuberculosis Transmission in the Community in Leuwikujang, Majalengka Regency	HFA & WFA	Journal of Pharmacy and Health
11.	Overview of Student Knowledge on HIV/AIDS Infectious Diseases in Adolescents	SA & IL	Journal of Pharmacy and Health
12.	Identification of Microorganisms Organic Fertilizer of Chicken Coop and Goat Shed and Inorganic Fertilizer	KRT & RR	Journal of Metamorphosa: Journal of Biological Sciences
13.	Effectiveness of Chinese Jatropha *multifida* L as a Natural Antimicrobial Substance against *Staphylococcus aureus Bacteria*	LAP & KN	Biosel: Biology Science and Education
14.	Analysis of the Spread of Influenza and Medicines in Gumulung Tonggoh Village in March-April 2023	LN & SR	Celebes Education Review
15.	Effect of *Saccharomyces cerevisiae* Concentration on Bread Making	MAE & NAH	Journal of Food Technology
16.	The Effect of Salt Concentration on the Quality of Pickled Cucumbers (*Cucumis sativus*)	MRHP & A	Biosel: Biology Science and Education

The results of student research in the form of articles are then assessed based on the ability to research, including the accuracy of choosing the intended journal in accordance with the theme or field of research conducted. As a result, at the end of the lecture, 16 journal articles were collected and submitted to scientific journals such as biology journals, food technology journals, pharmacy and health.

Retrospective analysis

As a result of the application of argumentation-based inquiry lectures in the microbiology course that has been designed in this study with HLT presented in Figure 2, each group experienced its own learning trajectory in accordance with the research theme they conducted to writing research report articles, but had a similar pattern in accordance with learning conditioning through argumentation-based inquiry learning. All research titles conducted by students on argumentation-based inquiry learning in this study are presented in Table 1.

One of the learning trajectories experienced by one group of students who conducted research on the effect of different wrapping leaves on sticky rice tape is presented in Figure 3. A pre-designed learning path, as can be seen in Figure 2, actively carried out in this research to guide students to carry out their research to produce research report articles using the Argumentation-based Inkuri Learning strategy. The stages of activities carried out and experienced by students from one of the groups who conducted research on the effect of different wrapping leaves on sticky rice tape are represented by the photos in Figure 4.

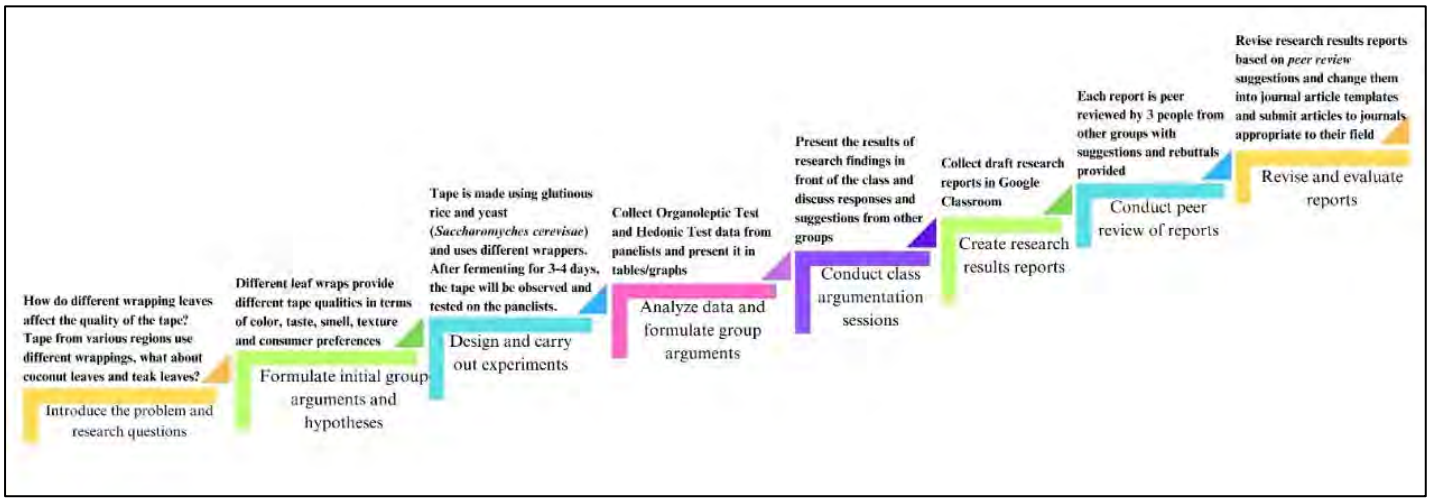


Figure 3. Hypothetical Learning Trajectory (HLT) of Tape group students in microbiology lectures with an argumentation-based inquiry model

Each stage in the application of the argumentation-based Inquiry Learning model experienced by students of this group can be described the learning trajectory they went through. In the first stage of the research journey, students who have gained some knowledge about the role of microorganisms in various fields in this microbiology course, begin to think about what research themes will be asked at the stage of introducing research problems and questions. Students who are formed into groups of 2 people or in pairs, discuss with their group members to determine research problems. The tape group consisting of Raaqa & Arin decided to research tape, proposing the research title "The effect of yeast concentration on the manufacture of glutinous tape". At this early stage, the two students have argued in groups to determine the research theme they choose based on knowledge, experience and literature study.

Furthermore, students conduct literature studies and compile proposals to fulfill the assignment in the second stage, namely formulating initial arguments and hypotheses. In the proposal, students hypothesized that the more yeast used, the better the quality of the glutinous rice tape produced. Students of this group argue that yeast is the microrganism that makes glutinous rice turn into glucose which causes glutinous rice to taste sweet. So the more yeast used, the more glucose produced and the sweeter the taste of the tape. At this stage, students present their proposals and are given input by course lecturers and other group students (as shown in Figure 4.a.). From the results of this discussion, the students of this group decided to change their research proposal to the effect of different wrapping leaves on the quality of sticky rice tape. This title change is based on the results of discussions obtained by data that there have been studies that discuss the composition of certain yeasts that are ideal in making tape, it cannot be too much or too little. However, there has been no research discussing tape wrapping leaves, even though sticky rice tape from various regions has distinctive characteristics on different wrappers. For example, sticky rice tape from Kuningan Regency uses guava leaf wrapping,

while in Cirebon it uses banana leaves and in Subang there are those who use candlenut leaves. They are also curious whether if the tape is wrapped in coconut leaves and teak leaves whether the results will be the same, considering that these two leaves are also used to wrap food.

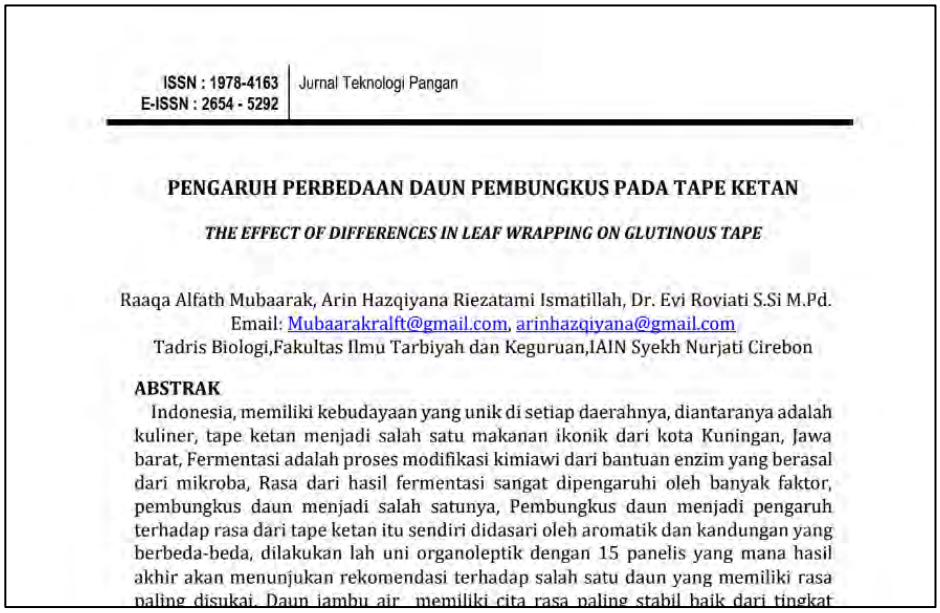
Figure 4. Documentation of research activities of Tape group students with the research title The Effect of Differences in Wrapping Leaves on Sticky Rice Tape. (a) Presentation and discussion activities of research design; (b) The process of making sticky rice tape; (c) Ripe sticky rice tape with different leaf wrappers; (d) Hedonic Test and Organoleptic Test Activities to the panelists

The third stage of learning is the implementation of experiments and data collection. Students first consult on research design, tools, materials and ways of working for the implementation of experiments with lecturers and laboratories so that data collection runs smoothly. Then students carried out experiments starting with the stage of making tape from glutinous rice (Figure 4.b.) and then wrapping it with different types of leaves, namely guava leaves, teak leaves, banana leaves and coconut leaves. Then the tape is fermented for 2 days until it becomes a mature/finished sticky rice tape (Figure 4.c.). After this ripening, sticky rice tape was then tested on 15 panelists in the form of organoleptic tests of aspects of color, taste, aroma and texture as well as hedonic or preferential tests (Figure 4.d.).

The next stage is to analyze the data and formulate group arguments, the results of observations at the experimental stage are then tabulated and analyzed to be presented in the draft research report. Data on organoleptic test results and hedonic tests on the panelists are presented in the form of tables and graphs in the observation results section in the draft research report document and discussion is added. The draft report is then presented in front of the class in the next stage of learning, namely to carry out class argumentation sessions. Tape group students presented research results that showed that wrapping leaves gave different sticky rice tape results, especially in terms of aroma and the panelists liked sticky rice tape wrapped in guava leaves the most. This presentation session presents the presenter's argument why the results are so and is supported by theory and research results. At this stage, there was an exciting discussion because other groups gave a lot of questions and suggestions. Similarly, lecturers also provide suggestions for improving research reports.

Next, students make research reports and upload them in Google Classroom assignments for peer review by colleagues from other groups. At this peer review stage, the research report is examined/assessed by 3 other group students on aspects of introduction, methods, arguments, research limitations and systematics & writing. Finally, students revise and evaluate the report to then change its format into a journal template for publication. Previously, students were asked to choose the journal to be intended to publish their research reports. This Sticky Rice Tape group chose the Journal of Food Technology published by the Department of Food Technology UPN Veteran East Java which is accredited by SINTA 4 and free of charge. Then students download the journal template and move the research report. The article looks as seen in Figure 5 The article is then submitted to the OJS Journal

of Food Technology and includes proof of submission to the assignment (Figure 6).



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PENGARUH PERBEDAAN DAUN PEMBUNGKUS PADA TAPE KETAN

THE EFFECT OF DIFFERENCES IN LEAF WRAPPING ON GLUTINOUS TAPE

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ABSTRAK

Indonesia, memiliki kebudayaan yang unik di setiap daerahnya, diantaranya adalah kuliner, tape ketan menjadi salah satu makanan ikonik dari kota Kuningan, Jawa barat, Fermentasi adalah proses modifikasi kimiawi dari bantuan enzim yang berasal dari mikroba, Rasa dari hasil fermentasi sangat dipengaruhi oleh banyak faktor, pembungkus daun menjadi salah satunya, Pembungkus daun menjadi pengaruh terhadap rasa dari tape ketan itu sendiri didasari oleh aromatik dan kandungan yang berbeda-beda, dilakukan lah uni organoleptik dengan 15 panelis yang mana hasil akhir akan menunjukan rekomendasi terhadap salah satu daun yang memiliki rasa paling disukai. Daun jambu air memiliki cita rasa paling stabil baik dari tingkat

Figure 5. Display of research reports that have been reformatted into Food Technology journal article templates

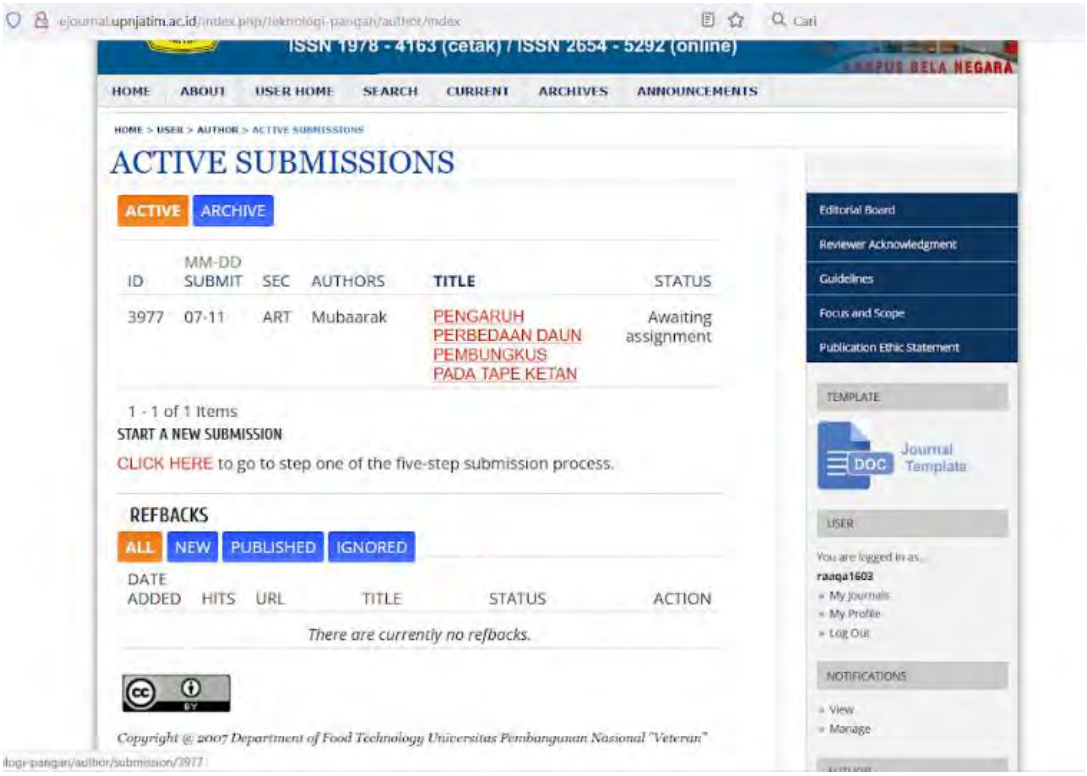

Figure 6. Screenshot as proof that students have submitted articles to OJS

This series of activities in argumentation-based inquiry learning allows students to experience the learning trajectory in planning, implementing, reporting and publishing research in the field of microbiology in a direct practical way. Although Tadris / Biology Education students are not experts in the field of pure biological research, as prospective biology teachers should have the ability to conduct biological research in order to teach it to their students, later when they become teachers. In addition, the ability to conduct research is also needed in fulfilling learning outcomes as a prospective research

assistant which is one of the profiles of graduates majoring in Tadris Biology FITK at IAIN Syekh Nurjati Cirebon.

The application of diverse learning models and strategies is very important to be applied to the learning process at all levels of education, including for students in universities. Moreover, students in the Department of Tadris Biology who are students who are prepared to become prospective biology teachers who do need exposure to various learning models and strategies so that they are expected to be able to apply them when they become teachers. But sometimes research on the application of learning models focuses too much on achieving numbers or values as learning outcomes with various variations (Biggs & Collis, 2014). Researchers are still lacking in exploring what students experience during learning to understand what happens in the learning process and the impact on their understanding and abilities. In every learning activity carried out at school or campus, the most important thing is the learning experience of students and changes in behavior and abilities that occur in students. So, teachers and lecturers should not only evaluate the results but also the learning process.

Hypothetical Learning Trajectory (HLT) is one way to describe the main elements in pedagogical thinking involved in understanding the learning process (Rezky, 2019). Research on learning trajectories or HLT is currently mostly done in mathematics learning, but it is still rarely done in other fields such as science or biology. Even though research like this is needed for the development of teacher competencies and prospective teachers (Jamilah et al., 2023), including prospective biology teachers. The results of this study also show that the discussion of student learning trajectories is very important in helping students develop research skills and abilities through planning, implementing and writing research reports accompanied by argumentation activities during microbiology lectures using argumentation-based inquiry learning models.

The argumentation-based inquiry learning in this study resulted in students' research skills that were quite satisfactory and developed among other abilities and skills during lectures. This shows the superiority of this learning model in developing research skills through the development of formal reasoning skills and argumentation skills, writing skills and science process skills (Jimenez-Aleixandre & Brocos, 2021). The findings in this study also show that argumentation-based inquiry learning is essential in developing complex thinking and problem-solving skills that go into higher-order thinking skills (Roviati & Widodo, 2019).

Meanwhile, argumentation-based inquiry lecture activities, like other research-based learning, are also known to develop research skills (Ibarra et al., 2019). This can happen because research skills are important in science education, especially for a prospective science teacher including biology (Maknun et al., 2020). Research-based learning is the application of scientific methods based on scientific reasoning that has been tested, through research skills, students can construct intellectual relationships between their learning and the research being carried out (Webb et al., 2011).

Inquiry in science learning requires the ability to ask questions, the ability to choose tools, materials and methods used to achieve the expected results. Inquiry is the art of asking questions in science when understanding about natural phenomena and finding answers to science questions. Inquiry is researched to improve higher-order thinking skills, science process skills and inquiry skills themselves (Rustaman, 2005). The use of inquiry learning as a recommended learning model in science learning in higher education has been shown to be effective in improving science process skills and concept understanding. A study shows that science learning should be carried out by scientific inquiry to instill competence in thinking, working, and being scientifically and able to communicate as an important factor in life skills (Mustofa, 2022).

Argumentation in science education itself is a type of discourse that provides opportunities for arguments to be built individually or collaboratively based on empirical and theoretical evidence, justifications, refutations and alternative views. While an argument refers to the content or substance that arises in the activity of argumentation. According to Toulmin framework (1958) an argument is built from the components of claims, data, warrants and supporting evidence (Yilmaz et al., 2017). Argumentation in science learning is also applied to develop critical thinking skills, reasoning abilities, and understanding concepts (Roviati & Widodo, 2019). Therefore, the use of argumentation can improve critical thinking skills, especially in the context of science learning. For example, a study using the Argument-Driven Inquiry (ADI) model with scaffolding and academic ability showed an increase in argumentation skills and critical thinking skills in students majoring in PMIPA (Hasnudiah, 2016).

Argumentation-based inquiry in science learning is an approach that integrates inquiry-based science teaching and inquiry to create a learning environment that effectively fosters and components language skills in science learning. This approach that uses inquiry and argumentation in science learning can be in the form of Science Writing Heuristic which is adopted as Argument-Based Science Inquiry. This approach has been used to direct students to improve critical thinking, reasoning, argumentation, writing and higher-order thinking skills (Demirbag & Gunel, 2014). Furthermore, argumentation-based inquiry has also been examined for its contribution in developing formal reasoning skills and argumentation skills, science learning achievement, and writing skills (Acar & Patton, 2012). Meanwhile, argument-driven inquiry has proven effective in improving academic achievement and science process skills in

practicum learning in prospective science teachers (Demircioglu & Ucar, 2015).
The findings as a result of this research are expected to be able to provide new developments in the treasures of science, especially in the field of science education. However, this study also has limitations, among which is that the research subject and limited time still cannot provide flexibility in the development of a more comprehensive analysis and represent a very diverse way of learning for students. In addition, this research is also not known further if applied to other courses or in other study programs. Furthermore, the application of the learning model used in this study has not been compared with other research-based learning that may equally have advantages in developing research skills.

Conclusion

The conclusions of this study is that students who carry out microbiology lectures using argumentation-based inquiry learning through the implementation of different research in the field of microbiology experience a similar learning trajectory so that a specific and distinctive set of Hypothetical Learning Trajectory (HLT) can be formulated. Even though the research activities are different, the pattern of applying argument-based inquiry provides the same learning experience for students in conducting research. The implication of the findings and results of this study is that the argumentation-based inquiry can be used as a reference for educators and researchers who are looking for learning models that allow students to develop research skills in addition to other essential skills that can be developed through this learning model.
The findings and results in this study are expected to be an inspiration for educators and researchers to apply and redevelop to strengthen theoretical studies on argumentation-based inquiry learning, research skills and also in the development of methodology. Therefore, it is hoped that further research with more and more diverse research subjects, as well as application to other similar courses can be carried out in a freer time.

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Conflicts of Interest

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

Author Contributions

E. Roviati: writing original draft preparation, Editing; **R. Y. Gloria:** methodology; and **R. S. Wijayati:** analysis.

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