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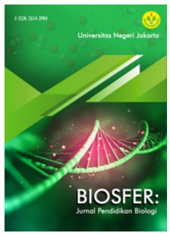

Analysis of scientific argumentation skills of prospective biology teacher students in inquiry-oriented laboratory activities

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ABSTRACT

Laboratory activities are essential and meaningful in science learning, especially biology. However, students often have no sufficient understanding of what is being practiced, beside they do not use their sklills to solve problems in the field of biology. Scientific argumentation is one of the skills that a prospective science teacher needs to develop and needs to be trained so that prospective teachers have experience and skills to apply when they become teachers later. The scientific argumentation skills in laboratory activities needs to be trained to provide training to students to use the results of laboratory activity to answer problems in the field of biology. This study aims to apply inquiry-oriented laboratory activities that focus on scientific argumentation in laboratory courses and to analyze the quality of scientific arguments of prospective biology teacher students during laboratory activities. The method used in this study is mixed *methods research* type *exploratoryy* which combines qualitative and quantitative approaches with complementarity. The research subject is a prospective student of a 5th semester biology teacher who takes microbiology courses. The results showed that the application of scientific argumentation in laboratory activity was carried out in 3 stages, namely initial discussion, experiment, observation and final discussion after experiment. The results of the analysis of the quality of scientific argumentation show that the argumentation skills of some students is at the middle level. The conclusion of this laboratory activity shows that students' scientific argumentation skills can develop well if they have the opportunity to discuss critically by using experimental data and their knowledge obtained from literature studies.

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INTRODUCTION

As teacher candidates, biology education students should have four main competencies, including personality, pedagogic, social, and professional competencies as listed in the Indonesia Teacher and Lecturer State Law (Wibowo et al., 2019). The debriefing to acquire these four competencies has been started since they are educated as prospective teacher students. Biology teacher candidates must be equipped with adequate knowledge and skills before being deployed as biology teachers, including scientific argumentation skills (Ecevit & Kaptan, 2022; NSTA, 2010).

Argumentation is defined as the claim of an author, including its degree and strength, its theoretical orientation, the quality of the evidence produced or demonstrated, and how it relates to the theory (Novaes, 2021; Du Boulay, 2012). Arguments can be defined as a series of propositions or postulates, as well as products which created from a claim supported by relevant evidence and juctification (Sengul et al., 2020; Nussbaum et al., 2012). While arguing is a social process in which two or more people build and criticize arguments (Holihan & Baaske, 2022). The process of scientific argumentation in science education is supposed to involve the construction and critique of scientific arguments, which involves the consideration of alternative hypotheses (Giri & Paily, 2020; Novaes, 2021). Argumentation, as part of what needs to be considered in critical thinking ability, is a verbal, social, and rational activity that aims to convince reasonable critics of an acceptable view (Gray & Kang, 2014). While scientific argumentation is a special case when dialogue is directed at the coordination of evidence and theories to improve explanations, models, predictions, or evaluations of a scientific knowledge (Tang, 2022; Gray & Kang, 2014).

One of the contributions of the argumentation to the purpose of education is to support the development of critical thinking (Giri & Paily, 2020; Roviati & Widodo, 2019). Effective argumentation skills are a core component of critical thinking, including the ability to construct an argument to agree or disagree with a claim or opinion behind a science news report. (Fan et al., 2020). Being a person who thinks critically and can develop independent opinions is important in the effort to become an active citizen in a democratic society (Jiménez-Aleixandre & Puig, 2012). According to Lin (2013), building an argument is the core process of critical thinking. Therefore, building and evaluating arguments about issues can be important in developing and assessing students' critical thinking skills. Students who can test and assess an argument for or against a claim, identify and evaluate an argument, the degree of supporting evidence, and the possibility of a claim, are realized to be a crucial part of critical thinking (Nussbaum, 2021).

Scientific argumentation is important in learning science and should be encouraged to be applied in science classes in a way that students are encouraged to play an active role in discussions (Gray & Kang, 2014; Van Lacum et al., 2014). Students must also be able to develop the skills needed to construct and support scientific claims through argumentation and to evaluate or face the challenges of claims or arguments given by others (Giri & Paily, 2020; Clark et al., 2009). However, opportunities for students to participate in authentic argumentation in common science class are very rare (Allchin & Zemplen, 2020; Bathgate et al., 2015; Sampson & Blanchard, 2012). Also little is known about the understanding of science teachers and prospective teachers about scientific argumentation (McNeill & Knight, 2013; Sampson et al., 2011), their ability to participate in complex practice, or their views on the use of argumentation as part of science learning (Henderson & McNeill, 2018; Noroozi et al., 2018).

Studying microbiology as science should practice many skills and abilities such as scientific argumentation skills and research skills (Faize et al., 2017; Salybekova et al., 2021). Scientific argumentation has garnered much attention as a main competency in science education research for the past 2 decades (Henderson & McNeill, 2018). Recent research has shown that engaging students in scientific argumentation can lead to a better understanding of science concepts and processes (Aydeniz & Ozdilek, 2015; Gultepe & Kilic, 2015). It is also well known that scientific argumentation is important for scientific literacy and critical thinking (Erduran et al., 2005; Giri & Paily 2020) In fact, science learning in many public schools in Indonesia nowadays is generally carried out with an emphasis on question-and-answer interaction and is dominated by the teacher. This is a practice that does not involve discussion, argumentation, or the social construction of knowledge, and does not provide opportunities for students to practice inquiry, be creative, and dare to solve problems (Ozdem et al., 2013; Sitohang, 2017).

It is now realized that science learning needs to involve the construction and use of tools that enable students to generate knowledge about the natural world by involving in argumentation activities

(Furtak & Penuel, 2019). Argumentations are used to build explanations, models, and theories, just as scientists use arguments to relate the evidence they choose to the claims they reach through the use of warrants and backings (von der Mühlen et al., 2016). Therefore, argumentation as an important discourse process in science must be promoted in science learning in the classroom (Martín-gámez & Erduran, 2018; Passmore & Svoboda, 2012). So far, the traditional view has always been that science learning only focuses on learning outcomes, such as understanding concepts, problem-solving, or science process skills (Jiménez-Aleixandre & Erduran, 2007).

Laboratory activities in science learning have several aims, such as to increase learning motivation, develop experimental techniques and skills, learn a scientific approach, and increase understanding of the theoretical aspects of the subject (Sevinc *et al*, 2011; Duda *et al.,* 2019). In science laboratory activity, students learn to observe objects and phenomena, ask questions, gain knowledge, construct explanations of natural phenomena, test explanations in various ways, and communicate their ideas to others (Gericke et al., 2023; Manz et al., 2020; Lunetta, et al., 2007). When writing a laboratory report, students practice arguing by writing down the findings of their experiments which are supported by empirical evidence or supporting libraries (Gouvea et al., 2022; Nuckels et al., 2020). However, the ability to write arguments in choosing the activities to be practiced has never been trained, eventhough this ability is needed when practicing inquiry in carrying out laboratory activity (Manz et al., 2020). Therefore, research on the analysis of scientific argumentation of prospective biology teacher students in inquiry-oriented laboratory activities is needed to explore.

Good quality practical work activities will help students develop important skills, understand scientific research processes, and develop a conceptual understanding (Hofstein & Kind, 2012). Unfortunately, the laboratory activities or practical work in the courses currently available at the research site is still confirmative and does not provide opportunities for students to practice inquiry, be creative, and have the courage to solve problems (Gericke et al., 2023; Hobstein & Walker, 2022). This type of laboratory activity causes a lack of training in investigative and argumentation skills that are demanded in studying science (Smith et al., 2020). In fact, sometimes students do not understand the relationship between what is done in laboratory activity and lecture material and its relation to everyday life (Kapici et al., 2022).

Inquiry-oriented learning activities are still not succesfully carried out among schools in Indonesia (Effendi-Hasibuan & Mukminin, 2019; Sudigdo & Setiawan, 2020). This is because teachers who teach science lack experience in conducting inquiry-oriented learning activities during their higher education (Baroudi & Rodjan Helder, 2021; Kolve et al., 2020). Science learning must be transformed into science learning as science is formed. Science is constructed not from one approval to another from scientists, but rather through argumentation and debate (Eronen & Romeijn, 2020). Students need to know how new knowledge is constructed and validated by scientists so that it becomes an important theory, law, and concept from a variety of different disciplines to understand science as a way of knowing something (Russel & Martin, 2023). Students must also be able to develop the skills needed to construct and support scientific claims through argumentation and to evaluate or face the challenges of claims or arguments given by others (Clark et al., 2009).

Microbiology is a field of science study that is part of the biological sciences that study aspects in the life of microorganisms and their role in human life (Murray et al., 2015). Microbiology lectures discuss microbial nutrition and metabolism, microbial growth and microbial growth, microbial classification, and the role of microbes in various fields (Oren, 2015). Microbiology laboratory activity equips students with basic skills in growing microbes, testing methods for antimicrobial materials, and the role of microbes in various fields (Erkmen, 2021). Antimicrobial agent testing consists of testing antiseptic chemicals, disinfectants, antibiotics, and natural antimicrobial ingredients in controlling the growth of microbes commonly encountered in everyday life such as *Escherichia coli, Pseudomonas aeruginosa* and *Staphylococcus aureus* (Abed & Hussein, 2016; McDonell, 2020).

Inquiry is a dynamic process that opens up and solves puzzles to know and understand the world (Kuhlthau et al., 2015; Alberta, 2004). Inquiry learning is a process in which students engage in learning, formulating questions, investigating extensively, and then building new understandings, meanings, and knowledge (Houghton et al., 2022). Inquiry is the formation of questions about nature, finding answers, studying and understanding thoroughly like a scientist, not just knowing in general from experts or other ways (Krajcik et al., 2014). The knowledge and skills gained by students are expected not from the results of remembering facts, but rather the result of discovering themselves through inquiry activities, namely observation, asking, proposing hypotheses, collecting data, and concluding (Duran & Dokme, 2016). Inquiry-oriented laboratory activities are mostly applied to develop science process skills, scientific skills and increase mastery of scientific conceptual knowledge (Belga 2022; Saputra et al., 2021; Rodriguez et al., 2020; Kirkup & Varadharajan, 2016; Valls-Bautista et al., 2021. Only a few studies have focused on developing argumentation skills through inquiry-oriented lab activities, especially in microbiology topics. So, this study needs to apply inquiry-oriented laboratory activities that focus on scientific argumentation and analyze the quality of scientific argumentation of prospective biology teacher students. This study investigated the scientific argumentation skills of prospective biology teacher students in inquiry-oriented laboratory activities.

METHODS

Research Design

The research method used in this study is mixed methods research (Creswell & Plano-Clark, 2007). This research method allows the use of qualitative and quantitative research approaches simultaneously or alternately. The research design used in this study is an exploratory sequential design, and the results obtained in the first method (qualitative) can help develop or provide information on the second method (quantitative) (Figure 1). This design is the most suitable for research exploring a phenomenon (Creswell & Plano-Clark, 2007). Qualitative data exploration in this study was carried out at the stage of the application process of inquiry laboratory activity which focused on argumentation and quantitative data exploration was carried out on the quality data of argumentation made by student teacher candidates during carrying out, discussing, and reporting their investigations.

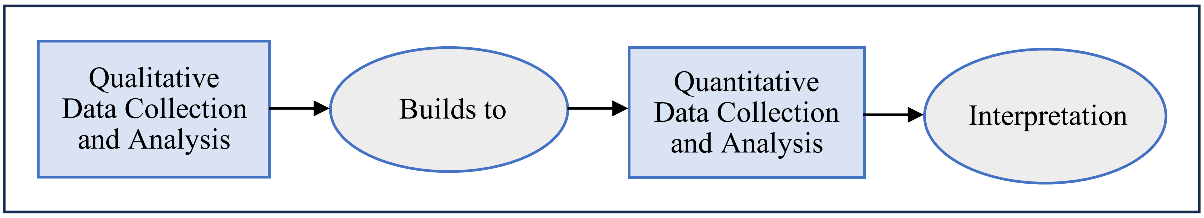

Figure 1. The exploratory sequential design used in this research

Population and Samples

The population of this research was 134 prospective biology teacher students in the Study Program of Biologi Education at one of the Universities in Cirebon. The sample of this study was 37 students of the fifth-semester taking microbiology course taken using random sampling techniques. This study focused on analyzing the scientific argumentation skills of prospective biology teacher students in inquiry-oriented laboratory activities. The laboratory activity carried out was prepared by students based on the inquiry questions given, and then students prepared an experiment plan and carried it out in the laboratory. Furthermore, students were allowed to discuss the results of the experiments and prepared a laboratory report.

Instrument

The instruments used for data collection in this study were:

1. Observation sheets for data collection regarding the implementation of activities in the guided inquiry laboratory activity program in the microbiology course that focuses on argumentation and whether it is carried out according to the expected stages.
2. Toulmin's argumentation model framework or *Toulmin Argumentation Pattern* (TAP) modified by Kutluca dkk (2014) to analyze the quality of students' argumentation with the data source of the transcription of their argumentative conversations when planning, implementing and discussing and reporting the results of the laboratory activity.
3. Questionnaires were given to students to collect data on their perceptions about the implementation of practical work and scientific argumentation.

Procedure

The data for this study were obtained from the application of laboratory activity in microbiology courses which consisted of 4 (four) sets of laboratory activity events. Each set of laboratory activity events consisted of 3 meetings. The activities in the first meeting was preliminary discussions, then continued with planning and carrying out experiments, the second meeting was observations of experimental results, then continued with collecting and analyzing data. The third meeting presented a laboratory report and critical discussions of practical results based on experimental Lab report (Table 1).

Every activity carried out in the laboratory activity was observed and recorded using a video camera. To make it easier for observers, students are labeled on the chest and back of their laboratory coats with different codes, such as M01, M02, and so on. The recording results were then transcribed and analyzed using the Toulmin argumentation model framework to measure the quality of student arguments during critical discussions of the results of practical experiments. Students

The implementation of this research was carried out on a limited basis and continued to students taking microbiology courses. The independent variable in this study was the implementation of guided inquiry-oriented laboratory activities, while the dependent variable was the quality of student arguments during preparing, carrying out laboratory activities, discussing, and reporting experimental results.

Table 1.
Student activities during implementation of each set of inquiry-oriented laboratory

Meeting	Activity	What students do
1st	Preliminary discussions	Students explore the experimental topics and formulate the problem
	Planning & carrying out Experiment	Students prepare experimental designs, prepare the tools and materials needed and carry out experiments.
2nd	Observation of the experimental result	Students observe the results of experiments after going through a microbiological incubation period.
	Collecting & Analysing data	Students carry out calculations or measurements and/or other observation methods and recapitulate the data, followed by data analysis to find out initial conclusions from the experimental results.
3rd	Presenting Lab Report	Students present the results of their findings and group discussions in the form of experimental reports and present arguments that support them.
	Critical discussion	Students from other groups responded and provided critical suggestions and arguments on the results of the presenter's report.

Data Analysis Techniques

The data from this study were analyzed using descriptive qualitative analysis which was used to describe the laboratory activity program stage and the results of video and audio recordings were transcribed as data sources and analyzed using the Toulmin Argumentation Pattern (TAP) modified by Kutluca et al. (2014). Meanwhile, the results of student argument transcription were analyzed quantitatively based on the level of argument quality compared to each laboratory activity. Each components of the argument was identified and recapped to determine whether it was in which level of TAP (Table 2)

Table 2.
Toulmin's argumentation model framework with its characteristics

Level	Means	Description	Toulmin (1958)	Characteristic
0		Unscientific		
1	Lower	Scientific claims	Claim	Students think scientific claims can be made without data support
2		Coordination between claims and evidence	Claims + data	Students recognize that sufficient evidence is needed to support a claim
3	Middle	Coordination with reasoning between claims and evidence	Klam + data + warrant/ backing	Students may use established theory or knowledge to coordinate claims and evidence

Level	Means	Description	Toulmin (1958)	Characteristic
4		Coordination with reasoning and modification between claims and evidence	Klaim + data + warrant/ backing + qualifier	Students recognize the uncertainty of claims given the power of warrants.
5	Higher	Coordination with reasoning, modification and conditionality between claims and evidence	Klaim + data + warrant/ backing + qualifier + syarat-syarat rebuttal	Students recognize the condition that claims can now be implemented through analysis of limitations related to measurements, theories or models of the present and phenymenee under investigation.

RESULTS AND DISCUSSION

1. Implementation of inquiry laboratory activities that focus on scientific arguments

a. Initial Discussion Before Experiment

Before the experiment begins, students were given a 15-minute quiz, to ensure that students were ready to carry out the laboratory activity. After completing the quiz, students carried out the initial discussion. Students, guided by a moderator, were introduced to the problem to be investigated and discussed what will be experimented on, starting from exploring what students know about what will be practiced, and the need for experiment activities, to leading to hypotheses that will be proposed in the experiment. At this stage students are allowed to observe the environment around them and what they encounter in their daily lives that sometimes they do not realize that there is anything there. From the results of these observations, then the discussion was continued by connecting it with what will be practiced next. From the results of observations, students are then given questions that lead to hypotheses that must be submitted before the experiment is carried out.

At the first laboratory activity event, which is about the diversity of microorganisms around us, students discussed their embedding of their surroundings and the possible presence of microorganisms in the environment, especially in the room and outdoors. In addition, students discussed why packaged liquid milk becomes damaged or stale when the packaging is opened. One by one, students expressed their opinions and responded to their friends' opinions. The discussion then continues until students can propose hypotheses about the diversity and number of microbes present in various media in their environment, such as from air, water, soil, foodstuffs, drinks, and the human body.

Meanwhile, in the second laboratory activity event, namely regarding the testing of antimicrobial materials, in the form of antiseptics, disinfectants, antibiotics, natural ingredients, and oligodynamic power of heavy metals. At the beginning of the event, students discussed their observations of antimicrobial ingredients that they often encounter in everyday life and the active ingredients contained in them. Students are also asked to identify various antimicrobial macas based on the type of active ingredient and how it works in controlling microbes. Students also expressed their opinions and responded to their friends' opinions regarding the factors that affect the working power of antimicrobial materials. At the end of the discussion, students proposed a hypothesis about which antimicrobial material would produce the greatest inhibitory zone as an indicator of the level of effectiveness of an antimicrobial material and the sensitivity of certain microbes to the types of antimicrobial materials that are often used daily.

The third one is about testing the quality of drinking water using the MPN (most probable number) method (Shakya et al., 2021; Reza et al., 2014). The initial discussion focused on the types of water used for drinking by the practice and how to ensure the water is suitable for drinking before finally being introduced to the problem of drinking water testing and proposing hypotheses. The fourth practicum is about the role of microbes in the food sector. Practicants discuss what foods in the manufacturing process involve microorganisms and what are the benefits of using microbes in making these foodstuffs. The discussion continued with what factors affect the results of making foodstuffs using microbes until finally the practice was asked to propose a hypothesis.

b. Laboratory activity implementation

After getting enough explanation, students experiment according to their respective assignments. Students work to carry out experimental procedures by the guidebook they searched and discussed. During the work of carrying out the experiments, students were guided by laboratory assistants who helped make the experiment run well. This is mainly focused on ensuring that students work microbiology experiments aseptically to prevent contamination of the experimental results, namely the growth of microbes that were not expected in the experiment.

At the first laboratory activity event, about the diversity of microorganisms around us, students worked on isolating microorganisms from various sources of medium, namely from the air, both indoors and outdoors, from soil, both dry, fertile, and muddy soil, from food, drinks, river water, from the surface of objects and the surface of the human body. This isolation procedure is carried out by sterilizing the tool and the material used, pouring the medium agar into a petri dish waiting until it is solid, and continuing with microbial isolation from various sources to the surface of the agar medium. The petri dishes inoculated with microbes are then incubated in an incubator for 2 x 24 hours to be observed on the appointed day, which is two days after inoculation.

In the second laboratory activity event, which is about testing antimicrobial materials, students tested the sensitivity of microbes to antimicrobial materials with the standardized diffusion method of agar disc paper called the Kirby-Bauer method. The antimicrobial ingredients tested include antiseptics (*betadine* and *alcohol*), disinfectants (*wipol* and *bayclin*), antibiotics (amoxicillin and tetracyclin), antimicrobial natural ingredients (turmeric extract *Curcuma domestica* and babadotan *Ageratum conizoides* leaves) and heavy metals (Cu / copper and Fe / iron) (Alhamadani & oudah, 2022; Heno et al., 2021). The stage of work is the pouring of agar media into a petri dish, after it is solid then on different petri dishes are inoculated with bacteria *Escherichia coli* and *Bacillus* sp. After that, the antimicrobial material soaked on the disc paper is placed in the center of the inoculum for later incubating for 2 days.

At the third laboratory activity event, the experiment conducted MPN tests on 3 water samples and collected data on which water was suitable for drinking based on the presence of coliform microbes. During the fourth laboratory activity event, the students observed the effect of temperature on yogurt making.

c. Observation of Experimental Results

After incubation for 1 or 2 x 24 hours, students observe the results of the experiment, collect data and record it on plano paper. The results of the first laboratory activity event were observations of microbial colonies growing on solid media to report both in number and diversity. Meanwhile, the second laboratory activity event observed a clear zone formed around the disc paper due to the inhibition of microbial growth by the antimicrobial material tested. Because each group worked on experiments with different samples, the observational data were recorded together in a plano paper to be used as a shared data source.

d. Discussion of Experiment Results

Two days after the observation, the student then conducted a critical discussion guided by directing questions to connect the results of the laboratory activity with student knowledge. Based on the data processed during observations, students discuss and argue about the results of the experiment and why the results of the experiment are appropriate, whether they are appropriate or not by the hypothesis, supported by the results of the appropriate research. At the first laboratory activity event, students argued about which sources produce the most number and diversity of microorganisms and which ones are the least. Students argue that their answers are linked to laboratory activity results and other data obtained from literature studies and their knowledge of the conditions of isolated microbial sources. Meanwhile, at the second experimental laboratory activity event, students discussed and argued about which antimicrobial material provides the largest inhibitory zone and its causes, both in terms of how the type of antimicrobial material works and the type of bacteria tested.

2. Analysis of the quality of scientific argumentation of prospective biology teacher students

The result of student's quality of argumentation while doing laboratory activities is presented in Table 3.

Table 3
The number of arguments that appear and their classification by argument level

Events no.	Discussion stage	Appear	Level				
			1	2	3	4	5
1	Beginning	7	-	5	2	-	-
	End	24	-	5	14	5	-
2	Beginning	15	-	11	4	-	-
	End	30	-	-	15	12	3
3	Beginning	18	-	2	16	-	-
	End	28	-	-	20	6	2
4	Beginning	16	-	-	16	-	-
	End	25	-	-	23	1	1
Total			**0**	**23**	**110**	**24**	**6**

The analysis revealed that the students' scientific argumentation skills improved significantly after engaging in the laboratory activities. Based on the table above, the number of argumentation occurrences from the first laboratory activity event to the second has increased and from the initial and late discussion stages has increased. This shows that students have increased their courage to express opinions and respond to their friends' opinions after experiencing two laboratory activity events with discussions. Meanwhile, the number of arguments appearing more at the time of the final discussion than the early stage shows that students are more confident to submit opinions after participating in laboratory activities and observing the results of the experiment.

Meanwhile, the emergence of argument levels that have from each stage and event also increases. This can be seen from the appearance of arguments dominated by low-level arguments. While in the final stage the arguments that appear are dominated by a higher level of arguments. This shows that students are able to use experimental data on the laboratory activity to answer the questions asked and accompanied by reasoning and coordination with the results of the literature studies they conduct.

Analysis of the quality of argumentation of laboratory activity participants was carried out using a framework to determine the level of argument according to Toulmin (1958). For this reason, it is necessary to first recognize the components of the argument in an argument. For example, in the following dialog:

> Sts 1: In my opinion, Why choose water, because those microbes tend to grow faster in water media. For example, a lot of water has nutritional elements that make microbes grow. Yes, the water is also there... Then also, the water has a temperature that is not too high, causing a large number of microbes to grow in the water.

The above student answer was gained when they were asked the question, which microbial isolation source media produces the greatest number and diversity of microbes and why this is so. This claim is given at the initial discussion before the laboratory activity, so it is a conjecture or hypothesis based on observations of the environment and preliminary knowledge possessed by the student concerned. The sentence above contains at least 1 (one) claim and 3 (three) data or evidence as well as a warrant or guarantee to support the claim it submits. However, the link between claims and data is still simple. As such, it is a level 3 or intermediate argument.

Meanwhile, the arguments presented at critical discussions always involve the results of observations from previously conducted experiments. An example is in the following dialog:

> Moderator: How does the number and diversity of microbes isolated from air, soil, and river water compare?
>
> Sts 2: so, the result of the observation, more is from water. Especially sewer water. The microbes in the water come from for example the rest of the water, washing clothes, taking a bath, right? Now after being observed, the shape is also when compared to mineral drinking water, it is more concentrated. That indicates that (the microbe in) the water from the sewer is indeed more.

In the dialogue above, it can be seen that the structure of the argument consists of claims, data, warrants, and coordination between the three with reasoning and is also accompanied by primary data derived from the results of students' observations during the observation of experimental results. In contrast, the following arguments contain a claim counter and are accompanied by data supporting it. So one argument contains two sets of arguments at once.

Sts 3:	Because there are a lot of nutrients, there. Sewer water contains its microbial needs. Sewer water gets nutrients from bathing, washing, and other domestic waste. Well, if it is in the air, it is from various sources, carried away by the air.

The results of the observations showed that all students were enthusiastic about following the course of the discussion but not all students were willing to actively express their opinions and argue in the discussion. Students construct arguments during the initial discussion before the laboratory activity and critical discussion of the laboratory activity results. The argumentation scheme shown by students shows that if they are allowed to argue, they will put all their knowledge into answering challenge questions and be equipped with data to support their answer claims. Students come to understand what they do during the laboratory activity, what it has to do with the lecture material, and its relationship to everyday life. So, The students were able to construct arguments based on evidence and scientific reasoning, and their ability to evaluate the quality of evidence also improved.

The results of this study are possible because inquiry-oriented laboratory activities provide opportunities for students to develop their argumentation skills using the data they have from investigation activities as evidence (Duda et al., 2019; Nuckels et al., 2020). Meanwhile, the reasoning and rationalization of evidence that they have with the theory they know at the time of the discussion provides training to students to improve the quality of their arguments by adding warrant, rebuttal and qualifier components (Gouvea et al., 2022; Manz et al., 2020). Thus the quality of student argumentation is increasing. This follows the results of the research of Chen et al (2016), which states that the practice of argumentation can be supported by an argument-based inquiry by practicing oral and written argumentation.

3. Student responses about arguments in laboratory activities

The results of the student questionnaire on argumentation in laboratory activity show that students' attitudes towards the application of laboratory activity accompanied by argumentation tend to be positive. This can be seen from the questionnaire value being in an average position of 80 which means it is strong.

The highest student response is given by students with the code M17 with a total of 90 points or a very strong category, while the lowest is the one given by students with the code M32 with 67 points and is in the strong category. Overall, the average student responded in a strong category, with 80.1 points. This shows that students consider the argumentation process important in laboratory activities.

CONCLUSION

Based on the results of research and discussion, several things can be concluded as follows: 1) The application of inquiry laboratory activities that focus on scientific argumentation consists of preliminary discussions before experiments, experiments implementation, observation of laboratory activity results, and critical discussion of laboratory activity results; 2) The results of the analysis of the quality of student argumentation show that students construct arguments that are relatively developed if allowed to have critical discussions, especially after having experimental data; and 3) Students' responses to arguments in laboratory activities are considered quite important in giving meaning to laboratory activity results in mastery of concepts and critical thinking. Laboratory activities in courses are not a barrier to the application of the argumentation process considering the magnitude of the benefits provided. Argumentation in laboratory activities provides opportunities for students to develop their critical thinking skills and provide answers to problems that occur in their daily lives using experimental data. Therefore, laboratory activities in other courses should also develop argumentation activities or critical discussions so that the benefits of argumentation can be felt by students on an ongoing basis. In addition, to contribute to the scientific treasures of argumentation, it is necessary to conduct further studies on the patterns of argumentation developed by students during lectures and practicums, or laboratory activities.

REFERENCES

Abed, A. R., & Hussein, I. M. (2016). In vitro study of antibacterial and antifungal activity of some common antiseptics and disinfectants agents. *Kufa Journal For Veterinary Medical Sciences*, *7*(1B), 148-159. https://doi.org/10.36326/kjvs/2016/v7i1B4255

Alberta Learning, E. (2004). *Focus on inquiry: A teacher's guide to implementing inquiry-based learning*. ERIC-Clearinghouse. http://www.learning.gov.ab.ca/k_12/curriculum/bysubject/focusoninquiry.pdf

Allchin, D., & Zemplén, G. Á. (2020). Finding the place of argumentation in science education: Epistemics and Whole Science. *Science education, 104*(5), 907-933. https://doi.org/10.1002/sce.21589

Alhamadani, Y. S. T., & Oudah, A. S. (2022). Study of the Bacterial Sensitivity to different Antibiotics which are isolated from patients with UTI using Kirby-Bauer Method. *Journal of Biomedicine and Biochemistry*, *1*(2). onlinelibrary.wiley.com/doi/pdfdirect/10.1111/cas.14993?download=true

Aydeniz, M., & Ozdilek, Z. (2015). Assessing Pre-Service Science Teachers' Understanding of Scientific Argumentation: What Do They Know about Argumentation after Four Years of College Science?. *Science Education International*, *26*(2), 217-239. https://files.eric.ed.gov/fulltext/EJ1064033.pdf

Baroudi, S., & Rodjan Helder, M. (2021). Behind the scenes: teachers' perspectives on factors affecting the implementation of inquiry-based science instruction. *Research in Science & Technological Education*, *39*(1), 68-89. https://doi.org/10.1080/02635143.2019.1651259

Bathgate, M., Crowell, A., Schunn, C., Cannady, M., & Dorph, R. (2015). The learning benefits of being willing and able to engage in scientific argumentation. *International Journal of Science Education*, *37*(10), 1590-1612. https://doi.org/10.1080/09500693.2015.1045958

Belga, J. M. (2022). Improving Students' Science Process Skills Using Argument-Driven-Inquiry (ADI) Laboratory Method. *Asian Journal of Physical and Chemical Sciences*, *10*(2), 42-49. https://doi.org/10.9734/ajopacs/2022/v10i2180

Cetin, P.S.; Dogan, N & Kutluca, A.Y. (2014). The Quality of Pre-service Science Teachers' Argumentation: Influence of Content Knowledge. *J Sci Teac. Educ.* 25:309–331. https://doi.org/10.1007/s10972-014-9378-z

Chen, Y. C., Hand, B., & Park, S. (2016). Examining elementary students' development of oral and written argumentation practices through argument-based inquiry. *Science & Education*, *25*, 277-320. https://doi.org/10.1007/s11191-016-9811-0

Chen, Y.C. & Steenhoek, J. (2014). Arguing Like A Scientist: Engaging Students In Core Scientific Practices. *The American Biology Teacher* 76 (4): 231-237. https://doi.org/10.1525/abt.2014.76.4.3

Clark, D., Sampson, V., Stegmann, K., Marttunen, M., Kollar, I., Janssen, J., & Laurinen, L. (2009). Scaffolding scientific argumentation between multiple students in online learning environments to support the development of 21st century skills. In *the National Academies' Board on Science Education workshop on Exploring the Intersection of Science Education and 21st Century Skills, the National Institutes of Health Office of Science Education* (pp. 1-44).

Creswell, J. W. & V.L. Plano-Clark. (2007). *Designing and Conducting Mixed Methods Research.* Thousand Oaks: Sage Publication.

Du Boulay, D. (2012). Argument in Reading: What does it Involve and How can Students Become Better Critical Readers? *Teaching in Higher Education* 4, 147–162. https://doi.org/10.1080/1356251990040201

Duda, H. J., Susilo, H., & Newcombe, P. (2019). Enhancing different ethnicity science process skills: Problem-based learning through practicum and authentic assessment. *International Journal of Instruction*, *12*(1), 1207-1222. http://repository.persadakhatulistiwa.ac.id/id/eprint/96

Duran, M., & Dökme, I. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills. *Eurasia Journal of Mathematics Science and Technology Education*, *12*(12). http://doi.org/10.12973/eurasia.2016.02311a

Ecevit, T., & Kaptan, F. (2022). The Efficiency of Argument-Based Inquiry Practices in Science Teacher Candidate Education. *Journal of Theoretical Educational Science*, *15*(4), 721-757. https://doi.org/10.30831/akukeg.1070893

Effendi-Hasibuan, M. H., & Mukminin, A. (2019). The inquiry-based teaching instruction (IbTI) in

Indonesian secondary education: What makes science teachers successful enact the curriculum?. *Journal of Turkish Science Education*, *16*(1), 18-33. https://www.tused.org/index.php/tused/article/view/202/158
Erduran, S. & Jiménez, M, P. (2007). *Argumentation in Science Education. Perspectives from Classroom-Based Research.* Science & Technology Education Library. Volume 35.
Erduran, S., Osborne, J., & Simon, S. (2005). The role of argumentation in developing scientific literacy. *Research and the quality of science education*, 381-394. https://link.springer.com/chapter/10.1007/1-4020-3673-6_30
Erkmen, O. (2021). *Laboratory practices in microbiology.* Academic Press.
Eronen, M. I., & Romeijn, J. W. (2020). Philosophy of science and the formalization of psychological theory. *Theory & Psychology*, *30*(6), 786-799. https://doi.org/10.1177/0959354320969876
Faize, F. A., Husain, W., & Nisar, F. (2017). A critical review of scientific argumentation in science education. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(1), 475-483. https://doi.org/10.12973/ejmste/80353
Fan, Y. C., Wang, T. H., & Wang, K. H. (2020). Studying the effectiveness of an online argumentation model for improving undergraduate students' argumentation ability. Journal of Computer Assisted Learning, 36(4), 526-539. https://doi.org/10.1111/jcal.12420
Furtak, E. M., & Penuel, W. R. (2019). Coming to terms: Addressing the persistence of "hands-on" and other reform terminology in the era of science as practice. *Science education*, *103*(1), 167-186. https://doi.org/10.1002/sce.21488
Gericke, N., Högström, P., & Wallin, J. (2023). A systematic review of research on laboratory work in secondary school. *Studies in sci. educ.*, *59*(2),245-285. https://doi.org/10.1080/03057267.2022.2090125
Giri, V., & Paily, M. U. (2020). Effect of scientific argumentation on the development of critical thinking. *Science & Education*, *29*(3), 673-690. https://doi.org/10.1007/s11191-020-00120-y
Gouvea, J., Appleby, L., Fu, L., & Wagh, A. (2022). Motivating and shaping scientific argumentation in lab reports. *CBE—Life Sciences Education*, *21*(4), ar71. https://doi.org/10.1187/cbe.21-11-0316
Gray, Ron & Nam-Hwa Kang. (2014). The Structure of Scientific Arguments by Secondary Science Teachers: Comparison of Experimental and Historical Science Topics. International Journal of Science Education. 36:1, 46-65. https://doi.org/10.1080/09500693.2012.715779
Gultepe, N., & Kilic, Z. (2015). Effect of Scientific Argumentation on the Development of Scientific Process Skills in the Context of Teaching Chemistry. *International Journal of Environmental and Science Education*, *10*(1), 111-132. https://files.eric.ed.gov/fulltext/EJ1060989.pdf
Henderson, J. B., McNeill, K. L., González-Howard, M., Close, K., & Evans, M. (2018). Key challenges and future directions for educational research on scientific argumentation. *Journal of Research in Science Teaching*, *55*(1), 5-18. https://doi.org/10.1002/tea.21412
Heno, F., Azoulay, Z., Khalfin, B., Craddock, H. A., Silberstein, E., Moran-Gilad, J., & Rapaport, H. (2021). Comparing the antimicrobial effect of silver ion-coated silicone and gentamicin-irrigated silicone sheets from breast implant material. *Aesthetic Plastic Surgery*, *45*(6), 2980-2989. https://link.springer.com/article/10.1007/s00266-021-02348-7
Hofstein, A., & Kind, P. M. (2012). Learning in and from science laboratories. *Second international handbook of science education*, 189-207. https://doi.org/10.1007/978-1-4020-9041-7_15
Hollihan, T. A., & Baaske, K. T. (2022). *Arguments and arguing: The products and process of human decision making*. Waveland Press.
Hosbein, K., & Walker, J. (2022). Assessment of scientific practice proficiency and content understanding following an inquiry-based laboratory course. *Journal of Chemical Education*, *99*(12), 3833-3841. https://doi.org/10.1021/acs.jchemed.2c00578
Houghton, D., Soles, G., Vogelsang, A., Irvine, V., Prince, F., Prince, L., ... & Paskevicius, M. (2022, December). Truth and Reconciliation Through Inquiry-based Collaborative Learning. In *The Open/Technology in Education, Society, and Scholarship Association Conference* (Vol. 2, No. 1, pp. 1-8). https://doi.org/10.18357/otessac.2022.2.1.126
Jiménez-Aleixandre, M. P., & Erduran, S. (2007). Argumentation in science education: Perspectives from classroom-based research, chap. Argumentation in Science Education: An Overview.
Jiménez-Aleixandre, M. P., & Puig, B. (2012). Argumentation, evidence evaluation and critical thinking. *Second international handbook of science education*, 1001-1015.

https://doi.org/10.1007/978-1-4020-9041-7_66
Kapici, H. O., Akcay, H., & Koca, E. E. (2022). Comparison of the quality of written scientific arguments in different laboratory environments. *International Journal of Science and Mathematics Education*, *20*(1), 69-88. https://doi.org/10.1007/s10763-020-10147-w
Kirkup, L., Varadharajan, M., & Braun, M. (2016). A Comparison of student and demonstrator perceptions of laboratory-based, inquiry-oriented learning experiences. *International Journal of Innovation in Science and Mathematics Education*, *24*(2). https://openjournals.library.sydney.edu.au/CAL/article/view/9034
Kolbe, T., Steele, C., & White, B. (2020). Time to teach: Instructional time and science teachers' use of inquiry-oriented instructional practices. *Teachers College Record*, *122*(12), 1-54. https://doi.org/10.1177/016146812012201211
Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J., & Soloway, E. (2014). Inquiry in project-based science classrooms: Initial attempts by middle school students. In *Learning Through Problem Solving* (pp. 313-350). Psychology Press.
Kuhn, D. (2019). Critical thinking as discourse. *Human Development*, *62*(3), 146-164. https://doi.org/10.1159/000500171
Kutluca, A.Y.; P.S. Cetin & N. Dogan. 2014. Effect Of Content Knowledge On Scientific Argumentation Quality: Cloning Context. Necatibey Faculty of Ed. Electronic Journal of Sci. and Math. Education Vol. 8, Issue 1, June 2014, pp. 1-30. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=ec4498e0f34d29b724ba1ddff9567499b5ed7385
Lin, S. S. (2014). Science and non-science undergraduate students'critical thinking and argumentation performance in reading a science news report. *International Journal of Science and Mathematics Education*, *12*, 1023-1046. https://doi.org/10.1007/s10763-013-9451-7
Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. *Handbook of research on science education*, *2*, 393-441.
Manz, E., Lehrer, R., & Schauble, L. (2020). Rethinking the classroom science investigation. *Journal of Research in Science Teaching*, *57*(7), 1148-1174. https://doi.org/10.1002/tea.21625
Martín-Gámez, C., & Erduran, S. (2018). Understanding argumentation about socio-scientific issues on energy: a quantitative study with primary pre-service teachers in Spain. *Research in Science & Technological Education*, *36*(4), 463-483. https://doi.org/10.1080/02635143.2018.1427568
McNeill, K. L., & Knight, A. M. (2013). Teachers' pedagogical content knowledge of scientific argumentation: The impact of professional development on K–12 teachers. *Science Education*, *97*(6), 936-972. https://doi.org/10.1002/sce.21081
McDonnell, G. E. (2020). *Antisepsis, disinfection, and sterilization: types, action, and resistance*. John Wiley & Sons.
Millar, R. (2004). The Role of Practical Work in the Teaching and Learning of Science. *Paper prepared for the Committee: High School Science Laboratories: Role and Vision, National Academy of Sciences*, Washington DC. York: University of York.
Murray, P. R., Rosenthal, K. S., & Pfaller, M. A. (2015). *Medical microbiology*. Elsevier Health Sciences.
National Research Council, (1996). *National Science Education Standards*. ISBN: 0-309-54985-X, 272 pages, 8 1/4 x 10 1/2, http://www.nap.edu/catalog/4962.html
Noroozi, O., Kirschner, P. A., Biemans, H. J., & Mulder, M. (2018). Promoting argumentation competence: Extending from first-to second-order scaffolding through adaptive fading. *Educational Psychology Review*, *30*, 153-176. https://doi.org/10.1007/s10648-017-9400-z
Novaes, C. D. (2021). Argument and argumentation. *The Stanford Encyclopedia of Philosophy* (Fall 2022 Edition), Edward N. Zalta & Uri Nodelman (eds.). https://plato.stanford.edu/archives/win2022/entries/chinese-logic-language/
Nückles, M., Roelle, J., Glogger-Frey, I., Waldeyer, J., & Renkl, A. (2020). The self-regulation-view in writing-to-learn: Using journal writing to optimize cognitive load in self-regulated learning. *Educational Psychology Review*, *32*(4), 1089-1126. https://doi.org/10.1007/s10648-020-09541-1
Nussbaum, E. M. (2021). Critical integrative argumentation: Toward complexity in students' thinking. *Educational Psychologist*, *56*(1), 1-17.

https://doi.org/10.1080/00461520.2020.1845173
Nussbaum, E. Michael, Gale M. Sinatra & Marissa C. Owens. (2012). *Chapter 2. The Two Faces of Scientific Argumentation: Application to Global Climate Change*. Dalam Khine, Myint Swe (ed) Perspective on Scientific Argumentation: Theory, Practice and Research. Springer, New York.
OECD (2014). *PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science* (Volume I, Revised edition, February 2014), PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264201118-en
Oren, A. (2015). Teaching microbiology to undergraduate students in the humanities and the social sciences. *FEMS Microbiology Letters*, *362*(19), fnv162. https://doi.org/10.1093/femsle/fnv162
Ozdem, Y.; Ertepinar H., Cakiroglu, J. & Erduran, S. (2013). The Nature of Pre-Service Science Teachers' Argumentation in Inquiry-Oriented Laboratory Context. International Journal of Science Education. 35:15, 2559-2586. https://doi.org/10.1080/09500693.2011.611835
Passmore, C. M., & Svoboda, J. (2012). Exploring opportunities for argumentation in modelling classrooms. *International Journal of Science Education*, *34*(10), 1535-1554. https://doi.org/10.1080/09500693.2011.577842
Reza, Z. M., Mohammad, A., Salomeh, K., Reza, A. G., Hossein, S., Maryam, S., ... & Saeed, F. (2014). Rapid detection of coliforms in drinking water of Arak city using multiplex PCR method in comparison with the standard method of culture (Most Probably Number). *Asian Pacific journal of tropical biomedicine*, *4*(5), 404-409. https://doi.org/10.12980/APJTB.4.2014C896
Rodriguez, J. M. G., Hunter, K. H., Scharlott, L. J., & Becker, N. M. (2020). A review of research on process oriented guided inquiry learning: Implications for research and practice. *Journal of chemical education*, *97*(10), 3506-3520. https://doi.org/10.1021/acs.jchemed.0c00355
Roviati, E., Widodo, A., Purwianingsih, W., & Riandi, R. (2019). Development of argumentation-based critical thinking skills tests in microbiology laboratory. *Scientiae Educatia: Jurnal Pendidikan Sains*, *8*(1), 76-87. http://dx.doi.org/10.24235/sc.educatia.v8i1.475
Russell, T., & Martin, A. K. (2023). Learning to teach science. In *Handbook of research on science education* (pp. 1162-1196). Routledge.
Salybekova, N., Issayev, G., Abdrassulova, Z., Bostanova, A., Dairabaev, R., & Erdenov, M. (2021). Pupils' Research Skills Development through Project-Based Learning in Biology. *Cypriot Journal of Educational Sciences*, *16*(3), 1106-1121. http://files.eric.ed.gov/fulltext/EJ1309234.pdf
Sampson, V. & M. R. Blanchard. (2012). Science Teachers and Scientific Argumentation: Trends in Views and Practices. *J. of Research in Science Teaching*, 49(9). 1122-1148. https://doi.org/10.1002/tea.21037
Sampson, V., Grooms, J., & Walker, J. P. (2011). Argument-Driven Inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: An exploratory study. *Science Education*, *95*(2), 217-257. https://doi.org/10.1002/sce.20421
Saputra, I. G. P. E., Harnipa, H., & Akhfar, M. (2021). Development of science learning device oriented guided inquiry with virtual laboratory to train science process skills of junior high school students in Kendari. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *7*(1), 13-22. https://doi.org/10.21009/1.07102
Sengul, O., Enderle, P. J., & Schwartz, R. S. (2020). Science teachers' use of argumentation instructional model: linking PCK of argumentation, epistemological beliefs, and practice. *International Journal of Science Education*, *42*(7), 1068-1086. https://doi.org/10.1080/09500693.2020.1748250
Sevinc, B., Ozmen, H., & Yigit, N. (2011). Investigation of Primary Students' Motivation Levels towards Science Learning. Science Education International, 22(3), 218-232. http://files.eric.ed.gov/fulltext/EJ941695.pdf
Shakya, B., Shrestha, S. R., & Silvanus, V. (2021). Bacteriological Examination of Water supply and Drinking Water at Household level in Makalbari Area by the Most Probable Number Method. *Nepal Medical College Journal*, *23*(2), 146-152. https://doi.org/10.3126/nmcj.v23i2.38525
Sitohang, J. (2017). Penerapan metode tanya jawab untuk meningkatkan hasil belajar IPA pada siswa sekolah dasar. *Suara Guru*, *3*(4), 681-688. http://dx.doi.org/10.24014/suara%20guru.v3i4.4851
Smith, E. M., Stein, M. M., & Holmes, N. G. (2020). How expectations of confirmation influence students' experimentation decisions in introductory labs. *Physical Review Physics Education Research*, *16*(1), 010113. https://doi.org/10.1103/PhysRevPhysEducRes.16.010113

Sudigdo, A., & Setiawan, B. (2020). Level of inquiry in senior high school Central Java, Indonesia. *Journal of Xi'an University of Architecture & Technology*, *12*, 2838-845. http://dx.doi.org/10.21009/1.06212

Tang, K. S. (2022). Material inquiry and transformation as prerequisite processes of scientific argumentation: Toward a social-material theory of argumentation. *Journal of Research in Science Teaching, 59*(6), 969-1009. https://onlinelibrary.wiley.com/doi/pdf/10.1002/tea.21749

Toulmin, S. E. (1958). *The Uses of Argument.* Cambridge University Press, Cambridge.

Valls-Bautista, C., Solé-LLussà, A., & Casanoves, M. (2021). Pre-service teachers' acquisition of scientific knowledge and scientific skills through inquiry-based laboratory activity. *Higher Education, Skills and Work-Based Learning*, *11*(5), 1160-1179. https://doi.org/10.1108/HESWBL-07-2020-0161

Van Lacum, EB., MA. Ossevoort & MJ. Goedhart. (2014). A Teaching Strategy with a Focus on Argumentation to Improve Undergraduate Students' Ability to Read Research Articles. *CBE-Life Sciences Education,* Vol.13, 253-264. https://doi.org/10.1187/cbe.13-06-0110

Von der Mühlen, S., Richter, T., Schmid, S., Schmidt, E. M., & Berthold, K. (2016). Judging the plausibility of arguments in scientific texts: a student–scientist comparison. *Thinking & Reasoning*, *22*(2), 221-249. https://doi.org/10.1080/13546783.2015.1127289

Wibowo, Y., Kurniawati, A., & Handziko, R. C. (2019, June). Competency of pre-service biology teachers on the academic and pedagogical aspects. In *Journal of Physics: Conference Series* (Vol. 1241, No. 1, p. 012059). IOP Publishing. http://dx.doi.org/10.1088/1742-6596/1241/1/012059

Woolnough, B. E. and Allsop, T. (1985). *Practical Work in Science.* Cambridge: Cambridge University Press.

Yalcinoglu, P. (2007). *Evolution as Represented through Argumentation: A qualitative Study on Reasoning and Argumentation in High School Biology Teaching Practices.* Dissertation Abstracts International, 68(09). http://rave.ohiolink.edu/etdc/view?acc_num=osu1190123554