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The Effect of Argument Driven Inquiry Learning Models on Scientific Argumentation Skills and Higher Order Students on The Topics of Acid Base

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Abstract: This study aims to determine the effect of the argument driven inquiry learning model on the simultaneous scientific argumentation skills and higher order thinking skills in students on the topic of acid base. The research uses a quasi-experimental method with a pretest-posttest control group design. This research was conducted on 137 students of class XI MIPA at a high school in Palembang. Sampling was done by the simple random sampling technique. The results of the study showed that there was a significant effect of the argument driven inquiry learning model on the scientific argumentation skills and higher order thinking skills of the students on the topic of acid base. There is an effective contribution of the application of the learning model of argument driven inquiry on the topics of acid base to enhance the scientific arguments skills and the higher order thinking skills of students at the same time of 18.90%. In general, the students gave a positive response to the application of the argument driven inquiry learning model to enhance the scientific argumentation skills and higher order thinking skills.

Keywords: Acid Base; Argument Driven Inquiry; Higher Order Thinking Skills; Scientific Argumentation Skills

Introduction

Education is a systematic effort aimed at developing and optimizing intellectual, physical, and spiritual abilities in accordance with the values, culture, and norms that exist in the social environment so that it can benefit itself, the religious community, and the nation (Zuhdi et al., 2021). Education plays a very important role in various aspects of life because, through education, the process of transformation and actualization of knowledge is easily achieved, especially in the field of science, which requires scientific knowledge and experience, so to acquire it, it must be through a scientific learning process too (Khuluqo, 2017).

The rapid development of science in recent decades has affected the lives of global societies, including Indonesia. Based on the conditions mentioned, ideas arose to reform and transform learning strategies, curricula, and evaluation methods (Barlia, 2011). Learning can be understood as the activity of a person searching for something learned, the learning process, and evaluating learning outcomes so as to be able to make behavioral changes better than before (Fathurrohman & Sulistyorini, 2012). The learning process occurs because of the good interaction between the teacher and the student. Interaction or interrelationship between teacher and student is the primary requirement of learning interaction in the teaching and learning process that will affect the learning outcome of the student. Therefore, the teacher's teaching process and strategy are required to ensure that the competence of the pupil corresponds to the expected achievement (Basar et al., 2021).

The quality of optimal learning outcomes is characterized by a healthy student, a healthy

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environment, appropriate content or curriculum, and a learning process focused on the student so that cognitive, psychomotor, and affective results are achieved according to the established standards (Setyosari, 2014). However, according to the latest PISA (Program for International Student Assessment), education in Indonesia consistently ranked in the top 10 lowest of all countries participating in the assessment, indicating that the current learning system in Indonesia is not at its maximum (Schleicher, 2018). It is a specific challenge for educators or teachers to undertake learning activities that emphasize the skills required by the 21st century: critical thinking, creativity, systematics, research-based, informational, communicative, and reflective (Jihannita et al., 2023; Susilawati et al., 2023).

The subject of chemistry as a part of science learning is mandatory to be studied at the level of secondary education, especially at the MIPA major, which requires a scientific approach using scientific methods, scientific attitudes, and scientific skills (Subagia, 2014). A science with a significant impact and a tight relationship to everyday life is chemistry (contextual). Because chemistry is so widely used in so many other professions, it is also sometimes referred to as a core science (Ihsani et al., 2020). However, according to most students, this is a difficult subject because to understand the true chemistry concepts, students are required to describe and associate macroscopic aspects (experimental), microscopic (atoms, molecules, ions), and symbolic (formulas, calculations), so this leads to the chemistry subject becoming very complex, plus students only memorize concepts and are less able to associate concepts with everyday life (Zulfadli & Munawwarah, 2016).

According to Utami et al. (2020) acid-base materials is considered a difficult matter because of the complex, interrelated nature of the calculation and the need for a gradual and in-depth understanding of concepts to understand it. Students' difficulties with acid and base solutions are believed to be derived from many misunderstandings related to the concepts of preconditioned knowledge of the chemical concept of base acid solutions such as the particle nature of matters, the nature and composition of solutions, structure of atom, ionic and covalent bonds, symbols, chemical reactions and equations, ionization and chemical equilibrium in the aqueous phase (Sheppard, 2006). Besides, the concept of basic acid has a close relationship with everyday life, so if the student has understood the basic acid concept, it is expected that they will be able to explain the symptoms and phenomena in daily life (Mubarokah et al., 2018). Dewi et al. (2018) Learning practice on acid base material requires research and scientific literacy that requires the involvement of students to formulate problems, plan solutions, and represent such knowledge well supported by existing facts and theories as scientists do. This can be done when training the skills of scientific argumentation and higher order thinking skills abilities of students (Khoirussaadah & Hakim, 2019).

The role of scientific argumentation skills for students is very important, especially in the chemistry subjects of acid base (Utami et al., 2022). However, based on the initial observations that have been made it has been obtained that students have weaknesses in argumentation. This is supported by research Widiastiningsih & Effendi-hasibuan (2022) that has been carried out by that low accuracy of scientific argumentation students caused by teachers are not accustomed to train students argumentation and scientific argumentation skills have not received special attention from teachers. According by Bulgren et al. (2014) stated that scientific argumentation skills are one of the skills that students should have in chemistry learning to train thinking skills, communication skills, and understanding of science concepts. However, looking at the current reality, the applied learning in schools has not specifically trained students in the skill of scientific argumentation. This is evidenced through a survey results support the problem that only 2% of junior high school students have the ability to file claims accompanied by well-structured written arguments (Songsil et al., 2019). Learning based on scientific argumentation is important to implement as it potentially develops the ability of the learners to build, communicate, and evaluate opinions scientifically and validly (Kadayifci & Celik, 2016).

This argumentation activity is related to the thinking skills that a person has mastered. This is because thinking skills are influenced by a variety of factors, especially the structure of thinking that can be expressed through language, both oral and written, which is later called argumentation (Hasnunidah et al., 2015). Scientific argumentation skills can help learners engaged in scientific practice where evidence and claims of scientific knowledge are justified or evaluated on the basis of empirical or theoretical evidence that emphasizes three aspects, namely: development of conceptual understanding, understanding of scientific epistemology, and enhanced research capacity (Grooms et al., 2018; Ozdem et al., 2013). Therefore, teachers can not only focus on explaining the legal theory, models, or concepts of various disciplines for the development of students; Teachers must also train students' thinking skills and provide structured opportunities for learners to practice and participate in scientific argumentation so that learners can learn thoroughly and provide solutions to problems in everyday life (Sampson & Blanchard, 2012; Walker et al., 2016).

Teachers should plan well and involve students in learning activities, as well as Teachers should plan well and involve students in learning activities, as well as arrange HOTS assessments that can encourage and develop higher order thinking skills (Febriyanti & Widjajanti, 2023; Yayuk et al., 2019). Thus, knowledge acquired through a higher order thinking skills process is more easily transferable, so a deep conceptual understanding of ideas, concepts, and theories is much more likely to be able to represent knowledge to solve problems relevant to the student (Rahmawati, 2023; Toledo & Dubas, 2016). The HOTS assessment can be implemented to help learners improve their higher order thinking skills. It supports another opinion that higher order thinking skills questions can encourage learners to think deeply about the subject matter (Barnett & Francis, 2012; Ramos et al., 2018). Thus, that test of higher order thinking skills can provide incentives to learners for developing higher order thinking skills as well (Istiyono et al., 2014). This research is based on the problem of still low implementation of learning that nurtures scientific argumentation skills and higher order thinking skills that students need to master. Scientific argumentation skills and higher order thinking skills need to be mastered by students in the study of chemistry subjects, especially acid and base matter. It is a challenge for educators to cope with it by applying various methods and models of student-centered learning that develop these skills (Salay, 2019). One of them is the application of an argument-driven inquiry-learning model.

The argument driven inquiry learning model was first introduced in 2009, becomes one of the learning models that emphasizes the existence of research activities (Hosbein et al., 2021; Sampson & Gleim, 2009). Argument driven inquiry was designed to advance laboratory-based activities to optimize student participation in qualified argumentation activities (Ozdem et al., 2013; Sampson et al., 2012). In this case, argument driven inquiry is a student-centered learning model that emphasizes research and argumentation to improve thinking skills and deepen understanding of an opinion so as to build a good understanding of concepts (Sampson et al., 2013).

Some studies show the application of argument driven inquiry learning to the development of an argumentation and thinking skills. Research on the influence of Argument driven inquiry on the thinking skills and argumentation of high school students on chemical materials has been carried out by (Wulandari et al. (2020) on the speed of chemical reactions and Siahaan, (2019) on soluble materials and the resulting times of solubility. The results of the study show that the argument driven inquiry learning model can influence the argumentation skills and understanding of the concepts of high school students. The research is expected to contribute to improving the students' scientific argumentation skills and higher order thinking skills, as well as providing knowledge in the application of argument driven inquiry learning models to the students. The argument driven inquiry model integrates opportunities for students to engage in scientific argumentation and peer review. When students are asked to build and maintain their answers, as in the case of argumentation, they are guided to think critically and with a higher level of abstraction (Demircioglu & Ucar, 2015). His hope is that the combination of all his activities with the application of the learning model argument driven inquiry will improve the higher order thinking skills ability and the argumentation skills of the pupils.

Method

This research is a quasi-experiment research with a pretest posttest control group research design, namely by comparing the scores of scientific argumentation skills and scientific argumentation skills of students from each experimental class and control class after being given different treatments. The population of this research is class XI MIPA students in the 2022/2023 academic year in Palembang City. The samples used were 4 classes using simple random sampling techniques. The independent variable in this research is the learning model. The treatment variations are the argument driven inquiry learning model for the experimental class and the discovery learning model for the control class.

The data collection methods used is test and documentation methods. The scientific argumentation skills test instrument includes pretest questions consisting of 6 essay questions and posttest questions consisting of 6 essay questions. The higher order thinking skills test instrument consists of 18 multiple choice questions and 2 essay questions.

The data analysis carried out in this research was an initial ability similarity test, descriptive statistical analysis, prerequisite analysis test, MANOVA hypothesis test, analysis of the influence between variables, effect size analysis using partial eta squared (Cohen et al., 2018). The interpretation of the effect size of partial eta squared is presented in Table 1.

Table 1. Interpretation Partial Eta Squared

Partial Eta Squared	Effect Sizes
$\eta^2 \geq 0.14$	Large
$0.6< \eta^2 \leq 0.14$	Medium
$0.1< \eta^2 \leq 0.6$	Small

Results and Discussion

This research aims to determine the effect of argument driven inquiry learning to improve students' scientific argumentation skills and HOTS on the topic of acids and bases. The research used a quasi-experimental pretest-posttest control group research design so that two groups were used consisting of two experimental classes and two control classes of high schools in Palembang. The research sample consisted of 137 students who were divided into 2 groups, namely the application of the argument driven inquiry learning model, 68 students in the experimental group and 69 students in the control group. The experimental group applied the Argument driven inquiry learning model, while the control group applied learning that is usually used by teachers, namely learning using the discovery learning model. The research carried out consisted of three meetings for each group. At each meeting in the experimental group argument driven inquiry learning steps were used and in the control group discovery learning steps were used. This research was carried out in five stages presented in Figure 1.

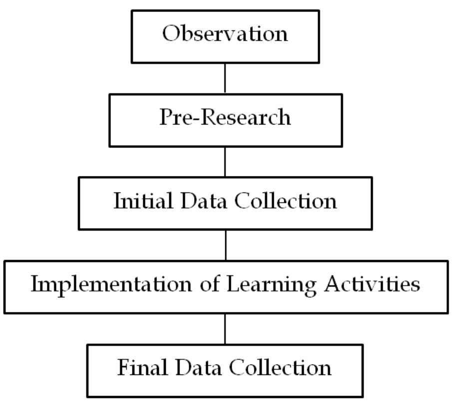

Figure 1. Research Flow

The first stage in Figure 1, an observation aimed at determining a suitable school as a place of research. Observations carried out in schools using curricula used are curriculum 2013, schools that are accredited A, as well as schools that have adequate facilities and facilities for conducting research. The sampling of the research was done using the simple random sample technique, after which the samples were taken randomly. The research was conducted in the high school in the city of Palembang. Then random samples were taken to determine the experimental group and the control group. The experimental groups were divided into two classes XI MIPA.

The second stage is pre-research which includes instrument validation and testing of the instruments that will be used. Instrument validation and testing are carried out on 12th grade science students from three public high schools in Palembang, namely five classes of 12th grade science students from SMA Negeri 3 Palembang, eight classes of 12th grade science students from SMA Negeri 8 Palembang, and three classes of 12th grade science students and one class of 12th grade science students from SMA Negeri 10 Palembang. Empirical validation is carried out to validate the validity of the instruments for scientific argumentation skills and high-level thinking skills that have been prepared. In addition, a small-scale test of the learning implementation plan and student worksheets is conducted. This is done to determine and ensure that the instruments developed in the study have good quality and can produce valid and reliable data.

The third stage is the collection of initial data which consists of pretest activities aimed at obtaining initial data on scientific argumentation skills and high-level thinking skills in both the experimental and control groups on acid-base materials. The pretest for scientific argumentation skills and high-level thinking skills was conducted outside the learning activities on Tuesday, January 11, 2023, and Wednesday, January 10, 2023.

The fourth stage is the implementation of learning activities. The learning activities were carried out in four classes as research samples, consisting of two experimental classes science students using the argument-driven inquiry learning model and two control classes science students using the discovery learning model. The learning activities in this study were carried out on the subject of acids and bases, which were divided into three meetings with an allocation of ninety minutes for each meeting. In the first meeting, students were given material on the development of acid-base theory. In the second meeting, students were given material on distinguishing acid-base pH and calculating acid-base pH. In the third meeting, students were given material on identifying acids and bases with natural ingredients.

The fifth stage of this research is an activity to obtain final data, which includes giving a posttest to obtain the final scientific argumentation skills and high-level thinking skills of students in both the experimental and control groups after being treated with the learning model. The posttest was conducted outside the learning activities on Tuesday, January 24, 2023, and Wednesday, January 25, 2023.

The learning process in each group runs smoothly with students who are active during the learning process. The research began with pretest activities aimed at finding out the initial argumentation skills and higher order thinking skills of students in the control group and experimental group before the learning process took place. This research ended with a posttest activity given after the learning process to determine students' scientific argumentation skills after being given treatment. This aims to determine the effect before and after treatment on students' scientific argumentation skills and HOTS in the experimental group and control group and to determine the effect of applying argument driven inquiry learning and conventional learning applied by previous teachers. Apart from that, to find out the effectiveness of implementing argument driven inquiry learning to improve students' scientific argumentation and HOTS skills in acid and base material.

Table 2. Multivariance Analysis of Variance Test Results

Test	F	Sig.	Partial Eta Squared
Hotelling's Trace	15.428 b	0.000	0.189

The learning is carried out by students who are directed to follow a series of stages of the argument driven inquiry learning model in accordance with the Learning Implementation Plan with the help of student worksheets (Sampson et al., 2015; Sampson & Gleim, 2009). The steps of the argument driven inquiry learning model are presented in Figure 2.

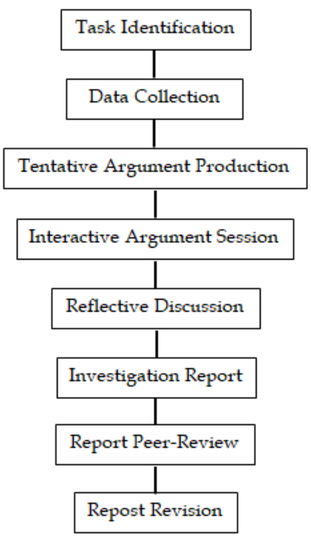

Figure 2. Steps of the argument driven inquiry learning model

The first step is identifying the problem, where students identify the problem and answer the questions that have been presented in the student worksheet. The second step is data collection. Students develop an initial claim in the form of a hypothesis formulation as a temporary answer to a problem. The third step is making tentative arguments, where students are trained to analyze and process the data obtained, as well as providing learning experiences for students to express ideas that are relevant to chemical concepts based on the data obtained. The next step is for students to conduct an argumentation session through presenting the results of the discussion. The group presenting will receive input, rebuttals, suggestions or questions. Apart from that, students are directed to discuss with their group friends and teachers to revise or add further investigation discussions so that other students have the same understanding. After that, students are given the opportunity to make reports and write conclusions on student worksheets. Then, students give their group's student worksheets to other groups at random for review. Next, students are given more time to respond and revise review from other groups, students can collect student reports and worksheets.

Test results using Hotelling's trace sig value. < α= 0.05, then Ho is rejected and Ha is accepted, which means that there is an influence of the two dependent variables with each treatment and an effective contribution which shows how much influence the learning model has on the dependent variable. Based on the results of the multivariate test analysis in Table 2, it shows that Hotelling's trace sig. 0.000 < 0.05 then Ho is rejected. So it can be concluded that there is an influence of scientific argumentation skills and HOTS on students in the experimental group who use argument driven inquiry learning with students in the control group. The effective contribution aims to find out the percentage of influence of the argument driven inquiry learning model on students' scientific argumentation skills and HOTS, so it can be concluded that the percentage of effective contribution of the argument driven inquiry learning model on scientific argumentation skills and higher order thinking skills is 18.9% in the large category. The argument driven inquiry learning model is a learning model that provides students with reflective learning opportunities in scientific investigations so that they can develop argumentation skills and higher level thinking abilities (Kadayifci et al., 2012; Sampson et al., 2012).

Based on the analysis that has been carried out, it shows that the results of the scientific argumentation skills and higher order thinking skills of the experimental group are higher than those of the control group, the application of argument driven inquiry learning shows better results compared to conventional learning (discovery learning) applied by previous teachers.

Scientific Argumentation Skills

Pretest activities are carried out before the learning process begins to determine students' initial scientific argumentation skills. according to research by Devi et al. (2018) that students' achievement of argumentation skills is influenced by students' initial knowledge regarding the material presented. The following results of the pretest and posttest of scientific argumentation skills are presented in Figure 3.

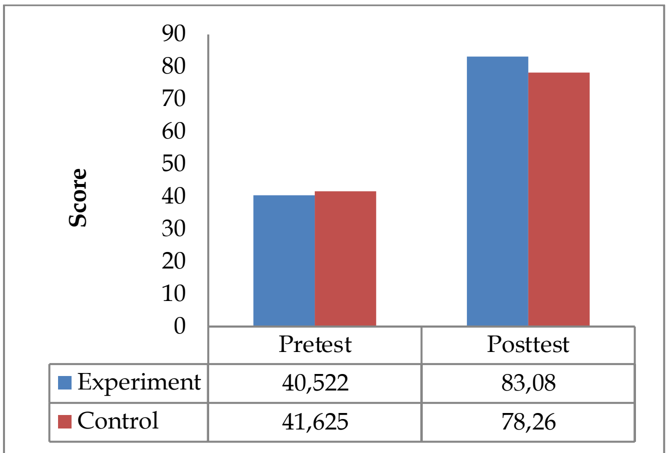

Figure 3. Scientific Argumentasi Skills Results

In Figure 3, it can be seen that the pretest score for the control group students' scientific argumentation skills was 41.63 and the experimental group score was 40.52. The pretest mean difference in scientific argumentation skills between the experimental group and the control group was 1.11. So it can be concluded that students in the experimental group and the control group have relatively similar scientific argumentation skills. Furthermore, the posttest means score for students' scientific argumentation skills in the control group was 78.26. Meanwhile for students in the experimental group it was 83.09. It can be concluded that students' scientific argumentation skills have increased in the experimental group and control group on acid and base material. However, students in the experimental group had higher scientific argumentation skills compared to students in the control group with a mean difference of 4.83. These findings are in line with research by Setiawan & Jumadi (2023) states that implementation of the argument-driven inquiry learning model in science education enhances students' understanding of a subject and improves students' ability to solve problems, enabling them to confidently construct arguments from various perspectives.

Table 3. Test of Between Subject Results

Variable	F	Sig.	Partial Eta Squared
Scientific argumentation skills	20.230	0.000	0.132
Higher order thinking skills	21.039	0.000	0.137

The application of the argument driven inquiry learning model in tentative and interactive argumentation sessions gives students the opportunity to improve their scientific argumentation skills. Therefore, students' ability to argue or put forward claims that are supported by data, accompanied by warrants and backing is clearly visible at this stage. Apart from that, this stage also provides an opportunity for students to rebuttal other students' initial claims. This is able to develop students' scientific argumentation skills Ginanjar et al., (2015); Yahmin et al., 2020). This is supported by Saracaloglu et al. (2011) stated that training in making arguments supported by data has an effect on improving students' skills in making arguments.

Based on tests that have been carried out on the pretest and posttest scores, it shows that there is an increase in students' scientific argumentation skills in both the experimental group and the control group. Furthermore, to find out the effect of the scientific argumentation skills of students who use the argument driven inquiry learning model and students who use the conventional learning model, it can also be seen from the MANOVA follow-up test, namely the results of the between subject effect test in Table 3. The results of the test on students' scientific argumentation skills show that the value is sig. 0.00 < α. So it can be concluded that there is a significant influence on scientific argumentation skills between students who use the argument driven inquiry learning model and students who use the discovery learning model. This finding is in line with research by Siregar & Pakpahan (2020) which states that the applied argument driven inquiry learning significantly influences students' scientific argumentation abilities because the argument driven inquiry learning process includes investigation activities through practicums thereby fostering students' arguments in providing claims, interpreting the data obtained, provide justification or reasons (warrants) as well as refutation of different ideas from the class discussion community during tentative and interactive argumentation sessions.

In this study, the experimental group and the control group both showed an increase in scientific argumentation skills based on the pretest and posttest scores that had been carried out, however for the experimental class the increase was more significant than the control class. Increasing scientific argumentation skills by obtaining effective contributions, namely the partial eta squared value in Table 3 which shows the acquisition of effective contributions of 13.2% in the medium category. So it can be concluded that chemistry learning by applying the argument driven inquiry learning model has a more effective influence compared to the control group which uses the discovery learning model to improve the scientific argumentation skills of class XI students on acid-base topics. These findings are in line with research by Ginanjar et al. (2015) & Kuki et al. (2023) which states that the application of an argumentation-based learning model is more effective in training and encouraging students' scientific argumentation skills and understanding of concepts. This is supported by the opinion of Sampson et al. (2012) who stated that the argument driven inquiry learning model is a learning model that facilitates students to carry out scientific investigations thereby helping students to develop thinking skills by emphasizing the important role of argumentation in generating the knowledge that students have. When implementing the argument driven inquiry learning model, students are also required to evaluate other students. This aims to train and encourage thinking skills in assessing the quality of arguments and identifying weaknesses or deficiencies in the arguments that have been made. This is supported by Marhamah et al. (2017) which states that students who are given the opportunity to revise research reports that have been given feedback based on the results of the reflective discussions carried out can improve because students are not only able to argue but students can also analyze other students' arguments.

Higher Order Thinking Skills

Students' initial higher order thinking skills (HOTS) are measured through a test in the form of 10 multiple choice questions and 2 essays which are arranged based on indicators of higher order thinking abilities. Based on the results of the analysis in Figure 4, it shows that the average HOTS pretest result for students in the control group was 42.36 and in the experimental group were 40.95. Based on the initial HOTS mean scores of students in the control group and the experimental group, they were not too different. Students experienced an increase in HOTS in both the control group and the experimental group. The mean HOTS posttest score in the control group was 79.22, while the experimental group got a mean score of 82.23. There was an influence on the mean scores of the experimental group and control group students after receiving treatment with a difference of 3.01. Therefore, it can be concluded that the HOTS of experimental group students is higher when compared to the control group

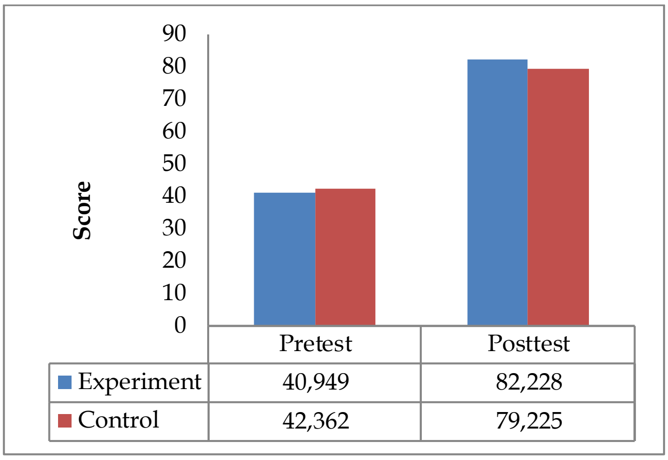

Figure 4. HOTS Results

The application of the argument driven inquiry learning model in this research aims to increase students' HOTS, especially in acid and base material. The skills trained in applying the argument driven inquiry model are scientific argumentation skills and HOTS. The steps of the argument driven inquiry learning model enable students to develop analytical skills in identifying problems, making arguments as claims along with backing and warrants. In peer review sessions, students criticize each other's claims made by other groups (Fadilah et al., 2020). All argument driven inquiry learning processes that integrate claims are made to support the development of student HOTS (Prayoga et al., 2020; Syuzita et al., 2023).

Based on the tests that have been carried out, it shows that there is an increase in student HOTS in both the experimental group which uses the argument driven inquiry learning model and the control group which uses the discovery learning model. The results of the increase are known from the pretest and posttest scores in the descriptive statistical test results in Figure 4. Furthermore, the testing carried out aims to determine the effect of HOTS on students in the experimental group who apply argument driven inquiry learning and students in the control group which can be seen from the MANOVA follow-up test, namely test of between subject effect in Table 3. There is an influence of student HOTS with a confidence level of 95% showing a sig. $0.000 < \alpha$. So it can be concluded that there is an influence of HOTS on students who apply argument driven inquiry learning and students who apply conventional learning. This finding is in line with research by Dani (2021) which states that there is a significant influence on the use of the argument driven inquiry learning model on HOTS. The instructional impact in this research is so that students can improve HOTS in solving a problem.

The application of argument driven inquiry learning is more effective in increasing students' HOTS in the experimental group compared to the control group. Testing the increase in HOTS for students who apply argument driven inquiry learning can be seen from the partial eta squared value in Table 3 showing the effective contribution of argument driven inquiry learning is 13.7% in the medium category. This is supported by what Fakhriyah et al. (2021) Argument driven inquiry learning which emphasizes the importance of scientific argumentation in improving higher order thinking skills, so that training students' HOTS which involves logical reasoning processes, has clear perception, and develops thinking skills. At the problem identification stage, students are also asked to express and make decisions in dealing with existing problems. The argumentation session is a very important part of improving HOTS because through tentative and interactive argumentation activities, a person's critical thinking develops. This is in line with research by Demircioglu & Ucar (2015) which states that the argumentation stage activities involve providing comments and suggestions to each other on reports that have been prepared, as well as providing assessments between friends. All of these processes will stimulate the development of students' thinking skills.

Conclusion

Based on the results of research, data analysis and discussion, it can be concluded that there is an influence of the argument driven inquiry learning model on students' scientific argumentation and HOTS skills on acid-base topics and has an effective contribution of 18.90% to improving scientific argumentation skills and higher order thinking skills. Meanwhile, the scientific argumentation skills were 13.2% due to the activities of identifying problems, making tentative arguments, conducting interactive argumentation sessions with debates, making investigation reports, double-blind peer reviews, and revising reports on the results of investigations, and the ability high level thinking was 13.7% due to activities identifying problems, generating data through experimental activities, temporary and interactive argument sessions, and double-blind peer reviews by providing comments, suggestions and criticism during the learning process.

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Authors Contribution
M. A. S. contributed to conceptualization, designing research, conducting research, formal analysis, investigations, resources, writing research of articles. S. R. contributed to conceptualization, writing-review & Editing, and supervision. All authors have read and agreed to published version of the manuscript

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Conflicts of Interest
The authors declare no conflict of interest.

References

Barlia, L. (2011). Konstruktivisme dalam pembelajaran sains di SD: tinjauan epistemologi, ontologi, dan keraguan dalam praksisnya. *Cakrawala Pendidikan*, *3*, 343–358. https://doi.org/10.21831/cp.v3i3.4200

Barnett, J. E., & Francis, A. L. (2012). Using higher order thinking questions to foster critical thinking : a classroom study. *Educational Psychology*, *32*(2), 201–2011. https://doi.org/10.1080/01443410.2011.638619

Basar, Z. M., Mansor, A. N., Jamaludin, K. A., & Alias, B. S. (2021). The effectiveness and challenges of online learning for secondary school students – a case study. *Asian Journal of University Education*, *17*(3), 119–129. https://doi.org/10.24191/ajue.v17i3.14514

Bulgren, J. A., Ellis, J. D., & Marquis, J. G. (2014). The use and effectiveness of an argumentation and evaluation intervention in science classes the use and effectiveness of an argumentation and evaluation intervention in science classes. *Journal of Science Education and Technology*, *23*, 82–97. https://doi.org/10.1007/s10956-013-9452-x

Cohen, L., Manion, L., & Marrison, K. (2018). *Research Methods in Education 8th Edition*. New York: Routledge Taylor and Francis Group.

Dani, A. U. (2021). Pengaruh model pembelajaran argument driven inquiry terhadap kemampuan berpikir tingkat tinggi peserta didik. *Edudeena: Journal of Islamic Religious Education*, *10*(2), 257–264. https://doi.org/10.24252/ip.v10i2.26684

Demircioglu, T., & Ucar, S. (2015). Investigating the effect of argument-driven inquiry in laboratory instruction. *Educational Sciences: Theory & Practice*, *15*(1), 267–283. https://doi.org/10.12738/estp.2015.1.2324

Devi, N. D. C., Susanti V.H., E., & Indriyanti, N. Y. (2018). Analysis of high school students' argumentation ability in the topic of buffer solution. *JKPK (Jurnal Kimia Dan Pendidikan Kimia)*, *3*(3), 152–159.

https://doi.org/10.20961/jkpk.v3i3.23308

Dewi, S. A., Susilaningsih, E., & Sulistyaningsih, T. (2018). Conceptual understanding analysis through two-tier model diagnostic tests on acid-base materials. *Jurnal Kimia Dan Pendidikan Kimia*, *3*(3), 160–170. https://doi.org/10.20961/jkpk.v3i3.21904

Fadilah, S. M., Jatmiko, B., & Prastowo, T. (2020). Validity and Effectiveness of Argument-Driven Inquiry Model With Contextual Approaches to Improve Critical Thinking Skills in Science Learning. *Studies in Learning and Teaching*, *1*(2), 66–75. https://doi.org/10.46627/silet.v1i2.32

Fakhriyah, F., Rusilowati, A., Wiyanto, & Susilaningsih, E. (2021). Argument-driven inquiry learning model: a systematic review. *International Journal of Research in Education and Science*, *7*(3), 767–784. https://doi.org/10.46328/ijres.2001%0AThe

Fathurrohman, M., & Sulistyorini. (2012). *Belajar dan Pembelajaran : Meningkatkan Mutu Pembelajaran Sesuai Standar Nasional*. Yogyakarta: Teras.

Febriyanti, R., & Widjajanti, E. (2023). Chemistry Teacher's Perception About Higher Order Thinking Skills Assessment. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 5921–5926. https://doi.org/10.29303/jppipa.v9i8.3040

Ginanjar, W. S., Utari, S., & Muslim, D. (2015). Penarapan model argument driven inquiry dalam pembelajaran IPA untuk meningkatkan kemampuan argumentasi ilmiah siswa SMP. *Jurnal Pengajaran Matematika Dan Ilmu Pengetahuan Alam*, *20*(1), 32. https://doi.org/10.18269/jpmipa.v20i1.559

Grooms, J., Sampson, V., & Enderle, P. (2018). How concept familiarity and experience with scientific argumentation are related to the way groups participate in an episode of argumentation. *Journal of Research in Science Teaching*, *55*(9), 1264–1286. https://doi.org/10.1002/tea.21451

Hasnunidah, N., Susilo, H., Irawati, M. H., & Sutomo, H. (2015). Improved the discourse pattern in students argumentation through the use of scaffolding on strategy argument-driven inquiry. *Proceeding Biology Education Conference*, *12*(1), 645–651. Retrieved from https://jurnal.uns.ac.id/prosbi/article/view/7034

Hewi, L., & Shaleh, M. (2020). Refleksi hasil PISA (the programme for international student assesment): upaya perbaikan bertumpu pada pendidikan anak usia dini). *Jurnal Golden Age*, *4*(1), 30–41. Retrieved from https://e-journal.hamzanwadi.ac.id/index.php /jga/article/view/2018

Hosbein, K. N., Lower, M. A., & Walker, J. P. (2021). Tracking student argumentation skills across general chemistry through argument-driven inquiry using the assessment of scientific argumentation in the classroom observation protocol. *Journal of Chemical Education*, *98*(6), 1875–1887. https://doi.org/10.1021/acs.jchemed.0c01225

Ihsani, N., Idrus, A. Al, & Jamaludin, J. (2020). Perangkat Pembelajaran Biologi Berbasis Masalah Terintegrasi Nilai-Nilai Islami Untuk Meningkatkan Penguasaan Konsep Peserta Didik. *Jurnal Pijar Mipa*, *15*(2), 103–109. https://doi.org/10.29303/jpm.v15i2.1326

Istiyono, E., Mardapi, D., & Suparno. (2014). Pengembangan tes kemampuan berpikir tingkat tinggi fisika (pysthots) peserta didik SMA. *Jurnal Penelitian Dan Evaluasi Pendidikan*, *8*(1), 1–12. Retrieved from https://journal.uny.ac.id/index.php/jpep/article /view/2120/0

Jihannita, Prasetyo, Z. K., & Wilujeng, I. (2023). How to Prepare HOTS to Face the 21st Century? *Jurnal Penelitian Pendidikan IPA*, *9*(8), 486–492. https://doi.org/10.29303/jppipa.v9i8.2847

Kadayifci, H., Atasoy, B., & Akkus, H. (2012). The Correlation between the flaws students define in an argument and their creative and critical thinking abilities. *Procedia - Social and Behavioral Sciences*, *47*, 802–806. https://doi.org/10.1016/j.sbspro.2012.06.738

Kadayifci, H., & Celik, A. Y. (2016). Implementation of argument-driven inquiry as an instructional model in a general chemistry laboratory course. *Science Education International*, *27*(3), 369–390.

Khoirussaadah, K. S., & Hakim, F. (2019). Keterampilan berpikir tingkat tinggi peserta didik kelas xi dengan model (experiential learning) pada materi titrasi asam basa. *Journal of Educational Chemistry (JEC)*, *1*(2), 62–68. https://doi.org/10.21580/jec.2019.1.2.4260

Khuluqo, I. El. (2017). *Belajar dan Pembelajaran: Konsep Dasar, Metode, dan Aplikasi Nilai-Nilai Spritualitas dalam Proses Pembelajaran*. Yogyakarta: Pustaka Pelajar.

Kuki, A. D., Agustini, R., & Azizah, U. (2023). Analysis of effectiveness argument-driven inquiry to improve students' argumentation skill and conceptual understanding. *IJORER : International Journal of Recent Educational Research*, *4*(3), 329–342. https://doi.org/10.46245/ijorer.v4i3.316

Marhamah, O. S., Nurlaelah, I., & Setiawati, I. (2017). Penerapan model argument-driven inquiry (adi) dalam meningkatkan kemampuan berargumentasi siswa pada konsep pencemaran lingkungan di kelas X SMA eegeri 1 Ciawigebang. *Quagga: Jurnal Pendidikan Dan Biologi*, *9*(2), 39–45. https://doi.org/10.25134/quagga.v9i02.747

Mubarokah, F. D., Mulyani, S., & Indriyanti, N. Y. (2018). Identifying students' misconceptions of acid-base concepts using a three-tier diagnostic test: a case of indonesia and thailand. *Journal of Turkish Science Education*, *15*(Special Issue), 51–58. https://doi.org/10.12973/tused.10256a

Ozdem, Y., Ertepinar, H., Cakiroglu, J., & Erduran, S. (2013). The nature of pre-service science teachers' argumentation in inquiry- oriented laboratory context 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

Prayoga, A., Hasnunidah, N., & Romli, S. (2020). Meningkatkan HOTS siswa kelas VIIA SMP IT ar raihan Bandar Lampung melalui penerapan LKS berbasis argument driven inquiry (ADI). *Seminar Nasional Pendidikan Ke-3 FKIP Universitas Lampung 2020*, 1–19. Retrieved from https://www.researchgate.net/publication/343987951

Rahmawati, T. (2023). Science Learning Management Based on Higher Order Thinking Skills (HOTS). *Jurnal Penelitian Pendidikan IPA*, *9*(1), 533–541. https://doi.org/10.29303/jppipa.v9i1.3152

Ramos, J. L. S., Dolipas, B. B., & Villamor, B. B. (2018). Higher order thinking skillss and academic performance in physics of college students: a regression analysis. *International Journal of Innovative Interdisciplinary Research, Issue 4, p: 48-60.*, *4*, 48–60. Retrieved from https://www.researchgate.net/publication/333507142

Salay, R. (2019). Perbedaan motivasi belajar siswa yang mendapatkan teacher centered learning (TCL) dengan student centered learning (SCL). *Education*, *1*(1), 1–12. https://doi.org/10.1039/c6rp00093b

Sampson, V., & Blanchard, M. R. (2012). Science teachers and scientific argumentation: trends in views and practice. *Journal of Research in Science Teaching*, *49*(9), 1122–1148. https://doi.org/10.1002/tea.21037

Sampson, V., Carafano, P., Enderle, P., Fannin, S., Grooms, J., Southerland, S. A., Stallworth, C., & Williams, K. (2015). *Argument-Driven Inquiry in Chemistry Lab Investigations for Grades 9-12*. USA: NSTA Press.

Sampson, V., Enderle, P., Grooms, J., & Witte, S. (2013). Writing to learn by learning to write during the school science laboratory: helping middle and high school students develop argumentative writing skills as they learn core ideas. *Science Education*, *97*(5), 643–670. https://doi.org/10.1002/sce.21069

Sampson, V., & Gleim, L. (2009). Argument-driven inquiry to promote the understanding of important concepts & practices in biology. *The American Biology Teacher*, *71*(8), 465–472. Retrieved from http://www.bioone.org/doi/full/10.1662/005.071.0805

Sampson, V., Walker, J. P., Grooms, J., Anderson, B., Zimmerman, C. O., & Adi, A. I. (2012). Argument-driven inquiry in undergraduate chemistry labs: the impact on students' conceptual understanding, argument skills, and attitudes toward science. *Journal of College Science Teaching*, *41*(4), 74–81. Retrieved from https://www.researchgate.net/publication/259041844

Saracaloglu, A. S., Aktamis, H., & Delioglu, Y. (2011). The impact of the development of prospective teachers' critical thinking skills on scientific argumentation training and on their ability to construct an argument. *Journal of Baltic Science Education*, *10*(4), 243–260. Retrieved from http://oaji.net/articles/2014/987-1410547733.pdf

Schleicher, A. (2018). *PISA: Insights and Interpretations*. OECD. https://www.oecd.org/pisa/

Setiawan, A., & Jumadi, J. (2023). Analysis of the Implementation of Argument Driven Inquiry (ADI) in Students' Argumentation Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 127–133. https://doi.org/10.29303/jppipa.v9i6.2725

Setyosari, P. (2014). Menciptakan pembelajaran yang efektif dan berkualitas. *Jurnal Inovasi Dan Teknologi Pembelajaran*, *1*(1), 20–30. Retieved from https://journal2.um.ac.id/index.php/jinotep/article/view/2103

Sheppard, K. (2006). High school students' understanding of titrations and related acid-base phenomena. *Chemistry Education Research and Practice*, *7*(1), 32–45. https://doi.org/10.1039/B5RP90014J

Siahaan, A. T. (2019). *Pembelajaran ADI Tentang Hasil Kali Kelarutan untuk Meningkatkan Keterampilan Generik Sains dan Berpikir Kritits Siswa SMA*. Doctoral dissertation, Universitas Pendidikan Indonesia. Retrieved from https://repository.upi.edu/49829/

Siregar, N., & Pakpahan, R. A. (2020). Kemampuan argumentasi ipa siswa melalui pembelajaran argumentasi driven inquiry (ADI). *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *10*(2), 94–103. https://doi.org/10.24929/lensa.v10i2.113

Songsil, W., Pongsophon, P., Boonsoong, B., & Clarke, A.

(2019). Developing scientific argumentation strategies using revised argument-driven inquiry (RADI) in science classrooms in Thailand. *Asia-Pacific Science Education*, *5*(7), 1–22. https://doi.org/10.1186/s41029-019-0035-x

Susilawati, Syuzita, A., & Sukarso, A. A. (2023). Practicality of Science E-Module with the Argument-Driven Inquiry Model to Improve the 21 st Century Abilities Students. *Jurnal Penelitian Dan Pmebelajaran Matematika*, *9*(11), 10259–10263. https://doi.org/10.29303/jppipa.v9i11.5682

Syuzita, A., Susilawati, S., & Sukarso, A. (2023). Validation of E-Module Based on Argument-Driven Inquiry using 3D Page Flip Professional to Improve Students' Generic Science, Critical Thinking and Scientific Argumentation Abilities. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6272–6277. https://doi.org/10.29303/jppipa.v9i8.4947

Toledo, S., & Dubas, J. M. (2016). Encouraging higher-order thinking in general chemistry by scaffolding student learning using marzano's taxonomy. *Journal of Chemical Education*, *93*(1), 64–69. https://doi.org/10.1021/acs.jchemed.5b00184

Utami, F. V., Saputro, S., & VH, E. S. (2020). Analisis jenis dan tingkat kesulitan belajar siswa kelas XI SMAN 2 Surakarta tahun pelajaran 2018 / 2019 dalam memahami materi asam basa menggunakan two tier multiple choice. *Jurnal Pendidikan Kimia*, *9*(1), 54–60. Retrieved from https://digilib.uns.ac.id/dokumen/detail/71199/

Utami, S. S., Aisyah, R. S. S., & Affifah, I. (2022). Application of the argument-driven inquiry learning model in stimulating students' scientific argumentation skills on acid-base material. *Jurnal Pendidikan Kimia Indonesia*, *6*(1), 38–45. https://doi.org/10.23887/jpk.v6i

Walker, J. P., Sampson, V., Southerland, S., & Enderle, P. J. (2016). Using the laboratory to engage all students in science practices. *Chemistry Education Research and Practice*, *17*(4), 1098–1113. https://doi.org/10.1039/c6rp00093b

Widiastiningsih, R., & Effendi-hasibuan, M. H. (2022). Pengembangan e-modul berbasis pola argumentasi toulmin untuk meningkatkan argumentasi siswa pada materi asam basa. *Journal of Science Education*, *6*(2), 410–414. https://doi.org/10.33369/pendipa.6.2.410-414

Wulandari, D., Liliasari, S., & Widhiyanti, T. (2020). The effect of argument-driven inquiry on chemistry reaction-rates to enhance pre-service chemistry teachers critical thinking skills. *Journal of Physics: Conference Series. International Conference on Mathematics and Science Education (ICMScE)*, 2–7. https://doi.org/10.1088/1742-6596/1806/1/012204

Yahmin, Amelia, R., & Budiasih, E. (2020). Promoting the scientific argumentation skills of students using adi-s and adi models in chemical kinetics teaching. *AIP Conference Proceedings*, *2215*. https://doi.org/10.1063/5.0000753

Yayuk, E., Deviana, T., & Sulistyani, N. (2019). Kemampuan guru implementasi pembelajaran dan penilaian hots pada siswa kelas 4 sekolah Indonesia bangkok Thailand. *Jurnal Inovasi Pembelajaran (JINoP)*, *5*(2), 107–122. https://doi.org/10.22219/jinop.v5i2.7106

Zuhdi, A., Firman, F., & Ahmad, R. (2021). The importance of education for humans. *SCHOULID: Indonesian Journal of School Counseling*, *6*(1), 22–34. https://doi.org/10.23916/08742011