

Effectiveness of ADI-based student worksheets on students' argumentation skills in chemical equilibrium: A pre-experimental study

Adinda Nuriska Ragil Kinanthi, Utiya Azizah*

Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Ketintang Street, Gayungan, Surabaya 60231, East Java, Indonesia

*Corresponding author, email: utiyaazizah@unesa.ac.id

Article History

Received: 6 September 2025

Revised: 12 November 2025

Accepted: 20 November 2025

Published: 1 December 2025

Keywords

Argument Driven Inquiry (ADI)

Argumentation skills

Student worksheet

Abstract

This study aims to describe the profile of students' argumentation skills on chemical equilibrium material through the use of student worksheets based on the Argument Driven Inquiry (ADI) learning model. The method used is a Pre-Experimental One Group Pretest-Posttest Design. This research method was applied to 29 grade XI students. The data collection method used is a test method with a pretest-posttest sheet instrument for argumentation skills. The results of the study showed an increase in students' argumentation skills on chemical equilibrium material after using student worksheets based on the ADI learning model. This was reviewed based on the n-gain score obtained in argumentation skills for the claim indicator of 1.00, the data indicator of 0.75, the warrant indicator of 0.77, and the backing indicator of 0.81, all n-gain scores on the four indicators were classified as high. In addition, this was also supported by an increase in the percentage of pretest-posttest argumentation skills and the results of the Wilcoxon test which showed an Asymp. Sig. (2-tailed) value of 0.000 < 0.05 which indicated a significant difference between the pretest and posttest scores of students' argumentation skills. Based on these results, it can be concluded that there are significant differences and improvements in students' argumentation skills after using student worksheets based on the ADI learning model.

How to cite: Kinanthi, A. N. R., & Azizah, U. (2025). Effectiveness of ADI-based student worksheets on students' argumentation skills in chemical equilibrium: A pre-experimental study. *Journal of Environment and Sustainability Education*, 3(4). 635-643. doi: 10.62672/joease.v3i4.177

1. Introduction

Argumentation plays a central role in science education because it reflects how scientific knowledge is constructed, justified, and communicated. Through argumentation, students learn to articulate ideas, evaluate evidence, and defend their reasoning within a scientific discourse community (Erduran et al., 2015). This process helps them develop deeper conceptual understanding and supports the formation of scientific literacy (Faize et al., 2017). Therefore, strengthening students' argumentation skills is essential to ensure that they can participate meaningfully in inquiry-based learning and develop the ability to make well-reasoned scientific judgments.

Argumentation skills can be measured by referring to Toulmin's Argument Pattern (TAP). TAP is a structural model of argumentation skill indicators developed by Stephen Toulmin to describe how someone can argue realistically in everyday life, not only using formal logic, but also by considering context, evidence, and rebuttal (Erduran S., 2018). Toulmin (2003) emphasized that there are six indicators of argumentation skills, including claim, data, warrant, backing, qualifier, and rebuttal. A claim can be defined as an opinion or statement. Data is a statement related to the evidence needed to support the claim. Warrant is a statement used to explain the relationship between the data and the claim. Backing is an assumption or theoretical justification that supports the evidence. Qualifier is justification for the claim, and rebuttal is a statement that contradicts the data (Iordanou & Costantinou, 2015).

Despite its importance, numerous studies have reported that students' argumentation skills in science remain low. Many students are able to state claims but struggle to provide warrants and backing that logically connect evidence to scientific principles (Walker et al., 2019). This condition was confirmed through pre-research conducted at SMA Negeri 1 Menganti, where the percentages of students' argumentation skills were low across all indicators: 24.44% (claim), 20% (data), 11.11% (warrant), and 7.94% (backing). Students also reported difficulty understanding chemical equilibrium due to abstract terminology, and 65.7% indicated that

they rarely practiced constructing arguments in class. These findings suggest that students need structured opportunities and scaffolding to develop stronger scientific reasoning.

The Argument-Driven Inquiry (ADI) model is one instructional approach widely recognized for supporting argumentation development in science classrooms (Arslan et al., 2023). ADI integrates inquiry activities with explicit argumentation sessions, peer review, and revision processes that encourage students to justify claims using evidence and reasoning (Walker et al., 2011). Prior research shows that ADI can improve argumentation skills; however, many studies have not incorporated scaffolding that explicitly aligns with each component of Toulmin's structure. Additionally, only a limited number of ADI-based studies focus specifically on chemical equilibrium, a topic known for its conceptual complexity and tendency to cause student misconceptions (Dulim & Madlazim, 2022). This gap highlights the need for ADI learning materials designed to support both inquiry processes and structured argument development.

Chemistry is the study of everything about matter, including its composition, structure, properties, changes, dynamics, and energetics at the molecular level, involving skills and reasoning (Kararo et al., 2019). One chemistry topic that relates to real objects and phenomena experienced by students in their daily lives is chemical equilibrium. Understanding this topic not only requires mastery of basic concepts but also the ability to analyze, evaluate, and construct arguments based on available data and information (Riddle & Fan-Hin, 2023). Several studies have shown that students' scientific argumentation skills in chemical equilibrium are still relatively low. This is due to the complexity of the abstract and hierarchical concept of chemical equilibrium, which makes it difficult for students to understand and connect these concepts (Aydeniz & Dogan, 2016). Furthermore, research conducted by Utami et al (2022) also explains that students' scientific argumentation skills in chemical equilibrium are still low. Students tend to only be able to convey claims and data without providing additional support or support to strengthen their arguments.

Building on these gaps, this study introduces ADI-based student worksheets that explicitly incorporate Toulmin's argument structure to support students' reasoning throughout the inquiry process. Unlike previous research, the worksheets in this study combine general ADI-guided scaffolding with topic-specific prompts designed for chemical equilibrium. Therefore, the novelty of this research lies in the integration of dual-worksheet scaffolding within ADI to strengthen students' scientific reasoning. The purpose of this study is to analyse the improvement in students' argumentation skills on chemical equilibrium after learning with ADI-based student worksheets through a pretest-posttest design.

2. Method

2.1. Research Design

This study employed a quantitative pre-experimental design using a one-group pretest-posttest model (Saleh, et al., 2024). This design was selected to measure the difference in students' argumentation skills before and after the implementation of Argument-Driven Inquiry (ADI)-based student worksheets. The pretest was administered to determine students' initial skills, followed by the treatment using ADI-based worksheets, and finally the posttest to assess changes after the intervention.

2.2. Participants and Sampling

The participants consisted of 29 grade XI students from SMA Negeri 1 Menganti, Gresik Regency. A whole-class sampling technique was used, meaning that one intact class was selected based on existing classroom grouping without randomization. This sampling approach ensured that all students in the chosen class were included in the study (Lodico et al., 2006).

2.3. Materials and Instruments

The learning material used in this study focused on chemical equilibrium. The primary learning resource was an ADI-based Student Worksheet (LKPD) designed to integrate inquiry stages with explicit scaffolding aligned to Toulmin's Argumentation Pattern (TAP). The assessment instrument consisted of pretest and posttest sheets measuring four indicators of argumentation skills: claim, data, warrant, and backing. Each indicator included three open-ended questions, resulting in a total of 12 items per test.

2.4. Validity of Instruments

The instrument used to assess students' argumentation skills underwent a validation process focusing on content validity and construct validity. Validation was carried out by two chemistry education lecturers and one high school chemistry teacher who evaluated the alignment of the test items with the Toulmin Argumentation Pattern (claim, data, warrant, and backing), the suitability of the questions with learning objectives, and the clarity of each item. The validation results showed that the instrument obtained a score of 4 for content validity and a score of 4 for construct validity, indicating that the instrument met the criteria of very good validity. Based

on these results, the argumentation skills test was considered appropriate for use in data collection (Hikmah et al., 2023).

2.5. Procedures

The implementation of this study followed a sequence that began with a pretest, continued with the learning intervention using ADI-based worksheets, and ended with a posttest. At the beginning of the study, students were given a pretest to measure their initial argumentation skills on the chemical equilibrium topic. The pretest was administered under regular classroom conditions and required students to answer open-ended questions that represented the four argumentation indicators: claim, data, warrant, and backing (Turós et al., 2025).

Following the initial assessment, students participated in learning activities using the ADI-based student worksheet developed for this study. Throughout the learning process, students engaged in a series of inquiry-based tasks aligned with the phases of the Argument-Driven Inquiry (ADI) model. These activities included identifying the problem, conducting investigations, analyzing collected data, and constructing tentative arguments. Students then participated in argumentation sessions, where they presented their reasoning, responded to critiques, and refined their explanations based on peer discussion. Afterward, they completed an investigative report, underwent a peer-review process, and revised their reports accordingly. The ADI worksheet provided structured scaffolding to guide students through each of these stages and to support their development of scientifically grounded arguments.

At the end of the intervention, students completed a posttest consisting of the same argumentation skill indicators and item structure as the pretest. The posttest was administered to assess changes and improvements in their argumentation skills after participating in the ADI-based learning activities. Both the pretest and posttest responses were then scored using a rubric aligned with the Toulmin Argumentation Pattern and analyzed to determine the extent of improvement in students' argumentation abilities.

2.6. Data Collection

Data were collected through the pretest and posttest argumentation assessments. Student responses were scored based on TAP criteria, and the percentage results for each indicator were calculated. All data were documented and prepared for quantitative analysis.

2.7. Data Analysis

The data obtained from the pretest and posttest were analyzed to determine the extent of improvement in students' argumentation skills after participating in the ADI-based learning activities. First, the students' responses were scored using a rubric aligned with the four components of the Toulmin Argumentation Pattern, namely claim, data, warrant, and backing. The scores from each indicator were converted into percentages to describe students' performance before and after the intervention.

To measure the magnitude of improvement, the normalized gain (N-gain) score was calculated for each indicator as well as for overall argumentation performance. The N-gain analysis allowed the researcher to classify the level of improvement into high, medium, or low categories based on criteria established by Hake (1998). This analysis provided a quantitative overview of how effectively the ADI-based worksheets enhanced students' argumentation abilities. The argumentation skills are said to have increased after learning using Student Worksheets with the Argument Driven Inquiry (ADI) learning model if the N-gain value reaches ≥ 0.7 with high criteria or $0.3 \leq <g> < 0.7$ with medium criteria (Hake, 1998).

Next, a normality test is carried out to determine whether the data comes from a normally distributed population or is in a normal distribution with the basis for decision making if the probability value is < 0.05 then the data is declared not normally distributed, whereas if the probability value is > 0.05 then the data is declared normally distributed (Mishra, et al., 2019). After the data meets the normality, a paired t-test can be conducted to determine significant differences in students' pretest and posttest scores. The t-test used is a paired sample t-test with the following hypothesis:

- a. H_0 = There is no difference in the average value of students' argumentation skills for the pretest and posttest.
- b. H_1 = There is a difference in the average value of students' argumentation skills for the pretest and posttest.

The basis for making decisions from the paired sample t-test is if $\text{sig} < 0.05$ or $t\text{-count} > t\text{-table}$, then H_0 is rejected and H_1 is accepted, thus there is a difference in the average value of students' argumentation skills for the pretest and posttest (Wardani et al., 2025).

If the data does not meet the requirements for normality test, then it can be continued with non-parametric statistical analysis in the form of the Wilcoxon Signed Rank Test with the aim of analyzing whether a certain value is significantly different or not from the average of a sample with the following hypothesis.

- H_0 = There is no difference in the average value of students' argumentation skills for the pretest and posttest.
- H_1 = There is a difference in the average value of students' argumentation skills for the pretest and posttest.

The basis for making decisions from the paired sample t-test is if $\text{sig} < 0.05$ or $t\text{-count} > t\text{-table}$, then H_0 is rejected and H_1 is accepted, thus there is a difference in the average value of students' argumentation skills for the pretest and posttest.

3. Results and Discussion

On the argumentation skills test sheet, there are four argumentation skill indicators that are practiced, including claim, data, warrant, and backing indicators, where each indicator consists of three essay questions. The argumentation skills test was conducted twice, namely a pretest and a posttest. The pretest was conducted with the aim of determining students' argumentation skills before carrying out learning activities using the ADI learning model, while the posttest was conducted with the aim of determining students' argumentation skills after being given treatment in the form of using the ADI model student worksheet during learning activities. The results of the students' pretest and posttest can be seen in the Figure 1.

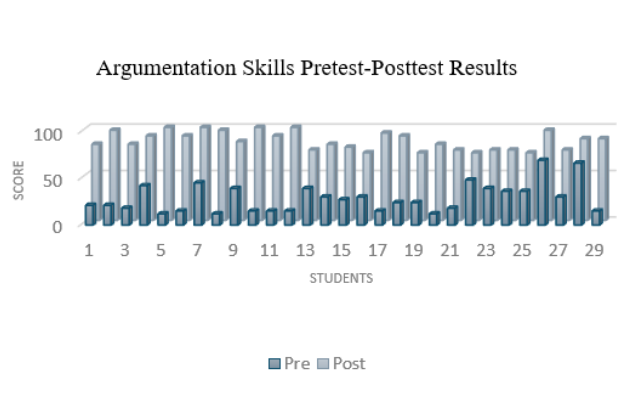


Figure 1. Argumentation Skills Pretest-Posttest Results Diagram

Based on the pretest and posttest data on argumentation skills that have been obtained, data processing is then carried out according to the argumentation skills indicators listed in the Table 1.

Table 1. Percentage of Argumentation Skills Indicators

Indicators	Pretest (%)	Posttest (%)
Claim	66.67	100
Data	30.65	82.38
Warrant	19.16	81.61
Backing	11.49	83.52

Table 1 shows the percentage scores for each argumentation indicator. The pretest results indicated percentages of 66.67% for claim, 30.65% for data, 19.16% for warrant, and 11.49% for backing. After the intervention, the posttest results showed percentages of 100% for claim, 82.38% for data, 81.61% for warrant, and 83.52% for backing. The next step is to calculate the n-gain score for each student's argumentation skills. The n-gain score is also calculated for each argumentation skills indicator. The results of these calculations are listed in the Table 2.

Table 2. N-Gain Score Results of Argumentation Skills Indicator

Indicators	N-Gain Score	N-Gain Score (%)	Criteria
Claim	1.00	100	High
Data	0.75	75	High
Warrant	0.77	77	High
Backing	0.81	81	High

Based on the results listed in the table above, it can be seen that all argumentation skill indicators obtained a high n-gain score. The claim indicator obtained a high n-gain score of 1.00, the data indicator obtained a high n-gain score of 0.75, the warrant indicator obtained a high n-gain score of 0.77, and the backing indicator obtained a high n-gain score of 0.81. The percentage of the n-gain scores obtained is then listed in the following diagram. In addition to the n-gain score analysis, the data obtained were also statistically analyzed using SPSS (Statistical Program for Social Science) software using a paired sample t-test. Before conducting the paired t-test, a normality test was first performed. The results of the normality test are listed in the Table 3.

Table 3. Normality Test Results

Tests of Normality						
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Skor Pretest	.143	29	.137	.876	29	.003
Skor Posttest	.156	29	.069	.901	29	.010

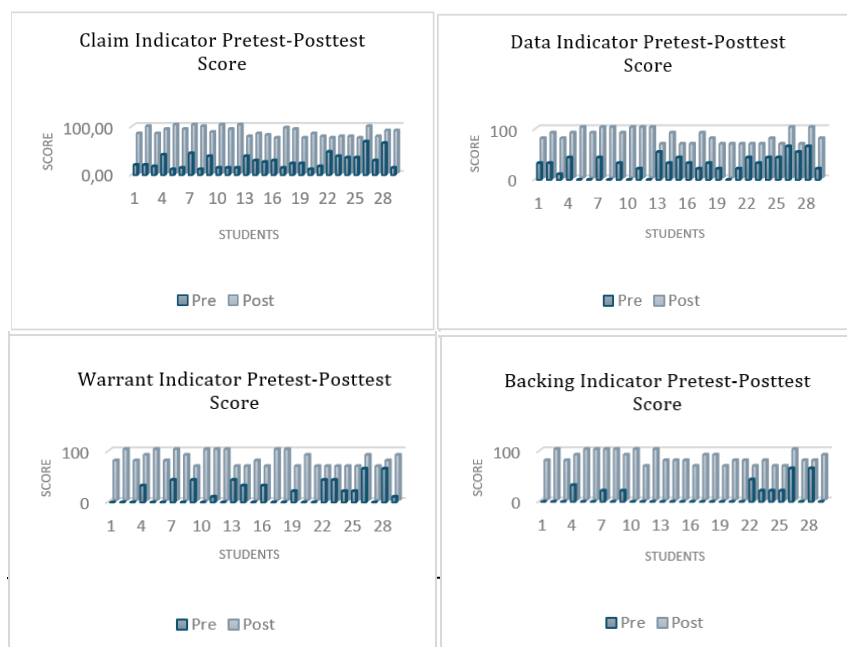
a. Lilliefors Significance Correction

Based on the normality test using Shapiro-Wilk, the sig. value for the pretest score was $0.003 < 0.05$, indicating that the pretest score was not normally distributed. For the posttest score, the sig. value was $0.10 > 0.05$, indicating that the posttest score was normally distributed. Because one of the scores did not meet the normality test requirements, a non-parametric statistical analysis, namely the Wilcoxon test, was conducted. The results of the Wilcoxon test are listed in the Table 4.

Table 4. Wilcoxon Signed Rank Test Results

Test Statistics	
	Skor Posttest - Skor Pretest
Z	-4.705a
Asymp. Sig. (2-tailed)	.000

Based on the results of the analysis using the Wilcoxon test, the Asymp. Sig. (2-tailed) value was obtained at $0.000 < 0.05$, so this indicates that H_0 is rejected with the conclusion that there is a significant difference in the average pretest and posttest scores of students' argumentation skills. Pretest-posttest scores for each indicator can be seen in Figure 2.

**Figure 2. Pretest-posttest scores for each indikator**

Based on Figure 2, it can be seen that there is a difference in students' pretest and posttest scores for each indicator. The figure shows that the posttest score for argumentation skills is higher than the pretest score. N-Gain percentage for each indicator can be seen in Figure 3.

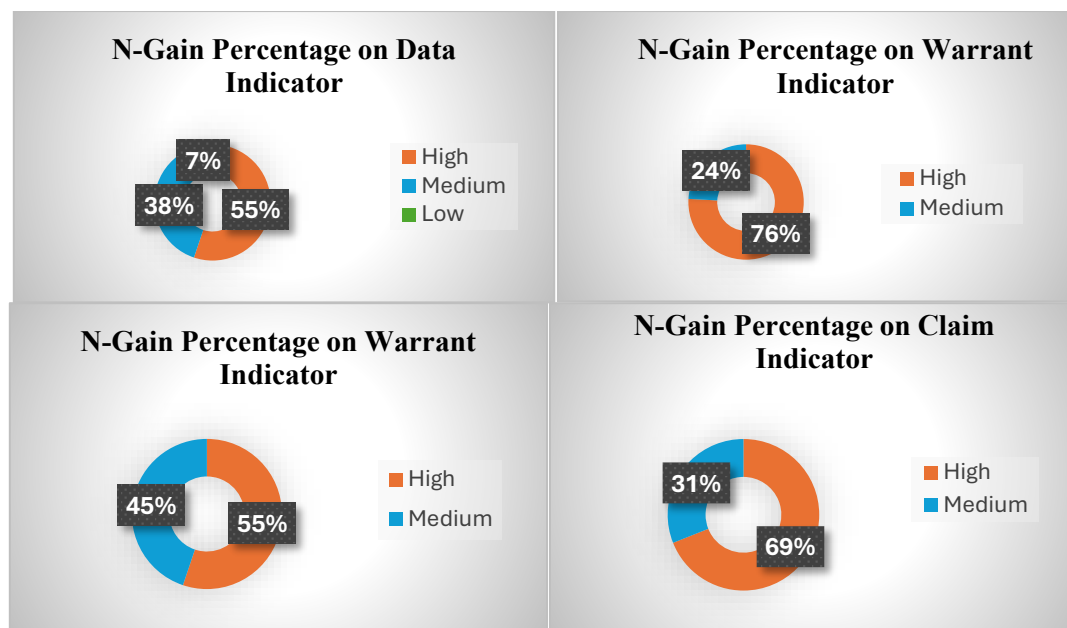


Figure 3. N-Gain Percentage for each indicator

Argumentation skills are a very important process in learning as a form of communication to externalize thoughts through a series of scientific discourses. Argumentation is an important component in scientific literacy, the goal of which is to strengthen students' mentality so that students can express themselves freely (Cigdemoglu et al., 2017). Student argumentation is students' understanding of the process of social interaction and constructivism. Students are not only able to express any theories they know but students must also be able to prove their truth (Iwuanyanwu, 2023). In this study, students' argumentation skills were measured using pretest and posttest argumentation skills instruments on chemical equilibrium material. The pretest activity was carried out before the learning activity using the student worksheet based on ADI learning model with the aim of determining the initial argumentation skills of students, while the posttest activity was carried out after the learning activity using the student worksheet based on ADI learning model with the aim of determining the final argumentation skills and their improvement after using the student worksheet based on ADI learning model.

The data obtained from the pretest and posttest results were then processed and analyzed quantitatively descriptively using the N-Gain Score formula and statistically analyzed using SPSS software. Quantitative descriptive analysis of N-Gain is a value that indicates how much students' argumentation skills have improved after receiving treatment (Hake, 1998). In this case, the improvement referred to is students' argumentation skills after receiving treatment in the form of learning activities using the student worksheet based on ADI learning model. Based on the pretest and posttest data that have been processed, the results obtained show that there is an increase in argumentation skills as indicated by an increase in the percentage of all argumentation skill indicators and also the n-gain score obtained and is described as follows.

3.1. Claim Indicator

Claim is a student's ability to express an opinion based on the information obtained or the student's argumentation in answering the questions given (Toulmin, 2003). The pretest and posttest scores for the claim indicator for 29 students are shown in the following diagram. Based on the pretest-posttest data, the percentage for the claim indicator was 66.67% in the pretest and 100% in the posttest, and an n-gain score of 1.00 was obtained, proving that there was an increase in students' argumentation skills in the claim indicator with a high category. Based on the Figure 3, 69% of students obtained a high n-gain score and 31% of students obtained a medium n-gain score. So, it can be concluded that through the use of the student worksheet based on ADI learning model, students' argumentation skills in the claim indicator can be improved. This is evidenced by the n-gain score obtained of 1.00 in the high category and also a percentage increase of 33.33%.

3.2. Data Indicator

Data refers to students' ability to use the data they have obtained to support claims they have made (Toulmin, 2003). The pretest and posttest scores for the data indicator for 29 students are shown in the following diagram. Based on the pretest-posttest data, the percentage obtained for the data indicator was 30.65% in the pretest and 82.38% in the posttest, and an n-gain score of 0.75 was obtained, proving that there was an increase in students' argumentation skills in the data indicator with a high category. Based on the Figure 3, 55% of students obtained a high n-gain score, 38% of students obtained a medium n-gain score, and 7% of

students obtained a low n-gain score. So, it can be concluded that through the use of the student worksheet based on ADI learning model, students' argumentation skills in the data indicator can be improved. This is evidenced by the n-gain score obtained of 0.75 in the high category and also a percentage increase of 51.73%.

3.3. Warrant Indicator

Warrant is a student's ability to provide reasons that can connect evidence or data with claims that have been made (Toulmin, 2003). The pretest and posttest scores on the warrant indicator for 29 students are listed in the following diagram. Based on the pretest-posttest data, the percentage obtained for the warrant indicator was 19.16% during the pretest and 81.61% during the posttest, and an n-gain score of 0.77 was obtained, which proves that there was an increase in students' argumentation skills on the warrant indicator with a high category. Based on the Figure 3, 55% of students obtained a high n-gain score, and 45% of students obtained a medium n-gain score. So, it can be concluded that through the use of the student worksheet based on ADI learning model, students' argumentation skills on the warrant indicator can be improved. This is evidenced by the n-gain score obtained of 0.77 in the high category and also a percentage increase of 62.45%.

3.4. Backing Indicator

Backing is a student's ability to include strong evidence or theoretical studies that can support a claim (Toulmin, 2003). The pretest and posttest scores for the backing indicator for 29 students are shown in the following diagram. Based on the pretest-posttest data, the percentage for the backing indicator was 11.49% in the pretest and 83.52% in the posttest, and an n-gain score of 0.81 was obtained, proving that there was an increase in students' argumentation skills in the backing indicator with a high category. Based on the Figure 3, it can be concluded that in the backing indicator, 76% of students obtained a high n-gain score, and 24% of students obtained a medium n-gain score. So, it can be concluded that through the use of the student worksheet based on ADI learning model, students' argumentation skills in the backing indicator can be improved. This is evidenced by the n-gain score obtained of 0.81 in the high category and also a percentage increase of 72.03%.

The students' argumentation skill profile was also analyzed using SPSS software with the aim of knowing the results of students' argumentation skills before and after using the student worksheet based on ADI learning model. Before conducting a paired t-test, a normality and homogeneity test was conducted to determine whether the data were normally distributed and had the same variance or not. The normality test refers to the Shapiro-Wilk test because the sample used was less than 50 (Souza et al., 2023). The results of the normality test showed that the sig. value for the pretest data obtained was $0.003 < 0.05$, this indicates that the data was not normally distributed, so that a non-parametric analysis was carried out for the paired t-test, namely the Wilcoxon Signed Rank Test. The results of the Wilcoxon test showed that the Asymp. Sig (2-tailed) value was $0.000 < 0.05$ (Penberthy, et al., 2018). This indicates that H_0 is rejected and H_a is accepted, so it can be concluded that there is a significant difference in the pretest and posttest scores of students' argumentation skills. This is in line with research conducted by Widiastiningsih et al. (2022) which showed that there was a significant difference between the experimental class and the control class seen from the learning outcomes with a Sig. (2-tailed) value of $0.000 < 0.005$ so it can be concluded that there is a difference in the learning outcomes of the experimental class (using e-modules based on the Toulmin argumentation pattern) and the control class (using e-modules without the Toulmin argumentation pattern).

4. Conclusion

This study demonstrates that the implementation of Argument-Driven Inquiry (ADI)-based student worksheets effectively enhances students' scientific argumentation skills on chemical equilibrium concepts. Significant improvements were observed across all argumentation indicators such as claim, data, warrant, and backing with all achieving high N-gain categories. These findings indicate that structured scaffolding explicitly aligned with Toulmin's Argumentation Pattern within the ADI learning framework enables students to construct more coherent, evidence-based, and theoretically grounded arguments. Moreover, the statistically significant difference between pretest and posttest scores confirms the positive impact of the intervention on students' reasoning abilities. Therefore, integrating ADI-based worksheets that systematically guide inquiry and argument construction represents a promising instructional approach for addressing conceptual complexity and strengthening higher-order thinking skills in chemistry learning, particularly in abstract topics such as chemical equilibrium.

Author Contributions

All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

Funding

No funding support was received.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

- Arslan, H. O., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model. *Teaching and Teacher Education*, 121. <https://doi.org/10.1016/j.tate.2022.103905>
- Aydeniz, M., & Dogan, A. (2016). Exploring the impact of argumentation on pre-service science teachers' conceptual understanding of chemical equilibrium. *Royal Society of Chemistry*, 17, 111-119. <https://doi.org/10.1039/C5RP00170F>
- Cigdemoglu, C., Arslan, H. O., & Cam, A. (2017). Argumentation to foster pre-service science teachers' knowledge, competency, and attitude on the domains of chemical literacy of acids and bases. *Royal Society of Chemistry*, 18, 288-303. <https://doi.org/10.1039/C6RP00167J>
- Dulim, A. Y., & Madlazim. (2022). Penerapan Model Argument-Driven Inquiry (ADI) dengan bantuan PhET Simulation untuk melatih argumentasi ilmiah peserta didik kelas XI SMA pada topik Gas Ideal. *Inovasi Pendidikan Fisika*, 11(1), 20-28. <https://ejournal.unesa.ac.id/index.php/inovasi-pendidikan-fisika/article/view/45451>
- Erduran, S. (2018). Toulmin's argument pattern as a "horizon of possibilities" in the study of argumentation in science education". *Cultural Studies of Science Education*, 13, 1091-1099. <https://doi.org/10.1007/s11422-017-9847-8>
- Erduran, S., Ozdem, Y., & Park, J. (2015). Research trends on argumentation in science education: a journal content analysis from 1998-2014. *International Journal of STEM Education*, 2(5).
- 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. doi:10.12973/iejmste/80353
- Hake, R. R. (1998). *Analyzing Change/Gain Score*. USA: Department of Physics, Indiana University.
- Hikmah, S. I., Tukiran, T., & Nasrudin, H. (2023). Validity of student worksheets based on model argument driven inquiry integrated by STEM to train students' argumentation ability and self-efficacy in chemical equilibrium material. *IJORER: International Journal of Recent Educational Research*, 4(4), 416-433. <https://doi.org/10.46245/ijorer.v4i4.300>
- Iordanou, K., & Constantinou, C. P. (2015). Supporting Use of Evidence in Argumentation Through Practice in Argumentation and Reflection in the Context of SOCRATES Learning Environment. *Science Education*, 99(2), 282-311. <https://doi.org/10.1002/sce.21152>
- Iwuanyanwu, P. N. (2023). When science is taught this way, students become critical thinking friends: setting the stage for student teachers. *Research in Science Education*, 53, 1063-1079. <https://doi.org/10.1007/s11165-023-10122-9>
- Kararo, A. T., Colvin, R. A., Cooper, M. M., & Underwood, S. M. (2019). Predictions and constructing explanations: an investigation into introductory chemistry students' understanding of structure-property relationships. *Royal Society of Chemistry*, 20, 316-328. <https://doi.org/10.1039/C8RP00195B>
- Lodico, M. G., Spaulding, D. T., & Voegtli, K. H. (2006). *Methods in educational research: from theory to practice*. San Francisco: Jossey-Bass.
- Mishra, P., Pandey, C. M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of Cardiac Anaesthesia*, 22(1), 67-72. https://doi.org/10.4103/aca.ACA_157_18
- Penberthy, J. K., Chhabra, D., Ducar, D. M., Avitabile, N., Lynch, M., Khanna, S., & Schorling, J. (2018). Impact of coping and communication skills program on physician burnout, quality of life, and emotional flooding. *Safety and Health at Work*, 9(4), 381-387. <https://doi.org/10.1016/j.shaw.2018.02.005>
- Riddle, H., & Fan-Hin, S. L. (2023). Students' Misconceptions in Chemical Equilibria and Suggestions for Improved Instruction. *New Directions in the Teaching of Natural Sciences*, 18(1). <https://doi.org/10.29311/ndtns.v0i18.3900>
- Saleh, L. M., Russeng, S. S., Tadjuddin, I., Yanti, I. H., Syafitri, N. M., Rahmadani, Y., . . . Mallongi, A. (2024). A quasi-experimental one group pretest-posttest design in air traffic controller in indonesia: progressive muscle relaxation. *Pharmacognosy Journal*, 16(3), 638-643. <http://dx.doi.org/10.5530/pj.2024.16.100>
- Souza, R. R., Toebe, M., Mello, A. C., & Bittencourt, K. C. (2023). Sample size and saphiro-wilk test: an analysis for soybean grain yield. *European Journal of Agronomy*, 142. <https://doi.org/10.1016/j.eja.2022.126666>
- Toulmin, S. E. (2003). *The Uses of Argument (Updated ed.)*. Inggris: Cambridge University Press.
- Turós, M., Kenyeres, A. Z., Balla, G., Gazdag, E., Szabó, E., & Szuts, Z. (2025). A toulmin model analysis of student argumentation on artificial intelligence. *Education Sciences*, 15, 1-21. <https://doi.org/10.3390/educsci15091226>
- Utami, S. S., Aisyah, R. 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.v6i1.39162>
- Walker, J. P., Sampson, V., & Zimmerman, C. O. (2011). Argument-driven inquiry: an introduction to a new instructional model for use in undergraduate chemistry labs. *Journal of Chemical Education*, 88(8), 1048-1056. <https://doi.org/10.1021/ed100622h>

- Walker, J., Duzor, A. G., & Lower, M. A. (2019). Facilitating argumentation in the laboratory: the challenge of claim change and justification by theory. *Chemical Education Research*, 96(3), 435-444. <https://doi.org/10.1021/acs.jchemed.8b00745>
- Wardani, D. K., Shokiba, M. N., Chotimah, C., & Istiana, I. (2025). Peired t-test to determine the effect of smart paperboard learning media on student learning outcomes in the subject of islamic cultural history. *Tarbiyah: Jurnal Ilmu Kependidikan*, 14(1), 113-125. <https://doi.org/10.18592/tarbiyah.v14i1.15871>