# IMPROVING STUDENT'S CRITICAL THINKING ABILITY USING ARGUMENT-DRIVENT INQUIRY APPROACH IN THERMOCHEMISTRY

**Intan Diah Purwandari[1], Muntholib[2], Anugrah Ricky Wijaya[3]**

[1] Master Education of Chemistry, Departement of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang
[2,3] Departement of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang

**Corresponding author: muntholib.fmipa@um.ac.id*

***Abstract.*** *This study aimed to investigate the impact of applying the Argument-Driven Inquiry instructional model (ADI-Based Instruction) in thermochemistry teaching on students' critical thinking skills. This study applied the one group pretest-posttest type of pre-experiment design. The subjects of this study were 71 eleven grade students of Public Senior High School of Ambulu Jember on academic year of 2022/2023. The instrument, namely the critical thinking ability test on thermochemistry, was developed by the researchers based on Ennis' critical thinking ability framework. This test consists of 10 valid items with a Cronbach's Alpha reliability of 0.782. The results showed that thermochemistry instruction carried out using ADI instructional model improve students' critical thinking skills with an N-gain of 0.731 (high category) and Cohen's d-effect size of 1.023 (much larger than typical) with an interrater reliability of 0.619 (good categories). These results indicate that ADI-based instruction on thermochemistry can improve students' critical thinking skills. The implication of this study is that ADI-based instruction can be applied to other subjects who have the same characteristics of thermochemistry, namely having contextual, factual, conceptual, procedural, and metacognitive knowledge.*

***Keywords:*** *Argument-Driven Inquiry Instruction, Critical Thinking Skills, Thermochemistry.*

## INTRODUCTION

The 21st century demands the students to have critical thinking skill which is closely related to the scientific inquiry elements. In scientific inquiry, students are actively involved in the answer seeking process to scientific questions to build new knowledge [1]. New knowledge is built based on pre-existing knowledge and the new evidences obtained from an investigation. The process of new knowledge engages critical thinking. In this process, critical thinking is required to make a reasonable decision about new knowledge that needs to be believed and action (skill) that needs to be performed [2]. It means that critical thinking is one of skills that students must own to face life and compete in this era.

The survey about student's critical thinking has been widely carried out. According to the Programme for International Students Assessment (PISA) survey in 2012, Indonesian students' science literacy achievement level is low. The low of this achievement shows that students' critical thinking skill are also low because the PISA question type has high-level thinking skill standard that can measure students' critical thinking skills [3]. Some studies also [4-9] show that the average student's critical thinking skill is classified as low category and has not been developed optimally. From some of these studies, it can be concluded that, in general, students' critical thinking skill shows deficient result. This matter is very worrying; therefore it requires the correct method to improve students' critical thinking skills in chemistry learning.

The conventional learning method is less facilitating the development of students' critical thinking skills [10]. In this method, the

interaction between teacher and students is limited, where the teacher dominates the learning activity. Besides, the learning which emphasizes convergent thinking practice without involving the problem that needs to be reviewed and solved by students cannot improve students' critical thinking skills [11,12], and they need to master the learning material [10,11]. In this kind of learning, the thinking process is not practiced well in class [13]. Therefore, it requires alternative learning that is more in line with the critical thinking characteristics to improve students' critical thinking skills.

The inquiry learning model is one of the efforts to optimize the learning activity [14]. The alternative solution that can be performed to improve students' critical thinking skills is the implementation of the Argument-Driven Inquiry (ADI) model. According to Sampson et al (2012), the ADI model is a developmental learning model of inquiry and integrated learning that contains science aspects, namely investigating, arguing, writing, and reviewing. The ADI model has seven learning steps: (1) task identification; (2) data collection; (3) argumentative production; (4) argumentation interaction session; (5) investigation report preparation; (6) report review; (7) and report revision [16]. Argument-Driven Inquiry is a learning model that performs argumentation sessions as a part of the learning process. The ADI learning model also can be used to develop thinking skills and critical thinking skill by emphasizing the importance of argumentation role [16-19]. In its implementation, ADI learning always provides assistance in the form of constructive questions, so this learning is more suitable implemented in the effort to improve critical thinking skills compared to conventional learning because conventional learning does not emphasize students to think critically, so students sometimes still have difficulty understanding the material.

Thermochemistry is one of chemistry's principal materials relevant to critical thinking skill elements. Thermochemistry is one of the important components of chemistry learning. The thermochemistry material knowledge underlies the other chemistry concepts because the further chemistry concepts will be challenging to understand if the concepts cannot be mastered well by students.

Thermochemistry is a chemistry subject that is considered difficult by students. The previous studies show the average score of students' thermochemistry material is unsatisfying. It is proven by Cahyanto et al. (2016) and Febriyanti et al., (2019) studies that stated the percentage of student completion for thermochemistry material is still below the average. Rahmwati et al. (2021) also said that thermochemistry is a complex material, and concept misunderstandings are often found among students because it is abstract. Meanwhile, the research by Erna et al., (2018) stated that thermochemistry material consists the concepts and calculations that require students' comprehension to complete a problem by thinking critically. One of the reasons for the difficulty of learning thermochemistry is that students lack an understanding of the thermochemistry material correctly and properly [24]. Students with an excellent conceptual understanding show they have performed their critical thinking skills [25]. A good understanding is obtained because students have a mind frame that supports problem-solving and critical thinking.

Following the description above, this research will answer the question: How is the impact of Argument-Driven Inquiry (ADI) based learning on students' critical thinking skills in thermochemistry learning?

## METHOD

The approach used in this study is a quantitative approach using a Pre-Experiment-One Group Pretest-Posttest Design research design. The following is the Pre-Experiment-One Group Pretest-Posttest Design research design:

**Table 1 One Group Pretest-Posttest Design**

| Group | Pretest | Perlakuan | Postest |
|---|---|---|---|
| Experiment | $X_1$ | O | $X_2$ |

Notes:
$X_1$ : Pretest.
$X_2$ : Postest
O : Treatment (*Argument-Driven Inquiry instruction*)

### Time and Place of Research

This research was conducted in SMA Negeri Ambulu located in Candradimuka

Street No. 43 Ambulu Sub-district, Jember Regency, East Java. The research was conducted in the 1st semester of the 2022/2023 academic year, from July 25 to October 3, 2020. The research involved 71 students distributed into two classes: XI IPA 1 and XI IPA 2.

## The Treatment Procedure

The student's learning experiences in ADI-based instruction are presented in table 2.

**Table 2 The student's learning experiences follow the framework of the Argument-Driven Inquiry (ADI) learning model and its suit with the Subs of Ennis Critical Thinking Skill**

| Phase | Description | Ennis's Sub-skills |
|---|---|---|
| Task Identification | Identifying the task based on the problem found in the Student's Worksheet. | Elementary Clarification |
| Evidence Collection | The data planning and collection, the data processing and analyzing (e.g., an experiment or analysis) | Basic Support |
| Argument Development | The argument development in writing is the answer to scientific questions. The created argument has to contain a claim, evidence, and reason. | Conclusions |
| Argumentation Session | Perform a presentation and share the argument (result), ask the questions and critiques on the process (methods), and context (theoretical and empirical foundations). The teacher and students discuss what has been learned. | Advanced Clarification |
| Tentative Reports | The report making (the goal of investigation, method, and argument). | Strategy and Tactics |
| Peer Reviews | The implementation of evaluation criteria as a form of learner engagement in the evaluation where each student uses peer review combination to evaluate the report quality. | |
| Final Report | The report is revised based on the peer review result and submitted to the teacher for final evaluation. | |

[31]

The measurement instrument trial was performed to the SMA Negeri Ambulu students acquiring thermochemistry material outside the research subject. The measurement instrument used in this research was critical thinking skill test questions with the criteria of critical thinking skill developed by Ennis (2011). The validity test result of 12 critical thinking skill questions on the students showed that 10 questions were valid and 2 questions were invalid, so the questions used as students' critical thinking instruments were 10 questions. Based on the question reliability test result on the student's critical thinking skill test instrument, the Alpha Cronbach's score is 0.782 (Table 3). This result showed that the instrument is a reliable and trustworthy data measurement tool.

**Table 3 The Reliability Test Result of Critical Thinking Skill Test Instrument**

| Reliability Statistics | |
|---|---|
| Cronbach's Alpha | N of Items |
| .758 | 10 |

## The Data Collection Technique

The data analysis techniques in this research were descriptive analysis, statistical analysis, and reliability interrater test. In determining students' critical thinking skills, we used the consistency of students answered right on each critical thinking indicator by Ennis (2011). The critical thinking test instrument was arranged based on the critical thinking indicator by Ennis (2011) that consists of: (1) Elementary Clarification, (2) Basic Support, (3) making a conclusion, (4) Advanced Clarification, and (5) Strategi and Tactics. The test instrument was descriptive questions, where each question refers to the critical thinking indicator developed by Ennis (2011). Then, the result of the instrument test was categorized into the following critical thinking skill level [27].

**Table 4 The Category of Student's Critical Thinking Skill Determination**

| Interpretation (%) | Category |
|---|---|
| 0 < nilai ≤ 43,75 | Very Low |
| 43,75 < nilai ≤ 62,50 | Low |
| 62,50 < nilai ≤ 71,50 | Medium |
| 71,50 < nilai ≤ 81,25 | Height |
| 81,25 < nilai ≤ 100,00 | Very high |

## Data Analysis

The statistical analysis in this research consisted of prerequisite test, which is an analysis that includes normality, homogeneity, and hypothesis test. The data analysis of students' critical thinking skills includes Paired Sample *t*-Test, N-gain Test, and Effect Size Test. Paired Sample *t*-Test is a hypothesis testing method where the data used are paired (pretest and posttest data). The statistical analysis test was conducted using SPSS 16.0 Windows program.

The N-gain test measures the score improvement before and after the learning obtained by the students from the pretest and posttest average scores. The interpretation criteria of N-gain score were divided into three categories [28] that can be seen in the table below:

**Table 5 N-gain Score Criteria**

| Score (g) | Interpretation |
|---|---|
| (g) < 0,3 | Low |
| 0,3 ≤ (g) ≤ 0,7 | Moderate |
| (g) > 0,7 | High |

[28]

The effect size test measures the effect magnitude of the independent variable on the dependent variables [28]. The calculation result of effect size can be interpreted based on the Cohen classification in the table below:

**Table 6 Effect Size Score Criteria**

| *d*-Effect Size Score | *Interpretation* |
|---|---|
| ≥ \|1.00\| | Much larger than typical |
| \|.80\| | Large or larger than typical |
| \|.50\| | Medium or typical |
| \|.20\| | Small or smaller than typical |

[28]

The reliability interrater test is a type of test that is used to equalize the perceptions of two assessors. The criteria of reliability interrater test interpretation [29] can be seen in the table below:

**Table 7 The Criteria of Reliability Interrater Test Interpretation**

| Interrater Reliability | The Agreement Interpretation |
|---|---|
| 0,00 – 0,20 | Bad |
| 0,21 – 0,40 | Less than Moderate |
| 0,41 – 0,60 | Moderate |
| 0,61 – 0,80 | Good |
| 0,81 – 1,00 | Very Good |

[29]

The statistical analysis of student's answers to the critical thinking skill test questions shows the reliability interrater test result for the average of two assessors obtained by the Kappa statistical test with a score of 0,619, which means the instrument has good stability quality. The details of reliability interrater test result are in the picture below.

| | Value | Approximate Significance |
|---|---|---|
| Measure of Agreement Kappa | ,619 | ,000 |
| N of Valid Cases | 71 | |

**Figure 1 The Reliability Interrater Test Result on Student's Answer**

## RESULT AND DISCUSSION

The student's critical thinking skill data before and after learning is used to discover the student's skill before and after the learning. The critical thinking skill in this research was analyzed based on the student's answers to the ten descriptive questions. The test questions were presented to the students after obtaining thermochemistry material through ADI-based learning implementation. The level determination of student's critical thinking skill was converted in the score following the score guideline in Table 4 so that the hypothesis test could be performed and the research result could be tested statistically. The result of students' critical thinking skill data before and after the learning can be seen in table below.

**Table 8 The Result of Student's Critical Thinking Skill Before and After the Learning**

| Data | Student's Number | The Lowest Score | The Highest Score | Average |
|---|---|---|---|---|
| Pretest | 71 | 5 | 21 | 12,112 |
| Postest | 71 | 57 | 95 | 76,366 |

Table 8 shows the average score on the student's critical thinking skill before ADI-based learning is 12,112 and after ADI-based learning is 76,366. It indicates that the student's critical thinking skills have significant improvement. This research result is in line with Ryzal et al., (2020), Adnan et al., (2021), and Rahmat's (2020) studies that proved the inquiry learning can improve students' thinking skill. A student's critical thinking skill score is obtained from the score total on 10 critical thinking skill test questions. The average score of students' critical thinking skill before and after the learning can be seen in Picture 3.

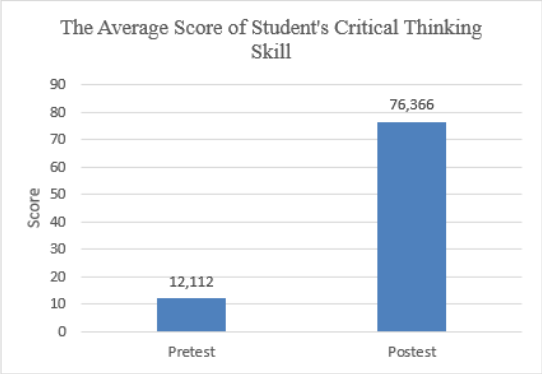


**Figure 2 The Average Score of Student's Critical Thinking Skill**

According to Picture 2 above, the average score of students' critical thinking skills learned by ADI is higher that before ADI-based learning was implemented. It raises an allegation that ADI-based learning significantly impacts the student's critical thinking skills on the thermochemistry material. This allegation substantiation requires statistical analysis using Paired Sample *t*-Test.

## The Result of Prerequisite and Hypothesis Test

Before conducting the hypothesis test, the student's critical thinking scores were first tested for normality and homogeneity data. These two tests are prerequisite tests to determine the statistic type for the hypothesis test.

**Table 9 The Result of Critical Thinking Skill Normality and Homogeneity Test**

| Data | Normality Test | Homogeneity Test |
|---|---|---|
| Pretest | 0,080 | 0,401 |
| Postest | 0,187 | 0,827 |

According to the significant score of > 0,05, the student's critical thinking skill is distributed normally and has a homogeny data variant. Thus, the data require normality and homogeneity conditions. Therefore, the data were further analyzed using Paired Sample *t*-Test.

**Table 10 The Result of Paired Sample *t*-Test**

| Data | t | df | Sig.(2-tailed) |
|---|---|---|---|
| Pretest_ Postest | -55,811 | 70 | ,000 |

Table 10 above shows the result of student's paired sample *t*-Test on the student's critical thinking skills. According to the significance score result, which is > 0,05, it can be concluded that Argument-Driven Inquiry-based learning significantly impacts the student's critical thinking skills on the thermochemistry material. It is proven by the result of the critical thinking skill paired sample test with a score of -55,811. The α significant value is 0,05, so that the $t_{tab}$ = 1,688. This result shows $t_{hit} > t_{tab}$, which means there is significant difference.

The Argument-Driven Inquiry Model implemented on the thermochemistry material improves students' critical thinking skills, as shown by the result of n-gain and effect-size test. The test result of students' critical thinking skill data can be seen in the Table below.

**Table 11 N-gain Score and Effect Size Results**

| Data | Score | Category |
|---|---|---|
| N-gain | 0,731 | High |
| Effect Size | 1,023 | Much larger than typical |

**The Impact of ADI Model on the Student's Critical Thinking Skill**

The learning steps on the ADI model are highly required to train students' critical thinking skills. The ADI learning model trains students' critical thinking skills through seven stages involving five critical thinking skill aspects: elementary clarification, basic support, making a conclusion, advanced clarification, strategy and tactics [31].

The first stage of the ADI model is problem identification. The students were presented with a discourse. Then, the students were guided to make a problem statement to be solved or complete the given problem. This stage is effectively trains students' thinking skill aspects, namely elementary clarification. This aspect trains students' skill to identify or formulate a question. In this stage, the students were also invited to think about the research variable that will be performed. The knowledge about variable is essential for the student to understand the purpose of the performed research, what data are measured, and what things affect the research result. Determining these variables will train the student to determine the right evidence to produce a claim. The right evidence must be based on the relevant data [32]. Whether the data is relevant or not is discovered after understanding the research variables. For example, in the third meeting on the endothermic and exothermic reactions topic, students must identify and determine salt crystals that have potential as a cool pack and hot pack reactants.

The second stage is students perform the data collection. In this stage, students were formed into groups and had the opportunity to perform an investigation and analyze the data obtained from the trial or practicum results that have been conducted. The students worked together in the group to observe the phenomenon that causes a problem to be researched and studied in the learning. This stage effectively trains the student's thinking skill aspect, namely building basic skill. This aspect trains the students to observe and consider the observation result to produce an idea from a question or situation they face. The obtained data were recorded in written form. These data were analyzed to draw a conclusion that answers the problem statement. This conclusion was a claim obtained from the student's inquiry activity through the practicum performed. The evidence element is the data of relevant research results. In this stage, students carried out an experiment in the laboratory to collect the supporting evidence to make an argument that will be conducted in the next stage.

The third stage is argumentation development, or making a written argument, where the students make a written argumentation on the presented problem. The argumentation has to include claim, evidence, and reason, as stated in the Student's Worksheet. This stage provided the explanation column for students to write a reason that explains why the evidence can support the claim. The explanation was based on the book material or other knowledge sources and was communicated among groups. Besides, students were trained to arrange an evidence-based argument to respond to the research questions. This third stage effectively trains students' thinking skill aspect, namely making a conclusion, such as training the students to perform deduction and induction, also making a conclusion and determining its result. This aspect trains the skill of identifying the truth between claim and evidence also making decisions with the correct information. This stage trains the student to identify the evidence based on the existing data and able to connect the reasons made based on the fact. In this stage, students were asked to make an argument by proposing ideas or thoughts accompanied by supporting evidence. This evidence was obtained by experimenting in the laboratory. The students must determine which salt crystals release heat and which absorb heat when dissolved in the water. The determination of heat releasing and absorbing can be observed through the temperature change of each solution.

Furthermore, students in the group discussed the experiment result and revealed their opinion both orally and written in turn to determine the most valid or the most accepted explanation. This stage was included in the argumentation interaction session, where the students were trained to argue by performing a presentation. The students were instructed to share the arguments with other groups and allowed to deliver their opinion and critique of other the groups' explanations. This syntax is

effective in training the aspect of making further explanations from the student's critical thinking skill, namely the skill to explain the applicable data and theory correctness and defend their opinion to be accepted by others.

The next stage is tentative report where the students were assigned to write the argumentation investigation result report discussed in groups. Then proceed to the report review stage. In this stage, students were instructed to exchange and assess the report with other groups. This stage corrects the report if something is incorrect or inappropriate. The report will be revised based on the peer review result to enhance the report content for better argument quality. This final stage of learning is effective for training the strategic and tactical aspects of student's critical thinking skills, namely assessing the credibility of a question by describing the perceptions, learning experiences, situations, determination, someone's belief, and able to arrange the right strategy to solve a problem or prove a concept. This stage also trains students' skills to reevaluate the decision taken thoroughly.

In this stage, all students were given an opportunity to correct their writings, reasoning and building better science comprehension by involving the writing process [33]. Besides, the teacher and students discussed so that the student later could draw a conclusion from what has been learned. The teacher's role was to observe students' activity during the learning process and ensure the students master the concept and can practice students thinking skills better. It indicates that ADI model syntax provides stages that can train students' critical thinking skill aspects, starting from the problem identification stage to improve their critical thinking skills.

The students who learn using the ADI model were trained to improve their critical thinking skills. It shows that ADI model learning highly influences students' critical thinking skills. The students initially had low pretest score; after performing the learning using the ADI model, their posttest scores improved, as proven by the N-gain score. The improvement of critical thinking skill pretest and posttest was proven with the N-gain test of 0,731 with high category. Besides, the effect-size test was performed in this research to measure the magnitude of the Argument-Driven Inquiry (ADI-Based Instruction) approach's effect on students' critical thinking skills. The result of the effect-size test on the student's critical thinking skill data shows a high category with a score of 1,023 which mean that ADI-based learning is highly effective in improving students' critical thinking skill in the thermochemistry material presented. The ADI effectiveness on the student's critical thinking skill is influenced by ADI syntax that gives an experience to the students in performing scientific inquiry to obtain the knowledge so that they can construct each aspect existed on Ennis' critical thinking skill.

## CONCLUSION AND SUGGESTION

The thermochemistry instruction, performed with Argument-Driven Inquiry instruction, can improve students' critical thinking skills (the N-gain = 0.731; Cohen *d*-effect size = 1.023). This shows that the students' learning experience developed based on the ADI learning model can be used to improve their critical thinking skills.

The implication of this research is that subject matter which has characteristics similar to thermochemistry can be used to improve students' critical thinking skills. Those characteristics are observable factual knowledge; conceptual knowledge that can be used to explain phenomena; procedural knowledge that can be used to collect and analyze data; as well as metacognitive knowledge that can be used to design data collection and analysis, drawing and interpreting conclusions, making explanations, and evaluating the entire inquiry process.

## REFERENCES

[1] Zuiker, S J., and Whitaker, J R. 2014. Refining Inquiry with MultiForm Assessment: Formative and Summative Assessment Functions for Flexible Inquiry. *International Journal of Science Education*, 36(6), 1037-1059.

[2] Ennis, R. H. 1996. *Critical Thinking*. USA: Prentice Hall, Inc.

[3] OECD. 2013. PISA 2012 Assessment and Analytical Framework: Mathematics, Reading, Science, Problem Solving and Financial Literacy, PISA. Paris: OECD Publishing.

[4] Ajunda, W. P., Haryono, dan Mulyani, S. 2017. Upaya Meningkatkan Prestasi Belajar Siswa dan Kemampuan Berpikir Kritis Siswa Kelas XI IPA Semester Genap pada Materi Kelarutan dan Hasil Kali Kelarutan (Ksp) dengan Menggunakan Model Pembelajaran Predict, Observe, Explain (POE) di SMA Negeri 1 Bayudono. *Jurnal Pendidikan Kimia*, Vol. 6, No. 2, pp 102-108.

[5] Yunita S., Rohiat, S., & Amir, H. 2018. Analisis Kemampuan Berpikir Kritis Mata Pelajaran Kimia pada Siswa Kelas XI IPA SMAN 1 Kepahiang. *Jurnal Pendidikan dan Ilmu Kimia*, 2(1):33–38.

[6] Fitriah, K.L & Ardi, W.S. 2020. Profil Keterampilan Berpikir Kritis Siswa pada Materi Ikatan Kimia. *Jurnal Pendidikan Kimia Indonesia*. Vol. 4, No. 1, pp. 26-31.

[7] Susilowati, Sajidan, & Ramli, M. 2017. Analisis keterampilan berpikir kritis siswa madrasah aliyah negeri di Kabupaten Magetan. *Seminar Nasional Pendidikan Sains 2017 Dengan Tema "Strategi Pengembangan Pembelajaran Dan Penelitian Sains Untuk Mengasah Keterampilan Abad 21 (Creativity and Innovation, Critical Thinking and Problem Solving,Communication,Collaboration/4 C)*",223–231. http://www.jurnal.fkip.uns.ac.id/index.php/snps/article/viewFile/11417/8102

[8] Subarkah, C. Z., & Winayah, A. 2015. Pengembangan Keterampilan Berpikir Kritis Siswa Melalui Process Oriented Guided Inquiry Learning (POGIL). Jurnal Pengajaran MIPA, 20(1), 48-52.

[9] Saputra, H. 2020. Kemampuan Berpikir Kritis Matematis. Perpustakaan IAI Agus Salim, 2(April), 1–7. https://doi.org/10.17605/OSF.IO/TJ76P

[10] Vishnumolakala. 2018. Students' attitudes, self-efficacy and experiences in a modified process-oriented guided inquiry learning undergraduate chemistry classroom. *Chemistry Education Research and Practice*, 18(1), 340-352.

[11] Pitukpong K., Sirinapa K., Wipharat C.C. 2018. An Action Research on Enhancing Grade 10 Student Creative Thinking Skills using Argument-driven Inquiry Model in the Topic of Chemical Environment. *J.Sci. Learn*, 2(1), 9-13.

[12] Ryzal Perdana RP, Ratu Betta Rudibyani RBR, Budiyono B,. 2020. The Effectiveness of Inquiry Social Complexity to Improving Critical and Creative Thinking Skills of Senior High School Students. *International Journal of Instruction*, 13: 1– 14.

[13] Mutoharoh. 2011. *Pengaruh Model Pembelajaran Berdasarkan Masalah (Problem Based Learning) terhadap Hasil Belajar Fisika*. Skripsi. UIN Syarif Hidayatullah : Jakarta.

[14] Mumpuni, I. P. 2017. *Pengaruh Model Pembelajaran Inkuiri Terbimbing dan ADI (Argument Drivent Inquiry) terhadap Keterampilan Argumentasi Ilmiah dan Hasil Belajar Peserta Didik pada Materi Hidrolisis.* Skripsi Malang: Universitas Negeri Malang.

[15] Sampson, V. 2009. The Impact of Argument-Driven Inquiry on Three Scientific Practices. *The Annual Internasional Conference of the National Association of Research in Science Teaching (NARST*). Garden Grove, CA

[16] Walker J.P., Sampson, V., Grooms, J., Zimmerman, C. & Anderson, B.2012. Argument-driven inquiry in undergraduate chemistry labs: the impact on students' conceptual understanding, argument skills, and attitudes toward science, *J. Coll. Sci. Teach.*,41(4): 74-81.

[17] 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.

[18] Driver R., Newton P.& Osborne, J. 2000. Establishing the Norms of Scientific Argumentation in Classrooms. *Science Education*, 84: 287-312.

[19] Sampson, V., Grooms, J., & Walker, J. 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): 212-257.

[20] Cahyanto, M.A.S. Suryadi, B.U., & Sri, Y. 2016. Penggunaan Model Pembelajaran Cooperative Problem Solving (CPS) dilengkapi Handout untuk Meningkatkan Kemampuan Berpikir Kritis dan Prestasi belajar Siswa Materi Termokimia Kelas XI IPA Semester Ganjil SMA Negeri 3 Boyolali Tahun Pelajaran 2015/2016. *Jurnal Pendidikan Kimia*., 5(4): 43-50.

[21] Febriyanti. 2019. *Variasi Sapaan Berdasarkan Perspektif Gender dan Keakraban pada Organisasi Ektra Kampus*. Universitas Pendidikan Indonesia: Program Studi Linguistik, Pascasarjana.

[22] Rahmat, R., 2020. Development of Sets-Based Teaching Materials in Acid Base Accompanied by Critical Thinking Exercises and Moral Forming. *EduChemia*, 5(2), 2502-4787.

[23] Mumpuni, I. P. 2017. *Pengaruh Model Pembelajaran Inkuiri Terbimbing dan ADI (Argument Drivent Inquiry) terhadap Keterampilan Argumentasi Ilmiah dan Hasil Belajar Peserta Didik pada Materi Hidrolisis*. Skripsi Malang: Universitas Negeri Malang.

[24] Hunddle, P.A. & White, M.D. 2000. Using a Teaching Model to Correct Known Misconception in Electrochemistry. *Chemical Education Research*, 66(1), 105-110.

[25] Zaman, T.U., Choudhary, F.R., & Qamar, A.M. 2015. Advance Organizes Help to Enhance Learning and Retention. *Internasional Journal of Humanities Social Sciences and Education*, 2(3), 45-53.

[26] Walker J.P. & Sampson, V. 2013. Learning to Argue and Arguing to Learn: Argument-Driven Inquiry as a Way to Help Undergraduate Chemistry Student Learn How to Contruct Arguments and Engage in Argumentation During a Laboratory Course, *Journal Research in Science Teaching*, 50(5): 561-596

[27] Karim, N. 2015. Kemampuan Berpikir Kritis Siswa dalam Pembelajaran Matematika dengan Menggunakan Model Jucama di Sekolah Menengah Pertama. *Jurnal Pendidikan Matematika*, 3(1).

[28] Morgan, G.A., Leech, N.L., Gloeckner, G.W., & Barrett, K.C. 2012. IBM SPSS for Introductory Statistics: Use and Interpretation, Fifth Edition (5th ed.). Routledge. https://doi.org/10.4324/9780203127315

[29] Altman, D. 1991. Practical Statistics for Medical Research, Inter-rater agreement. London: Chapman & Hall.

[30] Adnan G, Zulfikar T, Armia MS. 2021. Impacts of inquiry learning model on students' cognitive and critical thinking ability. *Cypriot J Educ Sci*; 16: 1290–1299.

[31] Ennis, R. H. 2011. *The Nature of Critical Thinking: An Outline Of Critical Thinking Disposition And Abilities*. University of Illinios.

[32] Sampson, V.& Walker, J.P. 2012. Argument-Driven Inquiry as a Way to Help Undergraduate Students Write to Learn by Learning to Write in Chemistry. *Internasional Journal of Science Education*, 34 (10): 1443-1485..

[33] Walker J.P., Sampson, V., Grooms, J., Zimmerman, C. & Anderson, B.2012. Argument-driven inquiry in undergraduate chemistry labs: the impact on students' conceptual understanding, argument skills, and attitudes toward science, *J. Coll. Sci. Teach*.,41(4): 74-81.