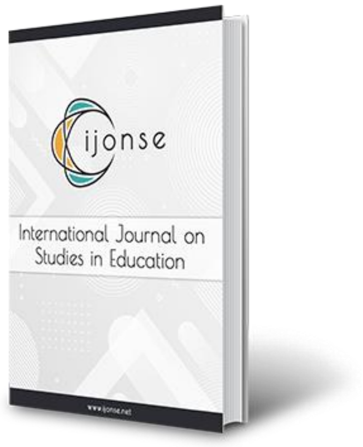

www.ijonse.net

Argument Driven Inquiry and Student Achievement in High School Chemistry, Moderated by Gender

Rebecca Yates
Tennessee Tech University, U.S.A.

George Chitiyo
Tennessee Tech University, U.S.A.

Britney Campbell-Gulley
Tennessee Tech University, U.S.A.

To cite this article:

Yates, R., Chitiyo, G., & Campbell-Gulley, B. (2023). Argument driven inquiry and student achievement in high school chemistry, moderated by gender. *International Journal on Studies in Education (IJonSE), 5*(3), 257-268. https://doi.org/10.46328/ijonse.135

International Journal on Studies in Education

2023, Vol. 5, No. 3, 257-268 https://doi.org/10.46328/ijonse.135

Argument Driven Inquiry and Student Achievement in High School Chemistry, Moderated by Gender

Rebecca Yates, George Chitiyo, Britney Campbell-Gulley

Article Info

Article History

Received:
16 October 2022
Accepted:
14 March 2023

Keywords

Argument-driven inquiry
Argumentation
Academic achievement
Science

Abstract

In the age of high stakes testing, the best instructional methods to promote academic achievement are frequently examined. The purpose of this study was to examine whether implementation of the Argument-Driven Inquiry (ADI) model in a high school chemistry course would be associated with improved student scores compared to a more traditional approach. The study employed a nonequivalent control group design to evaluate the posttest scores of students by instructional method and gender. Data were obtained from a sample of 28 honors students in a chemistry course in grades 10 and 11. The data consisted of pretest and posttest scores. A two-way analysis of covariance was used to address the study's research questions, controlling for the students' aptitude. The results showed that there were no significant differences in achievement between the ADI and traditional methods groups, controlling for the students' aptitude. Also, the interaction between instructional method and gender was not significant. Use of ADI methods was, thus, found to neither improve nor be negatively associated with student performance.

Introduction

In 1983, the U.S. Department of Education's National Commission on Excellence in Education published a report describing the United States as a nation at risk in relation to the rising mediocrity of education (Walker et al., 2011). While there have been some improvements, it can be argued that some areas of instruction, such as science, have worsened (Walker et al., 2011). There is a recent decline in students entering into scientific fields as well as a decline in the number of science educators (Walker et al., 2011), which may be partly attributed to the lack of actual science that takes place in classrooms today. School science often does not parallel actual work in science fields.

The traditional instructional methods in science classrooms and labs can be described as a cookbook or verification approach, in which the activities are given to the students in a standard step-by-step, fill-in-the-blank method (see e.g., Kadayifci & Yalcin-Celik, 2016; Walker et al., 2011). Students are "doing" very little science and are not exposed to an accurate representation of what science entails (see e.g., Kadayifci & Yalcin-Celik, 2016; Walker et al., 2011). To address the need of students to have the opportunity to participate in science and to meet the growing need of scientific proficiency, a new instructional model called Argument-Driven Inquiry (ADI) was developed.

The ADI model is a tool to enable educators to aid students in learning how to "do" science (see e.g., Sampson et al., 2009; Walker et al., 2011). ADI emphasizes the importance of student engagement in the practices of science such as argumentation, data collection, method development, writing, utilizing evidence, peer review, revision, and cooperative learning (Enderle et al., 2013). ADI is based on the social cognitive theory of learning and emphasizes the importance of argumentation and inquiry in science education (see e.g., Cetin & Eymur, 2017; Sampson et al., 2009; Walker et al., 2011). ADI consists of seven steps which are:

identification of the task,
generation and analysis of data,
production of a tentative argument,
the argument session,
the investigation report,
a double-blind peer review, and
revision of the report (see e.g., Sampson et al., 2009; Walker et al., 2011).

The identification of the task allows educators to introduce the topic of the study, capture student interest, scaffold learning experiences, and connect students to the phenomenon to investigate (Sampson et al., 2009; Walker et al., 2011). The second step of ADI gives students the opportunity to work collaboratively and to develop and design a method of investigation to explain or solve the phenomenon (Sampson et al., 2009; Walker et al., 2011). The production of a tentative argument gives students the opportunity to justify their claim with reasoning using the collected evidence with the intent to share with others (Sampson et al., 2009; Walker et al., 2011).

The argumentation session is one of the most researched parts of the ADI model. In this step the small group shares their claim, evidence, and reasoning with the class and then refines their results and argument based on feedback (Sampson et al., 2009; Walker et al., 2011). The investigative reports are written individually and describe, in essence, the research design and method conducted as well as the results (Sampson et al., 2009; Walker et al., 2011). This step in the ADI model aids in improving scientific writing as well as scientific literacy.

The sixth step of the ADI model is the double-blind peer review. This stage consists of students turning in three copies of their investigative report using only a number to identify their report. The teacher will then collect and distribute the reports, along with a rubric, giving students the opportunity to evaluate and offer suggestions about the report (Sampson et al., 2009; Walker et al., 2011). The last step involves the students receiving feedback and revising their reports when needed (Sampson et al., 2009; Walker et al., 2011).

While current literature investigates the many implications of the ADI model, studies specifically examining the association between ADI and academic achievement are extremely limited. For example, Eymur's (2018) study examined the relationship between ADI and self-efficacy, Rosidin et al. (2019) examined critical thinking skills and benefits of ADI on students of different ability levels, and Chen et al. (2019) evaluated student engagement when using the ADI model. Self-efficacy, critical thinking skills, and student engagement are all inextricably linked to student achievement, yet literature lacks a study investigating specifically the link between ADI and academic achievement.

Literature Review

While the research on the ADI model is limited, the benefits of ADI are well established. The stages of the ADI model are interrelated to the many benefits established in literature. The most studied and promoted benefit of ADI is the argumentation aspect. Argumentation has been found to benefit creative thinking skills, critical thinking skills, reflective thinking skills, student engagement, scientific literacy, and scientific proficiency and skills (see e.g., Antonio, 2020; Demirciogul & Ucar, 2015; Enderle et al., 2013; Hasnunidah & Wiono, 2019; Kadayifci & Yalcin-Celik, 2016; Kumdang et al., 2018). ADI has also been shown to improve students' self-efficacy (Eymur, 2017) as well as to bridge gender gaps in science education and argumentation (see e.g., Hasnunidah & Wiono, 2019; Nazila et al., 2019; Rosidin et al., 2019; Songsil et al., 2019). ADI allows students the opportunity to be engaged in the actual practice of science.

Scientific Literacy

One of the major areas for improvement in science education is scientific literacy (Erenler & Cetin, 2019). OECD (2015) defines scientific literacy as "the ability to engage with science-related issues with the ideas of science as a reflective citizen" (as cited in Erenler & Cetin, 2019, p. 628). A scientifically literate person will have the ability to conduct investigations, utilize and evaluate scientific explanations and arguments, write about scientific results and explanations, as well as understand the nature of science (Erenler & Cetin, 2019). Using a single-group pretest-posttest study examining the effects of ADI on 50 pre-service science teachers' meta-cognitive awareness and writing skills, Erenler and Cetin (2019) found that the ADI instructional method was positively associated with preservice science teachers' metacognitive awareness as well as their writing skills.

Cetin and Eymur (2017) conducted a similar study examining the effect of the ADI instructional method on students' writing ability and their ability to present scientifically. The results of pre and post scientific argumentative writing scores, which were analyzed using a paired samples t-test, showed an increase in scores at the end of the study. In fact, students' argument structure, argument content, and writing showed improvement. The study also determined that the ADI instructional model improved the students' scientific presentation skills.

Scientific Processes, Proficiency and Argumentation

Enderle et al. (2013) described scientific proficiency as possessing the content knowledge and having the ability to solve and explain problems related to science. Using a comparative case study, Enderle et al. found that while the participants in both groups had statistically significant gains in content knowledge, only ADI participants increased their scientific writing abilities as well as their scientific knowledge. The study also concluded that the ADI method may have a positive impact on scientific proficiency. Similarly, Demircioglu and Ucar (2015) found that the ADI method was associated with an improvement in the academic success, scientific process skills, and argumentation levels of students.

Argumentation skills are one of the most important aspects of scientific processes (Cetin & Eymur, 2017). Studies have shown that participating in scientific argumentation further develops students' scientific process skills as well as increasing their understanding of the nature of science (Songsil et al., 2019; Walker et al., 2012). In their study to gauge the potential effect of ADI on community college general chemistry students' conceptual understanding, argument skills, and attitudes toward science, Walker et al. found that the ADI students were more adept at the qualities of argumentation which included providing evidence and reasoning in support of their scientific claims and that the ADI and traditional sections were equivalent in their conceptual understanding. This is significant because the ADI sections covered less content. The ADI group also had more positive influence on the students' attitudes towards science.

Gender is a moderating variable in the current study. Some studies have looked at differences in attitudes towards argumentation between males and females. Hasnunidah and Wiono (2019) compared the ADI instructional method with the guided inquiry method in evaluating the argumentation skills between male and female eighth graders in Indonesia with a pretest-posttest non-equivalent control group design. Results of the study indicated that the ADI model had a greater impact on the quality of argumentation and argumentation skills compared to the guided inquiry model. Secondly, there were no gender differences in argumentation skills, thus the ADI learning model does not promote a gender discrepancy.

Chen et al. (2019) conducted a similar experiment examining the impact of a Modified Argument-Driven Inquiry (MADI) on the engagement and argumentation performances comparatively between boys and girls. The study was a quasi-experimental mixed methods design. The experimental group participated in a 24-week program that met weekly and was instructed using the MADI model in a standard school laboratory. The control group was taught using a traditional instructional method in their classrooms.

The experimental group was broken into smaller groups of five to six students to work cooperatively as is part of the MADI method. The researchers collected data using the Elementary School Student Questionnaire (ESSQ), the Engagement in Learning Science Scale (ELSS), and a four-level scoring rubric. Findings from the study indicated that the MADI method had a positive influence on the ELSS and argumentation of the students. In relation to gender, the MADI method was shown to bridge the gap in ELSS as well as argumentation in comparison to the control group.

ADI and Students' Thinking Skills

Thinking skills, whether creative, reflective, or critical are important skills to possess in science. In a K-12 framework science classroom, students should be developing investigations, arriving at conclusions, justifying (arguing) claims with evidence, and constructively reflecting on the process; all of which require the development of thinking skills (Grooms et al., 2015; National Research Council, 2012). Research conducted by Kumdang et al. (2018) assessed the impact of ADI on the creative thinking skills of 31 tenth grade Thai students using a single group action research design.

The qualitative data collected were analyzed using a data content analysis method with triangulation. The students' work was assessed over three cycles. The findings of the study surmised that the ADI instructional model exceeded the traditional teacher-centered method on improving the creative thinking skills of the students. Also, of special significance is that the advancements continued to improve through each cycle.

Kadayifci and Yalcin-Celik (2016) studied the impact of ADI on reflective thinking skills, science process skills, argumentation skills, and students' view of ADI for 125 pre-service science teachers. The study employed both quantitative and qualitative methods. Research questions were answered by the participants following each of the ADI activities. The researchers concluded that the ADI instructional method promotes an environment conducive to reflective thinking and that the ADI method increased the science process skills of the participants. The participants believed the ADI method to be more engaging.

Antonio (2020) defined reflective thinking as the "ability to make use of observations and experiences to shape decisions about what happened in the past or is occurring now to direct and control future activities" (p. 467). Reflective thinking skills are of great value in scientific processes and are part of thinking critically. Reflective thinking skills allow individuals to understand the experiences that have already taken place and implement that knowledge in the future choices and decisions to be made. Antonio designed and evaluated the effects of Metacognitive and Argument-Driven Learning Environment (MADLE) on students' ability to think reflectively and to develop reflective thinking skills. A pretest was administered to 23 undergraduate education students prior to implementation of the MADLE model and a posttest was administered after a four-week exposure. The researchers found that there were no significant improvements in the students' reflective thinking skills; however, the study did show improvements in the posttest mean scores, indicating that there were improvements to students' reflective thinking skills.

Critical thinking skills are vital in academic success and achievement, especially in high stakes testing. Argumentation requires students to evaluate scientific claims through a critical-analysis process dependent upon empirical evidence (Hasnunidah et al., 2020). Hasnunidah et al. conducted a correlational study examining the link between argumentation and critical thinking skills concurrently with students' understanding of Biology content and comparing the ADI instructional method to a traditional learning model. The study's findings were that argumentation and critical thinking skills and the students' comprehension of Biology concepts are directly correlated. Also found was that this correlation is inseparable from the instructional methods. It was determined that the ADI method can potentially have a greater impact on increasing students' argumentation, critical thinking skills, and the understanding of concepts in the real world.

Similarly, Rosidin et al. (2019) and Nazila et al. (2019) found that ADI was associated with improved critical thinking skills. Rosidin et al. found that both the ADI method and the conventional learning models had a positive impact on students' critical thinking skills. However, the ADI method was more effective on improving critical thinking skills. In addition, the ADI improved critical thinking skills of students of all abilities but was the most effective for high achieving students. The study further concluded that there were no significant differences of gender or personality types concerning critical thinking skills with the ADI method. Nazila et al. (2019), using a sample of eighth graders, found that the ADI instructional method had a greater effect than the traditional instructional method on the students' critical thinking skills. Both males and females exposed to ADI did better in terms of critical thinking skills. Within the experimental group, there was no variance in critical thinking skills between the male and female students.

Summary of Literature Review

Extant literature has promising results regarding the effectiveness of the ADI instructional model in science education. The ADI method's effectiveness is almost resoundingly linked to the argumentation aspect of the model (see e.g., Antonio, 2020; Chen et al., 2018; Kadayifci & Yalcin-Celik, 2016; Kumdang et al., 2018; Rosidin et al., 2019). The seven tasks of the ADI method (identify the task, generate and analyze data through a method of their design, produce a tentative argument, participate in the argumentation session, conduct a double blind peer review, revise the investigative report, discuss, and learn cooperatively) seemingly give students an opportunity to practice and develop scientific skills and thinking skills other methods seem to neglect (see e.g., Demircioglu & Ucar, 2015; Sampson et al., 2009; Walker et al., 2012). A review of the literature seems to agree that the ADI method tends to succeed compared to more traditional "cookbook" instructional methods, and it appears to be a promising model to fill the gap other methods have left (Walker et al., 2011).

Purpose and Research Questions

The purpose of the study was to examine the possible effect of the ADI model on academic achievement in comparison to the traditional instructional method and to determine which model will be most beneficial to all students in the instruction and learning of science. The research questions examined were:

(1) Will there be a significant difference in student achievement between students exposed to Argument-Driven Inquiry methods and those exposed to traditional methods, controlling for student aptitude?

(2) Is the difference in achievement scores between students exposed to Argument-Driven Inquiry methods and those exposed to traditional methods, if any, the same for males and females, controlling for student aptitude?

Methods

Study Sample

This study took place during the 2020-2021 school year. The sample consisted of 28 honors students enrolled in a Biological Sciences Academy at a high school in southeastern United States. Of the 28, 12 were in the ADI group and 16 were in the traditional group. The distribution of students by both group and gender is shown in Table 1. The majority of students 79% (*n* = 22) were in 11th grade, with 21% (*n* = 6) in 10th grade.

Table 1. Distribution of Students by Group and Gender

	ADI Group	Traditional Group
Female	8	11
Male	4	5
Total	12	16

Design, Instrumentation, and Data Collection

The study employed a nonequivalent control group design. Two intact honors classes received instruction on a particular unit using ADI, and the other class received instruction using traditional instruction. A pretest was administered at the beginning of the investigation, followed by a posttest at the end of the instructional unit. The pretest was the ACT science practice exam, and posttest questions came partly from the Pearson Chemistry test of the unit, as well as teacher developed questions. The assessments were evaluated by other chemistry instructors to verify content validity.

After taking the pretest, students were then introduced to the learning unit, stoichiometry. The learning unit was approximately two weeks in length consisting of an introduction, practice, the lab, and the post measure. Students in the control group participated in a traditional, recipe style lab. This lab format provided step by step instructions for the completion of the lab which evaluated theoretical yield verses the actual yield of a product. The treatment group participated in an ADI lab which required students to design an experiment to determine the best reaction, out of the four provided reactions, for the thermal decomposition of sodium bicarbonate. In the ADI lab, students were responsible for designing their own experiment and engaging in an argumentation process requiring students to justify their claim using evidence. At the end of the learning segment, students took the post measure quiz that was developed by the chemistry teaching team. The assessments were all administered and scored by the first author of this study and they were scored with the help of other chemistry teachers to ensure reliability of scoring. All scores were converted to percentages.

Results

The posttest scores of both groups of students were approximately normally distributed. The results showed no difference between the groups [$t(26) = -.009$, $p = .993$]. To address the research questions, a two-way analysis of covariance (ANCOVA) was conducted, using the pretest as the covariate. A necessary assumption for ANCOVA is homogeneity of regression slopes. This assumption was satisfied, owing to the lack of an interaction between the covariate and independent variables of method and gender [$F(3,21) = 1.10$, $p = .373$]. Levene's test for equality of error variances showed that the groups had equal variances [$F(2.25)$ $p = .108$]. Similarly, White's test for heteroscedasticity showed independence between variance of errors and the independent variables [$c^2(8) = 11.05$, $p = .199$].

Having satisfied the necessary assumptions, ANCOVA was conducted. The results are shown in Table 2. To address the first research question, there was not a statistically significant difference between the two groups, adjusting for aptitude [$F(1,23) = 2.98$, $p = .098$, $\eta^2 = .12$], though the difference was close to being statistically significant at the .05 alpha level. It can be concluded, therefore, that both groups performed similarly, and implementing the intervention had neither a positive nor adverse students on the students as far as achievement is concerned. The covariate was significant [$F(1,23) = 7.80$, $p = .010$, $\eta^2 = .25$], and it accounted for 25% of the variance in performance on the posttest.

Table 2. Test of Between-Subjects Effects

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Aptitude Premeasure	623.68	1	623.68	7.79	.010	.25
Method	238.08	1	238.08	2.98	.098	.12
Gender	62.44	1	62.44	.78	.386	.03
Method * Gender	115.81	1	115.81	1.45	.241	.06
Error	1840.50	23	80.02			

For the second research question, the ANCOVA results showed that there was no interaction between group and gender [$F(1,23) = 1.45$, $p = .241$]. Albeit not significant, a plot of the interaction showed that students in the control group on average tended to perform better than those who were exposed to ADI. There seemed to be a bigger difference in the performance of males though, with males in the ADI group performing much less (M_1 = 81.9) than those in the control group (M_2 = 92.6). Females tended to perform about the same. This interaction is illustrated in Figure 1.

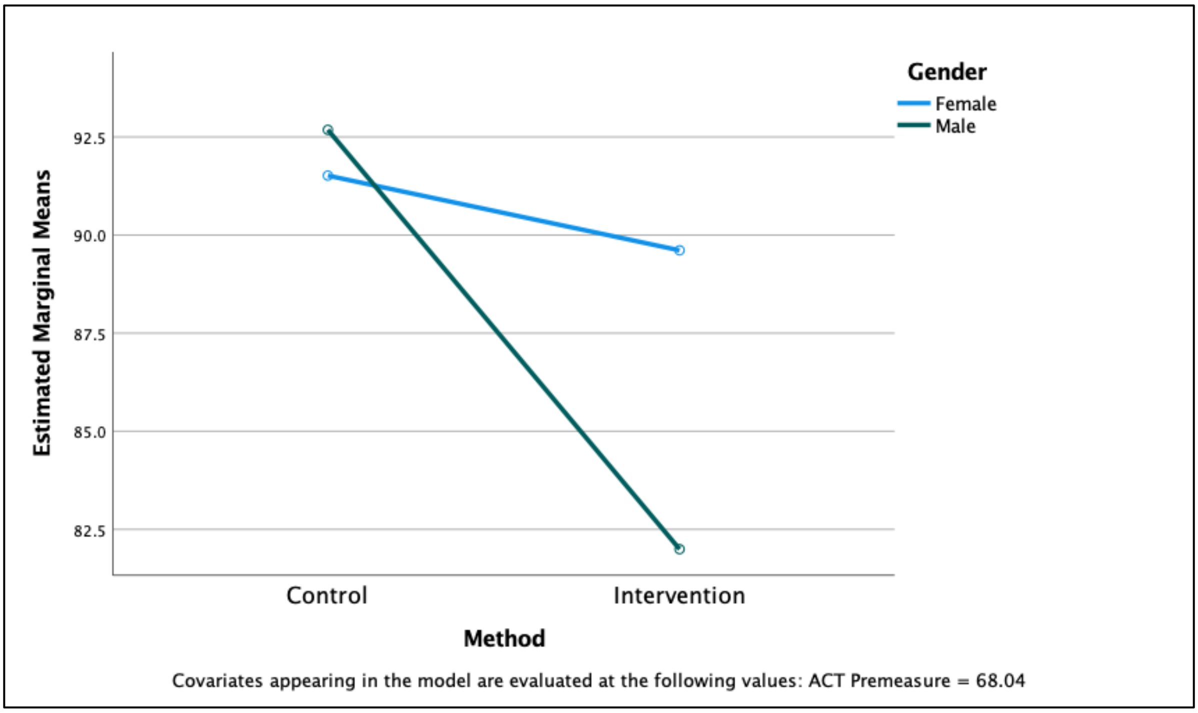

Figure 1. Interaction between Instructional Method and Gender

Discussion

Using a nonequivalent control group design, the purpose of this study was to examine possible differences in academic achievement due to the use of the ADI instructional model. The study further evaluated if a difference in achievement scores between students exposed to ADI methods and those exposed to traditional methods, if any, would be the same for males and females. The study found that there was not a statistically significant difference between the two groups' test scores, controlling for aptitude, concluding that both groups performed similarly, and the intervention did not hurt the students. The study further concluded that while there was no significant interaction between group and gender, the males in the control group performed better than the males in the ADI groups, with females performing about the same under each condition.

While the possible impact of the ADI instructional model on student academic achievement was not significant, there are other advantages to this instructional model found in both extant research as well as witnessed through the study. These advantages include, but are not limited to, scientific literacy, scientific proficiency, scientific argumentation, and thinking skills. An additional advantage to the ADI instructional model is its correlation to the K-12 Framework, the model from which the Next Generation Science Standards (NGSS) were derived.

The Framework for K-12 Science Education, is almost nationally recognized as the framework, or standards, to be utilized in the K-12 science classroom (National Research Council, 2012). The framework is inquiry based, requiring that students "do" science, something that the more traditional instructional methods lack. The ADI instructional method has shown to incorporate all aspects of the NGSS standards in its model, which requires that students design an experiment to solve for a phenomenon, gather and record data, use their data as evidence, develop an argument to justify their reasoning amongst their peers, and then to write about the process using scientific data (Sampson et al., 2009; Walker et al., 2011; National Research Council, 2012).

Erenler and Cetin (2019) identified that scientific literacy requires students to have the ability to conduct investigations, utilize and evaluate scientific explanations and arguments, write about scientific results and explanations, as well as have an understanding for the nature of science. These skills are the embodiment of the ADI instructional method and are often what is lacking in the more traditional methods utilizing a verification approach to scientific inquiry. The ADI model requires that students collect their data and in turn use their data as evidence to justify their argumentation. The investigation report, which is part of the ADI model, requires students to present and argue their claim, justify their claim with evidence, as well as creating tables for the data collected. While it was not part of the ADI model being investigated in this study, students in the treatment group participating in the ADI model were more thorough in their reports, backing up their claims with evidence, creating data tables for the evidence, and created stronger reports than those in the control group. It is believed that the students' skills for scientific writing and evaluation will only increase with more practice in the ADI model.

An outcome associated with ADI, which was not assessed in the current study, is argumentation. Argumentation is even touted as being one of the most important aspects of ADI (see e.g., Cetin & Eymur, 2017; Chen et al., 2019; Songsil et al., 2019; Walker et al., 2012). Other studies have shown that student participation in scientific argumentation further develops students' scientific process skills and increases their understanding of the nature of science (see e.g., Songsil et al., 2019; Walker et al., 2012).

The argumentation portion of the ADI model requires students to analyze data, state a claim, and then justify (argue) their claim using their evidence. This is done in a collaborative setting with small groups of students working together to argue their claim to their peers, who then further evaluate the data presented. Argumentation positively impacts students' scientific proficiency, increasing students' content knowledge, and increasing their understanding of the nature of science (see e.g., Enderle et al., 2013; Demircioglu & Ucar, 2015; Songsil et al., 2019; Walker et al., 2012). Chen et al. (2019) found that argumentation was also shown to increase student engagement which corresponds to the witnessed student engagement in this study. Through observation, students who participated in the ADI instructional method appeared to be more engaged in the learning segment as a whole, but especially the argumentation session. The students participating in ADI were actively involved in each step of the process which required communication and collaborative work. The students were excited for the argumentation process and eager to justify their claim as well as question the design and evidence of their peers' investigations. Their engagement in the ADI instructional method was above expectations.

Another notable advantage to the ADI model is the positive impact on thinking skills, especially critical thinking skills. Rosidin et al. (2019) and Nazila et al. (2019) found that the ADI method was effective on improving critical thinking skills. Nazila et al. (2019) found that the ADI method had a greater effect than the traditional instructional method on students' critical thinking skills. The students participating in the ADI instructional model were responsible for designing their own experiment using the tools and information given. This task required the students to think critically about the content as well as the lab processes and data necessary to develop a claim. In addition, these students also had to evaluate the data and determine what was essential to their argument as well as any potential errors that could have an impact on their data and thus their claim. The control group participating in the traditional model simply had to follow verification style lab, recording their data.

Conclusion

The evidence in this study shows that there were no differences in achievement between students exposed to the ADI instructional model and those who were not, while controlling for the students' aptitude. For teachers who want to experiment with ADI, this evidence is helpful as it shows that ADI methods may not be detrimental to achievement. Studies have shown that the ADI model is beneficial to scientific literacy, scientific proficiency, scientific argumentation, and thinking skills.

The ADI instructional method also aligns with the K-12 framework for science education (National Research Council, 2012). This study evaluated the significance of the ADI model on student achievement after only one learning segment. In light of the significant impact ADI has on other aspects of education that are directly linked to student achievement, it could be argued that further exposure to the ADI instructional model over time could possibly show a more significant impact on student achievement.

References

Antonio, R.P. (2020). Developing students' reflective thinking skills in a metacognitive and argument-driven learning environment. *International Journal of Research in Education and Science (IJRES),* 6(3), 467-483.

Cetin, P. S., & Eymur, G. (2017). *Developing students' scientific writing and presentation skills through argument driven inquiry: An exploratory study* doi:10.1021/acs.jchemed.6b00915

Chen, H., Wang, H., Lu, Y., & Hong, Z. (2019). Bridging the gender gap of children's engagement in learning science and argumentation through a modified argument-driven inquiry. *International Journal of Science and Mathematics Education, 17*(4), 635-655. doi:10.1007/s10763-018-9896-9

Enderle, P., Grooms, J., & Sampson, V. (2013). The use of argumentation in science education to promote the development of science proficiency: A comparative case study. *Society for Research on Educational Effectiveness (SREE).* www.sree.org.

Erenler, S., & Cetin P.S. (2019). Utilizing argument-driven-inquiry to develop pre-service teachers' metacognitive awareness and writing skills. *International Journal of Reasearch in Education and Science (IJRES),* 5(2), 628-638.

Demircioglu, T., & Ucar, S. (2015). Investigating the effect of argument-driven inquiry in laboratory instruction*. *Kuram Ve Uygulamada Egitim Bilimleri, 15*(1), 267-283. doi:10.12738/estp.2015.1.2324

Eymur, G. (2018). Developing high school students' self-efficacy and perceptions about inquiry and laboratory skills through argument-driven inquiry. *Journal of Chemical Education, 95*(5), 709-715. doi:10.1021/acs.jchemed.7b00934

Hasnunidah, N., & Wisnu, J. W. (2019). Argument-driven inquiry, gender, and its effects on argumentation skills. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah, 4*(2), 179-188. doi:10.24042/tadris.v4i2.4676

Hasnunidah, N., Susilo, H., Irawati, M., & Suwono, H. (2020). The contribution of argumentation and critical thinking skills on students' concept understanding in different learning models. *Journal of University Teaching & Learning Practice,* 17(1), 1-11.

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

Kumdang, P., Kijkuakul, S., & 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. *Journal of Science Learning, 2*(1), 9-13. doi:10.17509/jsl.v2i1.11995

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting, and core ideas.* The National Academies Press. https://doi.org/10.17226/13165.

Nazila, L., Rosidin, U., I, W. D., Herlina, K., & Hasnunidah, N. (2019). The effect of applying argument driven inquiry models to the critical thinking skills of students based on gender differences. *Scientiae Educatia, 8*(1), 35-50. doi:10.24235/sc.educatia.v8i1.4145

Rosidin, U., Kadaritna, N., & Hasnunidah, N. (2019). Can argument-driven inquiry models have impact on critical thinking skills for students with different personality types? *Cakrawala Pendidikan : CP, 38*(3), 511-526. doi:10.21831/cp.v38i3.24725

Sampson, V., Grooms, J., & Walker, J. (2009). Argument-driven inquiry. *The Science Teacher (National Science*

Teachers Association), 76(8), 42. doi:10.2505/3/tst09_076_08

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*(1), 1-22. doi:10.1186/s41029-019-0035-x

Walker, J. P., Sampson, V., Grooms, J., Anderson, B., & Zimmerman, C. O. (2012). Argument-driven inquiry in undergraduate chemistry labs: The impact on students' conceptual understanding, argument skills, and attitudes toward science. (Research and Teaching). *Journal of College Science Teaching, 41*(4), 74.

Walker, J., Sampson, V., & Zimmerman, C. (2011). Argument-driven inquiry: An introduction to a new instructional model for use in undergraduate chemistry labs. *Journal of Chemical Education, 88*(8), 1048. doi:10.1021/ed100622h

Author Information

Rebecca Yates
https://orcid.org/0000-0002-7473-9022
Tennessee Tech University
1 William L Jones Dr, Cookeville, TN 38505
U.S.A.
Contact e-mail: *rayates42@tntech.edu*

George Chitiyo
https://orcid.org/0000-0002-0264-6513
Tennessee Tech University
1 William L Jones Dr, Cookeville, TN 38505
U.S.A.

Britney Campbell-Gulley
https://orcid.org/0000-000201241-4652
Tennessee Tech University
1 William L Jones Dr, Cookeville, TN 38505
U.S.A.