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Developing scientific argumentation strategies using revised argument-driven inquiry (rADI) in science classrooms in Thailand

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Abstract

Scientific argumentation skills are important for students for expressing their opinions, making decisions and solving problems in daily life. Previous studies have focused on students' scientific argumentation skills, but few studies have proposed an instructional model for specifically developing these skills by creating a supportive classroom atmosphere that considers factors that may influenced on students' ability to successfully enact argumentation practices. In this study, researchers have adapted the Argument-Driven Inquiry (ADI) model, which is a model that meets several important criteria for fostering argumentation in the classroom and we have revised the model to satisfy practical constraints faced by teachers and students in Thai classroom contexts. In this study, we describe our revised Argument-Driven Inquiry (rADI) model and provide examples of how this model was used to increase students' scientific argumentation skills when learning about socio-scientific issues. We additionally examine factors, such as gender, reasoning ability, prior experience with scientific argumentation, and content knowledge to determine what influence they may have on students' post-instruction scientific argumentation skills. Specifically, we examined the effect the rADI model had on students' abilities after controlling for covariates. We surveyed 155 Grade 10 students to assess their scientific argumentation skills using a set of situational open-ended questions. The data were analyzed using descriptive statistics, correlation, and ANCOVA. Findings indicated that 1) most students could develop or improve scientific argumentation skills after the instruction in most components, although the supportive argument element tended to be weaker; 2) pretest scientific argumentation skills was correlated with posttest scientific argumentation skills, but gender, content knowledge, and reasoning ability were not correlated with posttest scientific argumentation skills; 3) and after controlling for pretest scientific argumentation skills, students in the experimental group produced higher posttest scores of scientific argumentation skills than those taught by the conventional approach ($p < 0.05$). Outcomes from our study using the rADI model may be beneficial to teachers who seek to improve students' scientific argumentation skills in science classrooms in the Thai context. Implications for local and international use of rADI are discussed.

Keywords: Revised argument-driven inquiry (rADI), Scientific argumentation skills, An instructional model

Introduction

Science is a sub-culture of the modern world, which is a learning society. It is advantageous for everyone to know science to gain a better understanding of the natural and man-made worlds and to be able to apply that knowledge wisely (Ministry of Education, 2008). A society with science and technology as the foundation for thought is crucial for cultivating thoughtful and rational thinking (Evagorou & Osborne, 2013; Zeidler & Nichols, 2009). Cavagnetto and Hand (2012), Osborne, MacPherson, Patterson, and Szu (2012), and Venville and Dawson (2010) discuss scientific argumentation as an activity that promotes critical reasoning and decision-making. The scientific process skills that students develop as a result of engaging in argumentation activities can help students to develop an understanding of the nature of science (Dawson & Venville, 2010). Finally, Newton, Driver, and Osborne (1999) and Venville (2010) argue that because these argumentation processes underlie the work of scientists, having students engage in scientific argumentation is essential to the learning of science. By taking knowledge from diverse sources and putting them together in a logical and reasonable manner, students can expand their knowledge to include those of other individuals and larger group perspectives. This process can be facilitated through scientific argumentation activities, which increase students' capacity for scientific thinking and reform prior misconceptions.

These studies all demonstrate that the argumentation skills are highly necessary for scientists and students. Thus, helping students to develop good argumentation skills and supporting students to be able to carefully consider information and reason about situations are critical for preparing students to be able to effectively make decisions about problems in society. Therefore, the promoting argumentation skills in school will be important for driving the progress of science, technology, and society. In the science classroom, educators wish to cultivate students who are knowledgeable in science and who can collaborate effectively. Science learning requires a classroom that provides opportunities for students to work together in a variety of ways to create new perspectives. Students should be able to identify sources for their research and reasoning in rational and evidence-based manners that enhance the problem-solving potential for social issues (Zeidler & Nichols, 2009). Through the promotion of reasoning and argumentation skills, students receive numerous benefits including advanced scientific thinking skills, communication skills, ability to assess the reliability of evidence and an understanding of the nature of science.

While these are among the main goals of learning science today (Jantarakantee, 2016), in Thailand, traditional lecture and inquiry-based learning approaches are widely used in high school science classrooms. Teachers convey information from the core content and indicators of Thailand's education system through their teaching (Faikhamta, Ketsing, Tanak, & Chamrat, 2018). While these approached may be able to promote conceptual understanding, inquiry skills, and positive attitudes toward science, these strategies have not been shown to effectively target and promote enough argumentative expression. In addition, when considering Thai traditional cultural contexts, we find that Thai students are taught to be skeptical about freely expressing opinions that are different from their teacher and peers. Consequently, it is common for students to simply accept their teachers' views and not to express differing viewpoints. Moreover, it is a social norm in Thai society that successful students should attend elite universities. Parents put high expectations and pressure on their children for to perform well on the entrance examination to university. Based on these factors, current instruction in Thai classrooms do not tend to encourage students to engage in argumentative practices, even though it is an important aspect of building scientific literacy.

As educational researchers, we seek new instructional models that can promote students' scientific argumentation skills in local contexts. Currently, research on argumentation has focused more on examining and describing students' scientific argumentation skills, but less attention has been paid to identifying the kinds of instruction, learning activities and learning atmosphere that all promote the development of these skills. Through this study, we intend to fill this gap in the literature by developing an instructional model with the power to make measurable improvements in student's scientific argumentation skills. In addition, we sought to develop an instructional model that considers content and time constraints faced by teachers in Thai classroom contexts so that the model would be suitable for implementation in Thai schools. To do so, we reviewed the literature and we identified the ADI instructional model developed by Sampson, Grooms, and Walker (2010). We synthesized key features from this model and we proposed a revised ADI (rADI) model, which was implemented in real classrooms to examine the effectiveness of the model on promoting Thai students' argumentation practices.

We believe this research is necessary because from the 2015 results of the Program for International Student Assessment (PISA), we observed that Thai 15-year-old high school students were ranked 54th out of 70 countries in the category of science. In addition, Thai students received very low scores on their written answers to analytical questions as students tended to respond to questions using short sentences, to offer completely unreasonable answers, and that failed to clearly show scientific concepts (Educational testing office by the PISA Office of the Basic Education Commission [OBEC], 2018). Analysis of Thai students' responses revealed a group of students who struggled to demonstrate adequate learning outcomes through analytical writing, reading and interpreting skills.

In an effort to address these critical problems related to argumentation, we sought to implement the rADI instructional model with the goal to explicitly support students to engage in basic writing, reading, critical thinking, interpreting and analysis of data. The research questions framing this study are as follows:

1. How well do Thai high school students make scientific arguments?
2. To what extent do gender, reasoning ability and content knowledge influence on their ability to effectively make scientific arguments?
3. After controlling covariates, how do students taught using the revised Argument-Driven Inquiry (rADI) instructional model perform compared to students taught using traditional inquiry- and discussion-based approaches?

In the sections that following, we provide the reader with context for understanding the role that argumentation plays in developing students' scientific literacy and we describe in more detail our reason for adopting the ADI model and our process for revising this model for use in the Thai educational contexts. Following this introduction, we describe findings from our implementation study aimed at identifying factors that influence on students argumentation abilities and we describe findings from our comparative analysis of students' argumentation practices after rADI instruction and after traditional lecture and inquiry instruction.

Background

Argumentation can be viewed as a social practice based on collaboration. This process can challenge wrong or unreasonable ideas, changing them into concepts that are justified by alternative interpretations of existing information and from credible evidence supporting emergent knowledge claim (Berland & McNeill, 2010; Evagorou & Osborne, 2013). This argumentation process has been of interest in many studies in the field of science education over many years and is often seen as the basis of scientific literacy (Emig & McDonald, 2014; Evagorou & Osborne, 2013; Iordanou & Constantinou, 2015).

Scientific argumentation skills play an important part in the science classroom because each student can share their ideas on socio-scientific issues. The activities of scientific argumentation are a scientific practice based on personal construction and social mediation of knowledge (Berland & McNeill, 2010; Sampson et al., 2010). To arrive at a common, justified conclusion, it is important to find the rationale for one's claims and use evidence to support those claims in manners befitting the work of a scientist. The creation of knowledge requires two important processes - research, upon which knowledge claims can be made, and criticisms and arguments from the community of scientists and the public, which allow those claims to be examined (Pongsophon, 2010). From this analytical process, students can acquire scientific argumentation skills, filter the information received from various sources and evaluate the credibility or reasonableness of the information. In doing so, students must be able to create and communicate effective scientific information (Iordanou & Constantinou, 2015). Yet, despite the clear importance of scientific argumentation skills, most studies have shown that students around the world are generally lacking in this area.

What is scientific argumentation?

In the context of science education, a scientific argumentation can be seen as a decision based on scientific proposal or proposition and presents an alternative viewpoint for scientific interpretation (Iordanou & Constantinou, 2015). Emig and McDonald (2014) demonstrate this idea by using an analogical comparison that can scaffold students' thinking to make a concept easier to understand or communicate.

Scientific argumentation means that an individual tries to create, support, oppose, or improve a scientific claim in order to lead to validation and credible conclusions. These conclusions must be based on empirical data and evidence (Evagorou & Osborne, 2013; Lin & Mintzes, 2010).

Determining factors of scientific argumentation

Various factors potentially influence the student's argumentation skills. The quality of argumentation may be influenced by the individual's content knowledge; higher-achieving students generally have the higher content knowledge and can make broader and more complex arguments than students who have lower academic achievement levels, suggesting a link between the quality of the argument and the knowledge of the content. Likewise, argumentation quality is also shown to be influenced by the social environment, and by the teacher (Dawson & Schibeci, 2003; Sampson & Clark, 2011; Simon, Erduran, & Osborne, 2006). Gender affects argumentation as well – data suggests that female students are more likely to understand the details of problem situations. Females have been found to be more capable of changing their own erroneous ideas, and can generally participate and interact better with others during the discussion of concepts compared to males (Asterhan, Schwarz, & Gil, 2012; Galotti, Drebud, & Reimer, 2001; Miller, 2005; Zohar, 2006). There is also the factor of reasoning ability, which is the student's general intellectual capacity to make use of data and evidence available to support their claims (National Research Council (NRC), 2012); this is closely related to the concept of scientific argumentation skills, though the latter also implies other abilities such as the capacity to absorb additional data and change one's own false assumptions.

We have analyzed the elements of scientific argumentation skills as presented in published studied by several researchers and presented our findings in Table 1:

The main common elements are the claims made that are supported by the warrants (reasoning) that are, in turn, based on the evidence (data). Lin and Mintzes (2010) and Toulmin (1958) have an added element to this: the backing to support the claim (supportive arguments). Furthermore, Lin and Mintzes added counter-arguments to encourage students to recognize and discuss views different from their original perspectives, and to be open to the opinions of others. Lin and Mintzes' framework encourage students to both consider and refute counter-arguments. This process of refutation is missing in other frameworks. It would help us understand why some students or develop stronger arguments than others for a more effective design of the model of argument-driven inquiry instruction in the science classroom.

Synthesis of key features for an instructional model of argument-driven inquiry

After synthesizing documents and studies of the factors influencing scientific argumentation skills and the instruction of argument-driven inquiry that promote those skills (Erduran, Ardac, & Yakmaci-Guzel, 2006; Howell-Richardson, Christodoulou, Osborne, Richardson, & Simon, 2009; Lin & Mintzes, 2010), we outlined six key features of argument-driven inquiry instruction (Table 2). We used these elements as a framework for developing and revising an instructional model that would be effective for enhancing students' scientific argumentation skills.

Based on these key features, we next worked to revise the ADI instructional model to create the rADI model, which we believe offers an important guiding framework that can facilitate a learning process that instills students with effective scientific argumentation skills. In the sections that follow, we provide more detailed description about the process of revision and the features that we introduced to specifically adapt the original model to the Thai educational context.

Table 1 A comparison of the main elements of scientific argumentation skills

Elements of scientific argumentation	Toulmin (1958)	Anuworrachai (2014)	Lin and Mintzes (2010)
Claims	√	√	√
Reasoning /Warrants	√	√	√
Data /Evidence	√	√	√
Counter-arguments	–	–	√
Backing/Supportive arguments	√	–	√

Table 2 Overview of the key features for an argument-driven inquiry instruction

Key features	Overview
Well-structured tasks	Instructor conducts teaching activities to encourage students to discuss and exchange ideas on scientific concepts and socio-scientific issues related to these concepts.
Explanation of argumentation process	Instructor explains to students the principles of the scientific argumentation process and the elements of good argumentation, as well as the use of good and reliable information or evidence to support their claims. Instructor also demonstrates and exemplifies good arguments to promote the use of socio-scientific issues linked to knowledge in the content.
Use of group discussions	Students learn together through group work processes to communicate and exchange their ideas. Group members consider counter-arguments before agreeing on a joint conclusion.
Argumentation-focused activities	Students learn to cite credible academic sources to support their claims and recognize views, ideas or other claims that differ from their own claims. Students learn rational methods to demonstrate and persuade others on the validity of their claims.
Immediate feedback	Immediate feedback is provided by the instructor regarding the quality of student arguments during activities in groups and as a class. The instructor asks timely questions that guide groups and students toward rational argumentation. Each student group also provides feedback to other groups' written reports on the topic of argumentation, and the instructor about each report provides final feedback.
Safe and respectful learning atmosphere	Instructor promotes a safe and respectful learning atmosphere for all students involved. Students feel safe to participate due to the use of neutral, unbiased questions that consider everyone's perspectives fairly and without prejudice. Kindness from instructor empowers students to be confident to contribute to argumentation activities using counter-arguments and opposing perspectives. The students are encouraged to recognize peers' viewpoints and understand the reasoning behind those who think differently from themselves.

Revising the argument-driven inquiry (ADI) model for use in Thai classrooms

Having identified the key features of instruction that enhance scientific argumentation skills, we conducted further research on the processes and steps for teaching science as argument-driven inquiry. We identified Sampson, Grooms and Walker's ADI instructional model (Sampson et al., 2010) as one that had particular strengths for improving students' expression of rational claims and for making reliable use of evidence. In addition, when used in argumentative activities, the ADI model was shown to promote argumentative thinking through writing, which supports students to carefully examine their reasoning. However, for use in the Thai context, we needed to revise the ADI model to satisfy time constraints and to improve the learning atmosphere in the classroom by encouraging teachers' feedback during argumentation activities. Table 3 provides an overview of the original ADI model (Sampson et al., 2010) that highlights the three different sessions recommended for engaging students in argumentative activities. We use this table to highlight the revisions we introduced for our model.

To make this model applicable to the Thai environment, we were required to make revisions aimed to improve student participation and ease of instruction. These modifications were a result of feedback from teachers who encountered practical difficulties when actually implementing certain specific steps in each session of the original ADI model. Examples of problems include challenges when using double-blind peer review and multiple revisions of student group reports and teachers running out of time when trying to carry out each step in real-life. Notably, Sampson et al. (2010) report findings from their use of the original ADI model with only 19 students in their sample. However, in Thai classrooms, there is an average of 36 students in the class – nearly double

Table 3 Overview of original ADI instructional model

Sessions	Overview of the ADI instructional model (Sampson et al., 2010)
Introduction session	The teacher informally surveys and examines students' prior knowledge in scientific concepts and then guides the inquiry activity by introducing data for discussion to find answers to the questions and to produce a tentative argument.
Argumentation session	The teacher asks each group to share their claims with the class and give their reason or evidence to justify those claims.
Conclusion session	Individual students express their understanding of the topic under investigation and about scientific argumentation by producing formal written reports, which are evaluated in a double-blind peer review process. The peer review sheet has specific criteria for assessing the quality of the report using comments and scores, which provide feedback to the students who wrote the report. Students have a chance to revise their report twice.

those in the original study. As originally intended, the ADI session recommendations introduced significant practical issues related to time because teachers in this model are required to review written reports from individual students during class time. This is not possible with 36 students. As such, we had to switch the model's format from individual reports to group reports, which is more suitable for use in larger classrooms.

The similarities and differences between the original ADI model and our revised ADI (rADI) are highlighted in Tables 4, 5 and 6. Each table provides a description of the revisions and their intention. In our revision, we expanded the original three sessions to include more steps. The titles of each step of our revised ADI model listed in Tables 4, 5 and 6 were chosen to represent our intended focus of instruction at each step. These titles may or may not be different from those used by Sampson et al. (2010) in the original model.

The main revisions needed to adapt the original ADI model to Thai context for the Introduction session focused on the need to minimize the use of scientific topics with generally fixed, known answers. In other words, rather than use topics with a right answer and a wrong answer, which each student was expected to know, we sought to increase student engagement by providing a SSI related topic that could promote individual interest and expression of ideas. Our experience indicated that some students who were not sure about their own answers would feel hesitant to participate, out of fear of getting the answer wrong. To remedy this, we introduced the use of controversial socio-scientific issues in the Argumentation Session. We did this because SSI topics, while related to the scientific concepts being discussed, do not always have clear right or wrong answers. Table 5, below, demonstrates the additions made to the argumentation session.

Since such issues are both interesting and open-ended, students of all skill levels can feel less stressed during participation while learning the process of argumentation. To further encourage a considerate, respectful atmosphere, we considered two additional elements of argumentation - the counter argument and the supportive argument – which received less emphasis in the original ADI model but are important in our model, because it deals with contentious social issues that involve multiple perspectives.

Finally, we made revisions to the Conclusion Session of the original ADI model to address the challenges faced by teachers working with larger class sizes in Thai contexts. Specifically, in the conclusion session, we chose not to focus attention only on evaluating students' answers, but we believe that students need to be able to express both the content knowledge behind the argument and to also have the confidence to feel comfortable and encouraged while making arguments. We feel that we can promote such an environment by refraining from focusing on judging what the best or worst answer

Table 4 Comparison of original ADI model and rADI model introduction sessions

ADI instructional model (2010)	(rADI) instructional model
Introduction: Engagement: Step 1	
The identification of the task	Determining students' prior knowledge[a]
Original: In the ADI model, the teacher dealt with only one major topic, and thus constructed the framework of instruction around this topic. The teacher quickly provides students with information and criteria for engaging and evaluating arguments.	
Revision: The rADI model emphasizes broader coverage of content by introducing a major topic and a related controversial socio-scientific issue. The presentation of a controversial issue is intended to further stimulate discussion and objective scientific thinking. Teacher presentation of information about how to engage in and evaluate high-quality arguments was moved to step 4	
Inquiry-based learning activities: Research and Data: Step 2	
Generation of data	Data and research activities in group
Revisions: No changes to original ADI model.	
Commonalities: Both ADI models support students to engage in argumentation practice by making a claim, using evidence, and engaging in reasoning. Teachers guide inquiry activities by introducing data for discussion and soliciting scientific answers to specific questions. Students may suggest ways to collect data to obtain accurate, complete and reliable information. This process allows the students to learn ways to find scientific answers to questions while practicing to collaborate and exchange distinct perspectives with others.	
Conclusion: Scientific explanation: Step 3	
Production of a tentative argument	Free exchange of scientific explanation"
Revisions: The ADI model emphasized the production of science content knowledge in small group discussions with a focus on establishing only the most valid or accepted answer. While these are crucial aspects of argumentation, we also feel that from a pedagogical perspective, the previous ADI model could benefit from some additional emphasis on promoting a free and safe learning atmosphere.	

[a]The titles of each step of our revised ADI model listed in Tables 4, 5 and 6 were chosen to represent our intended focus of instruction at each step. These titles may or may not be different from those used by Sampson et al., (2010) in the original model

Table 5 Comparison of original ADI model and rADI model argumentation sessions

ADI instructional model (2010)	(rADI) instructional model
Expanding the concept using a new topic (Steps 4–6)	
(Not included)	Presenting socio-scientific issues (Step 4)
Addition: We introduce socio-scientific issues (SSI), which by its nature is a controversial topic without a universal consensus, to demands students express claims, use evidence, and engage scientific reasoning skills and to also challenge their moral reasoning, decision-making, and problem-solving processes. SSI topics have a high potential for promoting lively class argumentation sessions.	
Inquiry-based learning activities: Research and Data	
(Not included)	Data/Research activities in groups 2 (Step 5)
Addition: Similar to Step 2, students form discussion groups to gather data and brainstorm ideas about the SSI topic. Students may use data provided by the teacher, look for new data online, or both. Students are given enough time in groups to collaborate and form basic ideas to support their arguments in the next step. Students are required to analyze information in a new dimension of argumentation in which definite conclusions may prove elusive. This is a nuanced task, which is missing, in the previous ADI model. We believe this step is important for expanding the scientific analytical capacity of students to evolve from a basic framework of the readily provided answer to one in which multiple perspectives or answers are potentially viable but whose empirical veracity have yet to be established, as is the case in much of theoretical science.	
(Not Included)	Make tentative claims about SSI as a group (Step 6)
Addition: Groups take the data they gathered in previous steps and construct proper arguments involving SSI topics using all the elements of scientific argumentation. Each group writes down their own tentative claims to share with peers. Students must use evidence and reasoning to reinforce their claims. Students can change claims if they encounter conflicting data. This may promote increased student participation by alleviating the pressure to get the answer correct immediately, which also teaches the idea of science as an open, dynamic process.	

Table 6 Comparison of original ADI model and rADI model conclusion sessions

ADI instructional model (2010)	(rADI) instructional model
Argumentation session	
An argumentation session (Step 4)	Engaging in argumentation as a class (Step 7)
Original: The ADI model emphasizes critique amongst students to determine which claim is the most valid response to questions with previously known answers.	
Revisions: The rADI model uses SSI topics and encourages students to listen to different perspectives and consider why others may express such claims without a need to assume that certain answers must be better than others. Each group is free to update or change their original position as new evidence is presented and the teacher explains the elements of argumentation so that students can apply those elements toward a real-life situation.	
Written reports	
The creation of a written investigation report by individual students (Step 5)	The creation of a written investigation report by groups of students (Step 8)
Original: The ADI model takes an individualistic approach to this step, requiring students to produce their own individual reports and then correct or refine each other's reports.	
Revisions: The rADI model switched to a group report format to promote democratic teamwork and asks students to collaborate with their own group to help prepare the group's report and conclusions.	
Peer review and revision report	
A double-blind peer review (Step 6)	Engaging in peer review and revising group reports (Step 9)
The revision of the report (Step 7)	
Original: The ADI model utilizes a double-blind peer review process, where each author submits his or her individual report for assessment without using identifiable personal information until each author get "good" or "excellent" scores.	
Revisions: The rADI model uses only a general peer review and controls for peer bias by having students evaluate other groups' reports using an objective criteria sheet. This process requires only one revision instead of revision until mastery level.	

is and instead, introduce students to an SSI topic in a secondary stage of argumentation development. This way, students will have opportunities to correct their own mistakes in an organic fashion. In our approach, the teacher would encourage all students to apply their own scientific reasoning and exchange whatever reasonable ideas they have with the class. Table 6 outlines the revisions to the Conclusions Session below.

In the peer review and revision report sections, we combined the final two steps of the original ADI model into one step (peer review, and the revision of group reports). We omitted the double-blind requirement during the peer review process for the sake of the teacher's convenience of the implementation of instruction. Double blindness is an integral part of professional scientific research, its necessity may be diminished in the context of a high school classroom session, where students often lack adequate argumentation skills and can benefit from additional basic training and instruction. By engaging in peer review in groups, students could gain the benefits of not only being able to share ideas and summarize conclusions together but also engage in argumentation collaboratively. To help control peer bias, we had students use a criteria sheet containing objective criteria to evaluate other groups' reports. We also ask the teacher to independently evaluate group reports and inspect each peer review report to correct potential bias. The teacher should provide instant and continuous constructive feedback in order to ensure each student stays the course toward improving his or her argumentation skills over time.

We found that the timesaving measure of switching from individual reports to group reports could also benefit students' ease of learning as the original ADI model asked for repeated corrections and revisions of written reports from individuals during the conclusion session; in our experience, while this was intended to sharpen argumentation skills, it also unfortunately caused stress for some students who were not already familiar with argumentation. In addition, we also relaxed the requirement to completely revise reports. The students make their report no more than one revision as a group after the class argumentation session. We believe it is not necessary to rush the students to create the most complete argument within a short time. Instead, we expect students to improve their argumentation skills organically and incrementally after being gradually exposed to a variety of content knowledge, socio-scientific issues, and argumentation know-how that the instructor would teach over a span of numerous classes. In contrast, when using the original ADI instructional model, incomplete reports from individuals would be considered unacceptable, and the author would rewrite his or her report for additional subsequent evaluations or revisions based on the reviewers' feedback.

After making these revisions, we aimed to implement the model and evaluate the effectiveness for its use in Thai classrooms. In the sections that follow, we describe the research design used to conduct a comparative analysis of students' argumentation skills when using the rADI and traditional lecture and inquiry activities.

Research design

The goal of this study was to examine and compare the scientific argumentation skills of students who received instruction using the rADI model (the experimental group) and students who received instruction using traditional inquiry-discussion group (the control group) (See Fig. 1). Comparative analysis was conducted using a two-group pretest-posttest design. A control group was used to test and estimate the effectiveness of instruction of both groups of students, both before and after the instruction.

We examined whether and how both groups of students have different scientific argumentation skills (See Fig. 2). The data were analyzed using analysis of covariance (ANCOVA) to compare post-instruction scientific argumentation scores between the two groups after controlling the covariates.

Research context and participants

The participants comprised of 155 Grade 10 Thai students who studied in a high school located in Bangkok, Thailand. They were assessed on their scientific argumentation skills by a set of situational open-ended questions, each targeting all components of argumentation (claim, warrant, evidence, counter-argument, and supportive argument). In addition, they were also assessed on their reasoning ability and conceptual understanding of biological concepts related to the issues in the scientific argumentation test.

Our research was carried out in biology classes in the unit of Life and Environment, which allowed us to choose from a variety of socio-scientific issues. Class instruction spanned a total of 24 periods, with each period lasting 50 min in the first semester of the academic year, 2017 (May–July). As mentioned earlier, the fact that we used a revised form of the ADI model influenced our choice of the control group – we compared our results against a traditional (non-ADI) inquiry and discussion group, instead of a group based on the original ADI model.

The reason we could not compare our results directly with the latter was that it was impossible to carry out under the conditions and constraints of our classrooms. Since

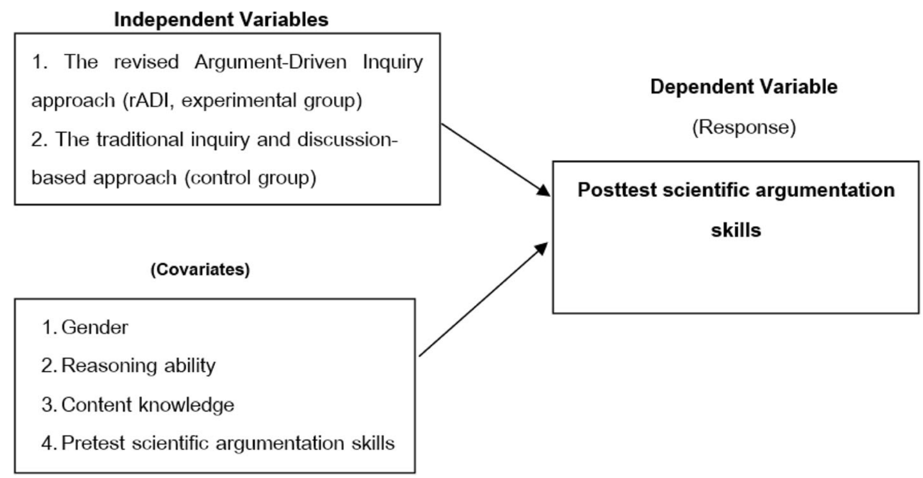

Fig. 1 Our analysis of covariance (ANCOVA) to compare the scientific argumentation score of two groups of students

the original ADI model could not be used, it also could not be used as a control group. Since the majority of Thai schools follow materials from the institute for the Promotion of Teaching Science and Technology, Thailand's Ministry of Education, which employ inquiry and discussion-based instructional approach, we consider this approach the most reasonable control group to use in our research.

Data collection and analysis

To help test the effectiveness of our teaching model, we assessed student abilities using 3 instruments: 1) the open-ended scientific argumentation test, 2) the reasoning ability test, 3) the content knowledge test (related to the life and environment learning unit of biology in this instance). In the following sections, we introduce the measurements used to evaluate students in these three areas.

Assessment of scientific argumentation skills

To assess the students' scientific argumentation, we use the approach by Lin and Mintzes (2010) and Seomsuk, Pitiporntapin, and Kovitvashi (2015). Our scientific argumentation test is divided into two parts: a scenario section addressing a socio-scientific issue and a

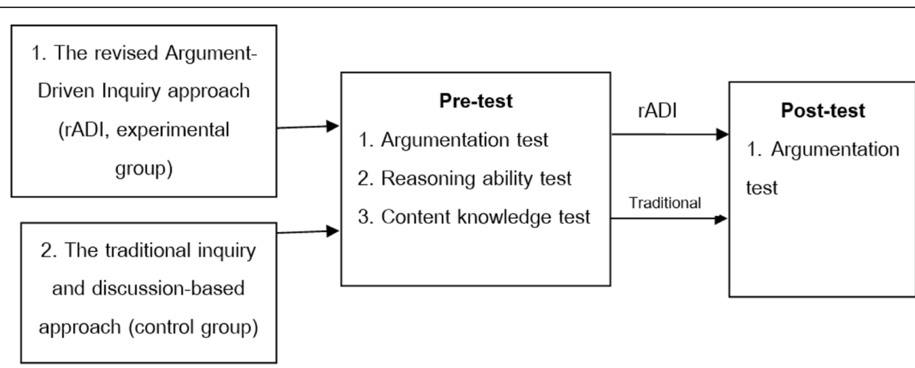

Fig. 2 Design for comparing pre-test/post-test groups after controlling covariates

question section containing four sub-questions measuring each element of scientific argumentation: claim, warrant, evidence, counter-argument, and supportive argument. We have ranked each element on four levels of quality: excellent (level 4), good (level 3), fair (level 2), and improve (level 1) using a scoring rubric in Table 7.

We analyzed the quantitative data by considering the frequency (means) of the overall number of students at each quality level.

Assessment of reasoning ability

In our context, reasoning ability pertains to a student's ability to think and reason logically and to solve problems they have not previously encountered. We have devised a pretest for reasoning ability using 5 categories: deductive reasoning, inductive reasoning, abductive reasoning, analogical reasoning and moral reasoning (Sawekngam, 2014). The test format was multiple choice, 25 questions, and last 30 min in total. Results are assigned one of 4 grades based on total points scored: Excellent (20–25 points); Good (14–19 points); Fair (8–13 points); Improvements needed (1–7 points).

Assessment of content knowledge

We conducted a pretest of student content knowledge in biology in the life and environment unit using the learning objectives of the core curriculum. This test was 30 questions, multiple choices, and 30 min in total. The possible grades for content knowledge were: Excellent (24–30 points); Good (17–23 points), Fair (10–16 points), Improvements needed (1–9 points).

Results

In this section, we present the results of the analysis in four parts as follows: 1) descriptive statistics, 2) analysis of change in argumentation skill, 3) correlation between factors, 4) analysis of covariance.

Descriptive statistics

In this section, we discuss statistics of gender and pre and post-instructional scientific argumentation skills (see Table 8). We have provided demographics of the subjects regarding the number of students by gender, instructional approaches. We employed two-group pretest/posttest research design to examine the effect of the instructional intervention on the whole and each elements of scientific argumentation controlling covariates.

From this table, 155 student subjects were evaluated in this research. Overall, there were more female students (63.9%) than male students (36.1%). The rADI group (experimental group) represented 46.5% of all subjects, which is comparable to the traditional inquiry group (control group), which represented 53.5% of subjects.

In this study, it was also important to measure students' pre- and post-test argumentation skills to be able to compare students' scores for those who participated in the rADI instructional course and those students who participated in traditional inquiry courses. Table 9 shows the mean levels of students' pre-and post-test scores for each element of argumentation skill, including students' usage of claims and warrants, evidence, counter arguments, and supportive arguments.

From this table, we found that after instruction, students in both the rADI and the traditional inquiry group improved their scientific argumentation scores. In

Table 7 Criteria used in rADI to evaluate student scientific argumentation skills

Qualities of scientific argumentation skills	Five elements of identifying scientific argumentation skills				
	Claim[a]	Warrant[a]	Evidence	Counter argument	Supportive argument
Excellent (4 points)	Make a claim with Excellent warrants	Give rational reasons to support a claim using 3 or more reasons	Provide scientific evidence to support their claim using 3 or more examples	Give a different claim and give credible reasons to support that claim using 3 or more reasons	Rebut the counter-argument using 3 or more valid reasons
Good (3 points)	Make a claim with Good warrants	Give rational reasons to support a claim using 1–2 reasons	Provide scientific evidence to support their claim using 1–2 examples	Give a different claim and give credible reasons to support that claim using 1–2 reasons	Rebut the counter-argument using 1–2 valid reasons
Fair (2 points)	Make a claim with Fair warrants	Give a reason based on emotions and feelings	Provide scientific evidence to support their claim but the evidence comes from emotions and feelings	Give a different claim but no reason to support that claim	Attempts to rebut the counter argument without using feelings, but the reasoning is poor
Improve (1 point)	Make a claim with no warrant Or	Give no reason or giving a reason that does not relate to the claim *Or*	No scientific evidence to support the claim *Or*	Not giving any different claim, and no reason *Or*	No attempt to rebut the counter argument *Or*
	Not making any claim	Give no reason	Provide evidence that does not support the claim.	Give a different claim but give unreasonable reasons which may involve emotions and feelings	Attempts to rebut the counter-argument based on emotions or feeling alone

[a]The elements "Claim" and "Warrant" are evaluated together, receiving up to 4 points for the pair
Student's argumentation performance in each socio-scientific issue or scenario is scored out of 16 points:
13–16 points = Excellent scientific argumentation skills
9–12 points = Good scientific argumentation skills
5–8 points = Fair scientific argumentation skills. The student should develop their skills further
1–4 points = Improvements much needed to develop scientific argumentation skills

Table 8 Number of students classified by gender and instructional approaches. ($n = 155$)

Instructional model	Number of classrooms	Sex		Total
		male	female	
rADI (experimental group)	2	24	48	72 (46.5%)
Traditional inquiry (control group)	2	32	51	83 (53.5%)
Total	4	56 (36.1%)	99 (63.9%)	155 (100.0%)

addition, while both groups showed no difference in initial scores, students in the rADI group achieved higher scientific argumentation scores in every element than students in the traditional inquiry group after instruction. During the learning session, the weakest element for both groups was the use of supportive arguments; students often had difficulty finding the valid reasons for their argument. Nonetheless, the student showed an improvement in this element under the rADI instructional model. These data suggested a generally larger improvement in student argumentation skills under the rADI instructional model compared to the traditional inquiry and discussion-based instructional model. In the next part, we analyze whether this difference in improvement was statistically significant.

Analysis of change in students' argumentation skills after instructions

We compared the means of scientific argumentation and its elements between the two groups using traditional inquiry and discussion-based approach using the independent t-test. First, we tested the equality of means between the two groups following hypotheses:

- H_0 = students who study under the rADI teaching method do not have different scientific argumentation skills from the students who study under the traditional inquiry and discussion-based teaching method
- H_1 = students who study under the rADI teaching method have different scientific argumentation skills from the students who study under the traditional inquiry and discussion -based teaching method

Table 9 Mean levels of students' pre-post test scientific argumentation skills ($n = 155$)

Instructional model		N (%)	$\overline{X}$ (%)	SD	$\overline{X}$ of argument elements (each scored out of 12 points)[b]			
					C_W	E	CA	SA
Pretest sci. argumentation skills (48 scores)[a]	rADI	72 (36.1%)	27.11 (56.25)	3.296	8.25	6.60	7.15	5.08
	Traditional inquiry	83 (63.9%)	26.82 (55.88)	2.927	8.40	6.40	7.10	4.93
Posttest sci. argumentation skills (48 scores)[a]	rADI	72 (36.1%)	31.76 (66.17)	2.651	9.56	7.58	8.26	6.36
	Traditional inquiry	83 (63.9%)	27.69 (57.69)	2.841	8.69	6.57	7.39	5.05

Definitions: *C_W* Claim and warrant, *E* Evidence, *CA* Counter argument, *SA* Supportive argument, *rADI* Revised-Argument-Driven Inquiry instructional model, *Traditional* Traditional inquiry and discussion-based instructional model

[a]There were 3 socio-scientific scenarios in this study, giving a total of 3 × 16 points = 48 maximum possible points per student over the course of the study

[b]Each element was up to 4 points per scenario; there were 3 scenarios, for 12 possible points per argumentation element over the course of the study

In Table 10, we share findings from an independent t-test analysis comparing students' pre- and post-test science argumentation skills after students participated in the rADI instruction and the traditional instruction courses.

As Table 10 above showed, we found no difference in students' pretest scientific argumentation skills between the experimental group (rADI) and the control group (Inquiry) at the 0.05 significance level. The null hypothesis H_0 could not be rejected for the pretest, suggesting uniform initial abilities across the student groups.

The posttest scores indicated a difference being formed between the two groups: the t-test for the equality of means was significant at the 0.01 level, whether equal variances between the two groups were assumed or not. Results of Levene's test confirmed a lack of significant difference in variances in student skill scores. As such, these data showed that the rADI teaching method produced a statistically significant improvement in mean post-instruction scientific argumentation skills compared to the traditional inquiry and discussion method.

Correlation between factors

To investigate potential covariates, we examined the correlation between these variables using SPSS 16.0 (Pearson's correlation and point biserial correlation) and Ranyon' correlation coefficient analysis criteria (1991). Specifically we wanted to identify any possible correlations between students' reasoning ability, content knowledge, pre-post test argumentation skills scores, and gender (Table 11).

From this table, we observe that the reasoning ability was positively correlated with content knowledge (0.271) at the significance level of 0.01; students who had more content knowledge also reasoned better than students who had lower content knowledge. However, a student's reasoning ability was not significantly correlated with their scientific argumentation skills; empirically, no correlation was found between reasoning ability and both pretest and posttest argumentation scores. In addition, we found that content knowledge (in the life and environment unit of biology) was not correlated with either pre- or post- argumentation test scores. Next we learned that the pretest scientific argumentation skills were positively correlated (0.335) with post-scientific argumentation skills at the significance level of

Table 10 independent t-test analyses of students' scientific argumentation skills ($n = 155$)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	SD	95% Confidence Interval of the Difference	
									Lower	Upper
Pretest sci. argumentation skills	Equal variances assumed	.669	.415	.584	153	.560	.292	.500	−.696	1.279
	Equal variances not assumed			.579	143.300	.563	.292	.504	−.704	1.288
Posttest sci. argumentation skills	Equal variances assumed	1.122	.291	9.191	153	.000	4.077	.444	3.201	4.954
	Equal variances not assumed			9.236	152.168	.000	4.077	.441	3.205	4.949

Table 11 Correlation between reasoning ability, content knowledge, pretest scientific argumentation skills, posttest scientific argumentation skills and gender ($n = 155$)

	Reasoning ability	Content knowledge	Pretest argumentation skills	Posttest Argumentation skills
Reasoning ability	1			
Content knowledge	.271[b]	1		
Pretest scientific argumentation skills	.047	.081	1	
Posttest scientific argumentation skills	.108	.067	.335[b]	1
Gender (point biserial correlation)	. 184[a]	.202[a]	.067	.093

[a]Correlation is significant at the 0.05 level (2-tails)
[b]Correlation is significant at the 0.01 level (2-tails)

0.01, indicating that students who had high scores in the argumentation pretest continued to have high scores in the posttest.

Interestingly, we found that gender was correlated with both reasoning ability (0.184) and content knowledge (0.202) at the statistical significance level of 0.05. Our pretest data suggested that female students had higher mean reasoning ability and content knowledge than male students. Gender was not, however, correlated with pre- or post- scientific argumentation scores. Since the only factor that was correlated with the posttest scientific argumentation test score was the pretest argumentation, we will consider the influence of pretest score on the posttest argumentation score in an analysis of covariance (ANCOVA) in the next part.

Analysis of covariance (ANCOVA) of posttest scientific argumentation skills

We conducted the analysis of covariance to examine the effect of the intervention on the outcome variable controlling covariates. Based on the previous correlational analysis, we trimmed the variables that have no or trivial relationship with the post-scientific argumentation skill scores from model including gender, reasoning ability, content knowledge. Table 12 shows a comparison of students' argumentation skills scores after controlling the covariate.

After controlling for the only covariate – the pretest scientific argumentation skills – results showed that different instructional styles still had significantly different effects on students' scientific argumentation skills, (F1, 152) = 93.425, $p < 0.05$. This demonstrated the capability of the rADI to improve students' scientific argumentation skills beyond the conventional discussion and inquiry approach. The adjusted R square showed that the instructional models and the pretest argumentation scores explained about 44% of the total variation in student posttest scores.

Table 12 Comparison of students' posttest scientific argumentation skills after controlling the covariate (pretest scientific argumentation skills) ($n = 155$)

	Type III Sum of Squares	df	Mean Square	*F*	Sig.
Different instructional models	608.715	1	608.715	93.425	.000
Pretest scientific argumentation skills	170.484	1	170.484	26.166	.000
Error	990.357	152	6.516		

R Squared = .450 (Adjusted *R* Squared = .443)

Conclusions and discussions

The objective of this research, we reconsidered a model to teach scientific argument and proposed a revised model that responds to the need and more practical in enhancing students' scientific argumentation skills called revised Argument-Driven Inquiry (rADI). In addition, we also study correlation between gender, reasoning ability, and knowledge in the content of science, existing scientific argumentation on post-instruction scientific argumentation and examined the effect of the intervention on gained scientific argumentation after controlling covariates.

Overall, we found that most students in the sample were able to develop or improve scientific argumentation skills in most elements of argumentation after receiving instruction based on the rADI model, although students tended to be weaker in the supportive argument element. In addition, we found that gender, reasoning ability, and content knowledge were not correlated the gained scientific argumentation skills. Finally, we learned that the students taught by rADI instructional model outperformed their counterparts taught by a traditional inquiry and discussion-based approach after controlling covariates.

Discussions

Based on the findings that we have summarized above, we found that most students in the sample were able to develop or improve scientific argumentation skills in most elements of argumentation after receiving instruction based on the rADI model, although students tended to be weaker in the supportive argument element. Both rADI and traditional instructional models produced an overall improvement in student argumentation scores, with rADI producing consistently higher scores than the traditional method. Students exhibited positive learning results in becoming more familiar with the argumentative elements of the claim, warrant, evidence, and counter-argument. The weakest element for both groups of students was the supportive argument (SA in Table 9). Following the traditional teaching method, students had improved their overall argumentation score by about 2% (from 55.88% to 57.69%) and their use of supportive arguments by about 1% (from 41.08% to 42.08%). In comparison, under the rADI method, students had improved their overall score by about 10% (from 56.25% to 66.17%) and their supportive argument skill by about 11% (from 42.33% to 53.00%). These numbers imply that, as a ratio of the old scores, overall score had improved by about 3% under the traditional method but had improved by about 18% under the rADI method, while the weakest element improved by about 2% under the traditional method but had improved by about 25% under the rADI method.

We found that one of the main challenges faced by the students was in choosing reliable academic sources to support their claims, which made it difficult for others to accept their claims, despite the promotion of a collaborative atmosphere. This finding is consistent with Bell (2004), who promoted cooperative debates in the science classroom on various issues. Bell found that the students struggled to choose and make use of correct data to support their claims and rebut counter-arguments. Furthermore, those students often insisted on their initial claims even in the face of data contrary to those claims (Evagorou, Jimenez-Aleixandre, & Osborne, 2012).

In some studies, the argumentative process itself proved difficult in the science classroom because the instructor had not seriously supported the process, despite the important role of the instructor in facilitating an effective exchange of reasoning and evidence for the sake of collaborative learning. Although the argument arises in the science class, the students still felt that it was difficult to learn to argue from the activities (Newton et al., 1999). In our view, the use of more interesting and relevant topics such as contemporary socio-scientific issues may improve the level of participation by both instructors and the students. Controversial topics may prove to be more beneficial than agreeable topics in this context of education.

Our research has shown that most Thai students exhibit difficulty with arguing in accordance with the elements of scientific argumentation. While this result is similar to findings of studies focusing on other groups of students, certain environmental factors such as the context of Thai society and culture should be considered in discussing some our results – the Thai society is one in which subtlety is emphasized in interpersonal interactions. Thai people generally avoid overt criticism of others and refrain from engaging in conflicts directly. Thai students are taught to be subordinate to those who have seniority in terms of age or job position. These are pervasive social factors that affect the pattern of conversation and discussion in Thailand, including the expression of opinions between a student and other students, as well as between a student and his or her teacher. These cultural patterns are such that Thai science students often avoid offering a direct critique of different perspectives or even suggesting unique ideas during discussion and argumentation sessions. As such, certain instructional styles may be more suitable for this environment, including the use of groups in place of individuals during the argumentation process and promoting an atmosphere that encourages the free exchange of ideas.

To these ends, we used the rADI instructional model to stimulate students' courage to express their creative ideas in the class environment, instead of being held back or intimidated by the idea of conformity or authority.

Impact of gender on argumentative learning

In our experiment, the female students had the higher mean score on both reasoning ability and content knowledge than the male students as a whole; the females demonstrated better logical thinking and were better at expressing their own reasoning. Our results were consistent with our data from observing classes during argumentative learning activities. When it was their turn to bring their group claims to other groups in class, the male students tended to avoid sharing their claims as the teacher expected them to do. Instead, the males engaged in passive behavior such as whispering or signaling female members of the group to speak on their behalf to communicate the ideas to outside groups.

These results showed that female students in our sample generally had more courage to express their opinion than the males, especially in front of unfamiliar people. The male students appeared unconfident and unconvinced of the strength of own arguments; they appear preoccupied with the possibility that others may attack their ideas. An image emerged in our classrooms where females turned out to be the dominant gender that shaped the direction of intellectual discourse as well as taking on more responsibilities in class generally. This was similar to certain prior research, which suggested that gender difference affects reasoning, logical thinking and the process of understanding content knowledge (Belenky, Clinchy, Goldberger, & Tarule, 1986; Zohar, 2006). Miller (2005) suggested that females tend to pay more attention to the details of the information they receive. They had a more thorough analysis of data and expressed their knowledge more clearly than the males did. In addition, Costa, Terracciano, and McCrae (2001) found that females were more capable than males at changing their own opinions after learning reliable new evidence; the males, in contrast, were more likely to be confirmed in their original beliefs and claims despite having received new contradictory information. Instead of admitting their own mistakes, males were more likely to find various reasons to help their own initial claim stronger. Solving this gender gap problem will involve the promotion of equality in the expression of ideas.

Not all studies, however, found a difference between the genders in terms of either reasoning ability or understanding of content knowledge. Pholyeiym, Suksri-ngam, Parakan, and Suksri-ngam (2013) studied the arguments and critical thinking ability of Grade 10 students after learning socio-scientific issues. The female and male students in that study showed no difference in critical thinking scores in terms of inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. Furthermore, even if one gender (or some other sub-group) exhibited superior reasoning ability or content knowledge, those traits alone may not actually guarantee superior scientific argumentation ability – while reasoning ability and content knowledge are ingredients of scientific argumentation, a powerful scientific argument involves more than reasoning ability or content knowledge alone. This idea is consistent with our empirical results: while students with more content knowledge also tended to have better reasoning skills in our sample, neither reasoning ability nor content knowledge actually correlated with argumentation ability scores in live class scenarios.

Impact of introduction on argumentation skills

Before our instruction, students in the rADI group and the traditional inquiry group had statistically similar levels of scientific argumentation skills, but the level of skills of the groups diverged after the instructions; students in the rADI group achieved higher scientific argumentation skills than students in the traditional group. This apparent benefit of an argument-driven approach was consistent with the findings of Sampson et al. (2010), who studied the quality of students' argumentative writing by comparing the quality of the writing before and after 18 weeks of instruction. They found that students were able to create better writing afterward. Evagorou and Osborne (2013) explored student argumentation ability in two groups, with one group using teaching that supported argument through socio-scientific issues and another group that used regular teaching style. They then observed the argument process within the groups and from their argumentative writings. Their findings showed that students in the group that utilized socio-scientific issues had higher writing scores than students in another group.

Spaced repetition is a possible explanation for the fact that students receiving the rADI instruction had obtained higher argumentation scores: this teaching method teaches the students to express their opinions through writing multiple times. In each instance of writing, students receive comments and suggestions from peers and the instructor. In turn, each individual will have the opportunity to adjust his or her thinking through writing again. This writing strategy allows the students time to absorb and evaluate the information carefully before writing, and they will have enough time to correct their incorrect ideas via this reporting format.

Scientific argumentation is a dynamic, scholarly process that involves multiple elements, which encompass areas such as the ability to identify correct evidence, the mental capacity to acknowledge counter-arguments and the capability of rebutting them reasonably. Our data suggest that, far from being an exclusive domain of those with the strongest logical ability, the highest prior knowledge or even a predetermined gender, scientific argumentation is a distinct skill, which can be taught. We have shown that the teaching style matters in the instruction of scientific argumentation. With good approaches, students can significantly improve their ability to make proper scientific arguments. and implicit correction.

Implications

The result of this study offer many important implications for the implementation of argumentation instructional strategies that have been developed with attention paid to the educational contexts. Observing the students' learning behavior during discussions of controversial socio-scientific issues, it was found that females appeared to have more courage to express opinions and attitudes than males who often did not dare to express their own thoughts with others. Regardless of whether females or males happen to be leading a class, these findings are so essential to classroom practice in Thai context that the instructor should encourage a fun and safe learning atmosphere for all students to learn together, so that they may feel comfortable and safe enough to contribute to conversations as a class. Instructors can do so by promoting an equal role in argument sessions, encouraging each student to express their opinions objectively and courageously.

In addition, the rADI teaching demonstrated a greater impact on the development of students' scientific argumentation skills than the traditional inquiry and discussion setting. For the educational policy, we would like to propose this result to the educational institutions involved in educational management to consider this instructional style in science courses and provide teachers the training necessary to develop students' scientific argumentation skills line with learning in the twenty-first century, an era when students must possess analytical skills and insight in decision making and problem-solving. These requirements offer excellent opportunities for science teachers to develop their own knowledge of teaching skills and techniques.

Finally, the selection of socio-scientific issues appears to be highly important to students' learning experience during argumentation. Therefore, instructors can choose a situation that students are familiar with or have personal knowledge about. The content should be understandable at the students' level of knowledge, yet have no obvious conclusion so as to encourage class discussion. On the other hand, differences in the topic's level of familiarity may be useful for further research on student engagement.

Implications for continued further research

To extend on this work in the future, researchers could analyze the type of socio-scientific issues being used different topics affect the expression of students' scientific arguments. Instructors can introduce diverse situations and topics, such as those that students are intimately familiar with. For example, topics could include those that are far removed from students' daily life, those that affect emotions and feelings at a personal level, and those that require different levels of knowledge in science. Additionally, further studies can be done on the influence of gender on argumentation activities. This can be done by implementing and comparing all female groups, all male groups, equal male-female groups, and groups with significantly different ratios of males to females. And Different types of argumentative writing can be assessed for their effectiveness in teaching efficient argumentation.

Abbreviations
ADI: Argument-Driven Inquiry; C_W: Claim and warrant (Table 6); CA: Counter argument (Table 6); E: Evidence (Table 6); rADI: Revised-Argument-Driven Inquiry instructional model; SA: Supportive argument (Table 6); SSI: Socio-scientific issue

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Authors' contributions
WS and PP analyzed and synthesized the key features for teaching argument-driven inquiry and created the revised ADI model (rADI) and analyzed the results of the study. BB assisted in reviewing socio-scientific issues related to content about life and the environment. AC edited the criteria used to measure and evaluate scientific argumentation skills and edited this manuscript for clarity. All authors read and approved the final manuscript.

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