Argument-driven inquiry instruction to facilitate scientific reasoning of 11th grade students in light and visual instrument topic

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Abstract. Scientific reasoning is one of the most important processes for developing scientific knowledge and also one of the skills required for students to handle open ended real world tasks in their future career. This research aims to develop the scientific reasoning of 11th grade students through argument driven inquiry instruction (ADI) in the topic of light and visual instrument. The participants were 24 11th grade science emphasized program students. They were selected by purposive sampling. Research instruments were comprised of Lawson’s Classroom Test of Scientific Reasoning (LCTSR) and student reports. The data were analysed by using qualitative data analysis and quantitative data analysis, which were content analysis, mean and percentage. The student’s scientific reasoning measured by the pre and post LCTSR improved from 11 to 48 percentages. The results from student reports indicated 42 percentages of participants had good scientific reasoning. The argument processes, both verbal and written, are keys to practice and develop student’s scientific reasoning.

1. Introduction

Scientific reasoning is a vital aspect of international science education standards and be necessary skill that scientist use in their scientific inquiry process [1,2]. Scientist use scientific reasoning skill to construct claims base on observed evidence that be justified how implicate with the claim [3,4]. Similar to scientist’s work, students in science classroom need to develop in both specialized knowledge and scientific reasoning in order to successfully handle real-world tasks in future careers [5,6]. Scientific reasoning has a direct impact on student learning conceptual knowledge in order to understand how science knowledge was generated and tested and promote plenty aspects of relationship between theory and evidence [7,8].

However, despite the importance of scientific reasoning, students in Thailand still lack of this skill. Scientific reasoning was examined in Trends in International Mathematics and Science Study (TIMSS) as one domain in cognitive domain of science achievement. The result of TIMSS 2015 revealed that the average scale score of Thai students in reasoning domain was categorized into intermediate international benchmark (447) which is indicated that the reasoning skill of Thai students was significantly lower than the students in other countries [9]. In addition, there are some research’s findings that correspond to TIMSS result [2,10,11]. Several studies revealed that Thai students know
importance role of evidence in order to support their explanations, but could not identify the proper evidences [10,11]. Another study identified that students made incorrect claims and/or reasons; some of them did not use evidences for make claims and/or reasons; another could not justify relevant between claims and evidence [2]. In order to understand deeply about the problem of Thai students’ scientific reasoning, the author of this study did an investigation on studying scientific reasoning of 34 eleventh grade students by analyzing students’ report of their experiment “making giant bubble”. Students were required to explain which ingredients were appropriate to make bigger bubble and how that ingredients affect bubble’s physical properties. The results of study showed that most of them (74 percent) could make claim to explain which ingredient could make bubble bigger, but they could not justify reason how it affected the bubble’s physical properties. Some of them (20 percent) could not give reasoning correctly because they could not identify of proper evidence.

Argument-driven inquiry instruction (ADI), combination of inquiry-based learning and scientific argumentation, provide an opportunity for students to use, practice and develop their scientific reasoning skill [12]. ADI was first introduced in 2005 with purpose of developing necessary inquiry skills and engaging students to explain with scientific reasoning [13]. During this instruction, students have to carry out an investigation and use their scientific reasoning to analyze, conclude, and develop an initial argument, and then they have to share and argue about their inquiry results with their classmates. After that, they have to use scientific reasoning in order to create their own report. Finally, they are required to review other students’ report in order to verify other scientific reasoning and then each student revise feedback from their classmates who against their scientific reasoning [14,15].

Based on problems mentioned before, it is urgent to develop scientific reasoning of Thai students. The ADI instruction has potential to develop scientific reasoning [6,15,16,17]. Yet, the literature seems void of studies reporting on the effect of ADI on students’ scientific reasoning skills in Thailand. Therefore, the main purpose of this study is to examine the effect of ADI instruction on improving student’s scientific reasoning.

2. Method

2.1. Research design and participant
This research methodology employed in this study was action research with three learning cycles. Each cycle lasted 4 hours.

Participants, whom were selected by purposive sampling, were 24 eleventh grade students in science emphasized program comprising one female and twenty-three male students who enrolled in physic subject in 2017 academic year. None of students had ever learned with ADI lesson prior to participate in this study.

2.2. Argument driven inquiry instruction
All participants of this study were taught through Argument Driven Inquiry instruction. The detail of ADI instruction was described as following [18]. First, the instructor identified a situation to investigate. The situations that were used in this study covered three topics: light and shadow, color and visibility, and thin lens. In cycle one, students were required to investigate a variable that affect shadow of thing. In cycle two, students had to observe type and color of lens that is the most suitable for making sunglasses. In cycle three, students had to find out which type and sequence of two thin lenses was appropriate to create CCTV. Second, each group of 4-6 students had to design experimental procedure and carried out their investigation, then made an initial argument from the observed evidence. After that, they had to argue with their classmates in detail of claims, evidence, reasoning and data collection process. Next, the instructor would lead reflective discussion about the concepts that students mention in previous session to correct misunderstanding by using their investigated data. Then, each student wrote an investigation report that represented his or her final argument and then reviewed their classmates’ investigation reports in order to ensure quality and to
provide their classmates with the feedback for improving the reports. Finally, students used the feedback from the peer review to revise their reports then they had to submit the revised report to the instructor for a final evaluation.

2.3. Research instrument
In order to investigate students’ scientific reasoning which was defined as a skill to construct claims base on observed evidence that be justified how implicate with the claim, the Lawson’s Classroom Test of Scientific Reasoning (LCTSR) and student investigation reports were used.

The researcher adapted Lawson’s Classroom Test of Scientific Reasoning (LCTSR) [19] to use in this study. The test was in a form of pencil-and-paper based two tier tests. The first-tier was content-based multiple-choice question and the second-tier was an open-ended question that require student to identify the evidence and explain the reason they used to answer question in the first-tier. This test consisted of six items focusing on light and visual instruments topic: which light and shadow for item 1 and 2, colour and visibility for item 3 and 4, and thin lens for item 5 and 6.

Another research instrument was a student investigation report, which was used to reveal each aspect of scientific reasoning components. The students were asked to write an investigation report at the end of each cycle. The main component of an investigation report comprised of guiding question, research methodology, observed data, claims, evidence and scientific reasoning.

2.4. Data collection and analysis
The LCTSR was used to investigate students’ scientific reasoning before and after learning with ADI lessons. All students took the test for one hour prior to the first cycle and after the third cycle. The LCTSR for the pre-test and post-test were the same. After that, the researcher as an instructor of the lesson employed ADI instruction for three learning cycles. During the instruction of each cycle, each student was assigned to do an investigation report and submit the final reports to the instructor at the end of each cycle.

The data from LCTSR was analyzed through the following steps. First, the researchers check student first-tier answer, if student did not choose a correct answer, then their answer will be justified as incorrect claim. If students choose a correct answer in the first-tier then the researchers would continue to analyze the second tier of that item. The researchers read all written answers in the second tier and then categorized them into 4 levels; level 1: incorrect claim or not construct claim, level 2: correct construct claim but not identify evidences, level 3: correct claim and identify evidence but not justify relevant, and level 4: correct claim, identify evidence and justify relevant. Lastly, researchers calculated the number of students’ answer in each level into percentage.

The data from an investigation report were analyzed using the criteria as shown in Table 1. The researchers read each report and used the criteria to examine level of each scientific component: claim, evidence and justification.

| Level   | Criteria                        | Justification                                      |
|---------|---------------------------------|----------------------------------------------------|
| Good    | Claim correspond with guiding question in all aspects | Evidence can support claim                          |
|         |                                 | Justify all aspects of relevant between claim and evidence |
| Intermediate | Claim correspond with guiding question in some aspects | Evidence can't support claim in some aspects     |
|         |                                 | Justify some aspects of relevant between claim and evidence |
| Poor    | Claim not correspond with guiding question | Evidence can't support claim                       |
|         |                                 | Not justify relevant between claim and evidence    |
3. Result and discussion

3.1. Scientific reasoning before and after ADI instruction

The student answers from six items of LCTSR pre-test and post-test were categorized into four levels. Figure 1 and 2 shows the percentage of students’ scientific reasoning level before and after study with ADI lesson. Each bar graph represents the percentage of student answer at each level and the different colors in each bar graph indicate the portion of answer percentage of each item.

![Figure 1. Graph show percentage of answer in each level form pre-test LCTSR.](image)

![Figure 2. Graph show percentage of answer in each level form post-test LCTSR.](image)

Most students had scientific reasoning at low level before ADI instruction. The majority of the students were at level 1 and 2 (47 percent) which indicate fault in creating claim. The students’ scientific reasoning before learning through ADI instruction inclines to be at low level. According to figure 1, before study through ADI, most of students’ answers were categorized to be at level 3 (42 percent) because they could explain about the theory they used but could not clarify how it relate with claim and situation. Only 11 percent of students’ answers were categorized to be at level 4. The highest portion of level 4 is answer in item 4 that was about lens.

The students had significantly changes of their scientific reasoning after ADI instruction. After student learned through ADI, they were able to construct better scientific reasoning as represented in figure 2. It can be seen from percentage of scientific reasoning level in pre-test and post-test has considerably shifted from level 1 and level 2 to level 3 and level 4. The most of answers (90 percent) are in level 3 and level 4 that are considered as high levels of scientific reasoning, while a little of answers (10 percent) left in level 2. At this level, they could not identify evidences to support the reason why a shadow from one light source has shape as they thought in item 1 and they could not explain the theory related to lens and compound lens in item 3 and item 4 respectively. Considering at level 4, students had improved their scientific reasoning the most in item 5 (66 percent increased), while the lowest is in item 2 as student could explain shape of the shadow from various sources and why it had more than one shadow but could not explain why the middle one is the darkest.

3.2. Scientific reasoning during ADI instruction

The analysis of investigation reports during ADI instruction revealed that scientific reasoning skill of the students had developed continuously from cycle 1 to cycle 3 as shown in figure 3, 4, and 5 respectively.
After learning through ADI in cycle 1, students created quite good scientific component level as represented in figure 3. The graph shows that none of students create poor claims, while most of them (58 percent) created intermediate claim since their claims explained only shape of the shadow but were not correspond to all aspect of guiding question. For quality of evidence, most students (50 percent) created intermediate evidence as they could identify data that measure size of shadow at fixed distance screen. The evidence could support their explanations of the difference of shadow properties only in shape aspect, but they did not have evidence to support claim in intensity aspect. In addition, the students created intermediate justification (71 percent) the most as they could describe the difference between distance of source and object or object and screen that affected the size of shadow, but they could not describe how their data could explain about umbra and penumbra).

During cycle 2, students’ scientific reasoning component significantly improves from cycle 1 as revealed in figure 4. Most of them (92 percent) created good claim as they could explain the effect of lens type on image and the effect of color on visibility that correspond with guiding question. Moreover, the rest (8 percent) forgot to answer one of their variables mentioned in guiding question. The highest percentage of evidence aspect (75 percent) is good level as students managed to measure wavelength from light passed colored lens to answer effect of color to visibility and study images from convex and concave lens at various ranges. Some of them (4 percent) only used theory of light trajectories to explain which type of lens is the best for sunglasses making. In justification aspect, the highest percentage (63 percent) is good level as students explained that lens type was not affect sunglasses making, but the different color of lens could reflect and transparent difference color that affect to visibility.

The student scientific reasoning component in cycle 3 has good progression as shown in figure 5. None of students created any scientific reasoning components at poor level. All students could improve quality of claim creating to good level, as they were able to answer which type and sequence of lens should use to make CCTV in order to get widest angle and/or highest resolution. For evidence aspect, the highest percentage (88 percent) is good level as student examine views of image form each pattern of compound lens and area size in image. Moreover, in the justification aspect, the most students (58 percent) create good justification while the rest (42 percent) create intermediate justification, as they cannot explain how resolution they got form views of image.

During 3 cycle of ADI learning management student showed their development in all aspect of three vital components of scientific reasoning. Students who were in poor and intermediate level is continue decreasing in each cycle except form cycle 2 to cycle 3 that percentage of intermediate justification has increased. None of them created poor claim from beginning to the end.

3.3. Discussion
Student had improved scientific reasoning through argument-driven inquiry approach in all aspect of vital component. The highest improvement in scientific reasoning component is claim constructing since students have to make a claim correspond with their own guiding question. Student also learned...
to ask provable guiding question that they could design and carry out investigation to find the answer. For overall aspects, student scientific reasoning increased because during learning cycle they had many opportunities to construct their scientific explanation and reflected on the other scientific reasoning through argumentation and report reviewing. Similar to several studies, the ADI instruction are able to promote the development of scientific reasoning by addressing inquiry in a systematic and comprehensive [16,17,20]. After taught by argument-driven inquiry approach, students was trained to be able to explain scientific phenomenal or event based on supported theory or evidence and also clarify relevant of theory or evidence to their explanation [15,18]. Scientific reasoning of students improved since they recognize importance and role of components of scientific reasoning in scientific process in order to construct explanations and express them to other [20].

4. Conclusion
Learning through argument-driven inquiry has a significant effect on the improvement of student’s scientific reasoning in light and visual instrument topic. Students’ scientific reasoning improved continuously over time while the major change happened between cycle one and two. Claim constructing was improved the most among all aspects of scientific reasoning components.

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