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Research article

The attitudes of teachers of rural areas towards the state of learning materials, school curriculum, simulation software, and argument-based inquiry activity to enhance middle school students' scientific reasoning ability

ทัศนคติของครูในเขตชนบทที่มีต่อสภาพของสื่อการเรียนรู้ หลักสูตรสถานศึกษา ซอฟต์แวร์สถานการณ์จำลอง และกิจกรรมการสืบสอบที่ใช้การโต้แย้งเป็นฐาน ที่ส่งเสริมความสามารถในการให้เหตุผลเชิงวิทยาศาสตร์ของนักเรียนระดับชั้นมัธยมศึกษาตอนต้น

Jettnipith Thantong[1*] Jaitip Na-Songkhla[2] Pornsook Tantrarungroj[3]

เจตนิพิฐ แท่นทอง[1]* ใจทิพย์ ณ สงขลา[2] พรสุข ตันตระรุ่งโรจน์[3]

[*1,2,3] Department of Educational Technology and Communications, Faculty of Education, Chulalongkorn University.
254 Phayathai Rd. Wangmai Patumwan Bangkok 10330 Thailand
[*1,2,3] ภาควิชาเทคโนโลยีและสื่อสารการศึกษา คณะครุศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
254 ถนนพญาไท แขวง วังใหม่ เขตปทุมวัน กรุงเทพมหานคร 10330
*Corresponding author. Email: jett.bioteacher@gmail.com

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Abstract

This study aimed to investigate the attitude of rural teachers towards the problem in the current state of learning materials, school curriculum, simulation software, and argument-based inquiry activity for enhancing middle school's scientific reasoning ability. The survey research method was used in this study, and data were collected from 42 small, medium, large, and extra-large schools in Sisaket province (northeastern of Thailand) using 105 questionnaires. The research findings reveal that the analysis of descriptive statistics and PNI_{mod} showed that the essential features of simulation, which could be improved, were displaying a relationship between multivariable, feedback, and result. Likewise, the argument-based inquiry could be empowered with an emphasis on evidence or question-based evidence, presentation of evidence supporting the claim, presentation of a counter-argument, a stipulation of a conflict of arguments, and use of mathematics, information, information technologies, or computational thinking.

Keywords: scientific reasoning; simulation software; argument-based inquiry; rural teachers

บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อศึกษาทัศนะของครูในโรงเรียนเขตชนบทที่มีต่อสภาพปัจจุบันของสื่อการเรียนรู้ หลักสูตรสถานศึกษา ซอฟต์แวร์สถานการณ์จำลอง และกิจกรรมการสืบสอบที่ใช้การโต้แย้งเป็นฐาน ที่ส่งเสริมความสามารถในการให้เหตุผลเชิงวิทยาศาสตร์ของนักเรียน การวิจัยเชิงสำรวจถูกนำมาใช้ในการดำเนินการศึกษาและเก็บรวบรวมข้อมูลจาก 42 โรงเรียน ทั้งโรงเรียนขนาดเล็ก ขนาดกลาง ขนาดใหญ่และขนาดใหญ่พิเศษ ในจังหวัดศรีสะเกษ (ภาคตะวันออกเฉียงเหนือของประเทศไทย) โดยใช้แบบสอบถามจำนวน 105 ฉบับ ผลการวิจัยพบว่าจากการวิเคราะห์สถิติเชิงพรรณนา และดัชนีจัดเรียงลำดับความสำคัญของความต้องการจำเป็น แสดงให้เห็นว่าลักษณะของสถานการณ์จำลองที่ต้องถูกพัฒนาให้ดียิ่งขึ้น คือ การแสดงความสัมพันธ์ระหว่างตัวแปรเชิงพหุ การให้ข้อมูลย้อนกลับ และผลลัพธ์ นอกจากนี้ลักษณะของการสืบสอบที่ใช้การโต้แย้งเป็นฐานที่ต้องถูกพัฒนาให้ดียิ่งขึ้น ได้แก่ การให้ผู้เรียนเน้นประจักษ์พยาน หรือประจักษ์พยานของคำถาม การนำเสนอประจักษ์พยานเพื่อสนับสนุนข้อกล่าวอ้าง การนำเสนอข้อโต้แย้งของข้อกล่าวอ้าง การกำหนดเงื่อนไขของข้อขัดแย้งในการโต้แย้ง และการใช้คณิตศาสตร์ สารสนเทศ เทคโนโลยีสารสนเทศ หรือการใช้การคิดเชิงคำนวณให้มากขึ้นในกิจกรรมสืบสอบ

คำสำคัญ: การให้เหตุผลเชิงวิทยาศาสตร์ ซอฟต์แวร์สถานการณ์จำลอง การสืบสอบโดยใช้การโต้แย้งเป็นฐาน ครูในชนบท

Introduction

Scientific reasoning was defined as “the reasoning and problem-solving skills involved in generating, testing and revising hypotheses or theories” (Köksal-Tuncer & Sodian, 2018). Scientific reasoning involves the thinking that leads to proof and judges with an emerging scientific reason. Scientific reasoning can be the thinking tools for specific explanations and considerations about an evidence-based intervention influential to a situation via systematic hypothesizing and testing (Bolduc, 2014; Dennis, Dorsey, & Gitlow, 2015; Mayer, Sodian, Koerber, & Schwippert, 2014). It is personal thinking to link a cause and result by using emerging evidence from investigation or experimentation leading towards assumption. Scientific reasoning consists of hypothesizing, controlling, and designing experiments (Mayer et al., 2014). Scientific reasoning is needed, not only with scientists, but in other occupations, i.e. physiologist, engineer, architecture, urban planner, or occupational therapist (Thuneberg, Hautamäki, & Hotulainen, 2014). Moreover, it has a relationship with learner's intelligence, reading comprehension, spatial ability, and problem-solving skill (Mayer et al., 2014). Furthermore, it has been used to measure scientific literacy in PISA assessment (Thuneberg et al., 2014).

The report of the PISA 2015 assessment result of scientific literacy shows that the OECD average is 493 points among 57 participated countries. Thailand's average is 421 points. Thailand ranks 41st amongst the countries (OECD, 2016). Based on the PISA report in Thailand, the main issue is that a student is not performing well on a scientific literacy test. Therefore, we can suppose that scientific reasoning score in Thailand is below international levels among participating countries.

Though, recent studies have shown instructional approaches that can advocate student's scientific reasoning. For example, inquiry-based learning (Gillies, Nichols, Burgh, & Haynes, 2014), theory-based learning (Hoban & Nielsen, 2014), and argumentation-based guided inquiry course (Acar, 2014a, 2014b). Whilst It is challenging to implement a seminar that can educate and convince teachers across the country to change their conventional teaching methods. Therefore, to consider modern technologies as an alternative teaching method, which has similar efficiency to the excellent teaching method, the economic cost is considered to be lower than the conventional teaching method.

The last decade**,** studies reveal emerging technologies that can promote learner's scientific reasoning. The Simulation software (Zhu, Liu, & Lee, 2020) and simulation video (Kant, Scheiter, & Oschatz, 2017; Lazonder, Hagemans, & Jong, 2010; Psycharis, 2013; Zhu et al., 2020) are effective technologies for improving students' scientific reasoning. Because the simulation is a technology that students can send input and receive instant feedback (Zhu et al., 2020); therefore, scientific phenomena will be investigated in real-time.

Although many research studies show the effectiveness of simulation and argument-based inquiry, few studies describe how a Thai teacher thought about the limitation of these implementation with the learning materials and school curriculum activities.

The objectives

This study aimed to investigate teachers' attitudes towards the problem in the current state of learning materials, school curriculum, simulation program, and argument-based inquiry activity for enhancing middle school's scientific reasoning ability in rural schools located in Sisaket province (northeastern of Thailand).

Related Works

1. Scientific Reasoning

A person who has scientific reasoning could generate a hypothesis, test hypothesis systematically through experimentation, test the hypothesis's feasibility, and generate a new hypothesis when the previous hypothesis was rejected (Mayer et al., 2014). Scientific reasoning comprises of content free reasoning ability. However, it depends on student development. Reasoning skill is part of scientific reasoning (Acar, 2014b). Interestingly, the previous study showed that presenting video modeling examples in a simulation-based inquiry learning environment can enhance a student's scientific reasoning (Kant et al., 2017). It is crucial evidence that real world experiments are unnecessary for enhancing scientific reasoning.

2. Simulation as Learning Materials

Simulation is the dynamic nature of the system process and the obvious mathematical structure computationally driven (Vallverdú, 2014). The objective of each scientific computer simulation is the same: to predict some behavior of the physical universe accurately (Kaizer, Heller, & Oberkampf, 2015). The prior study revealed that simulation in chemistry has equal learning benefits to real experiments (Zendler & Greiner, 2020). Moreover, it also enhances learner's cognitive processes and inquiry skills (Efstathiou et al., 2018). It is quite apparent that simulation is a reasonable learning material for enhancing a student’s scientific reasoning. However, it is difficult to claim that all of the simulation software available will have sufficient benefits for students’ learning, especially scientific reasoning. This study will reveal the deficient features of simulation from a rural teacher’s aspect.

3. Scientific Argumentation

Scientific argumentation involves two parts. The first part is to create an evidence-based claim about a scientific question by adhering to the scientific knowledge and scientific processes. The second part is to join the boundaries of the claim’s application by inspecting the limitations of investigations, where evidence is obtained (Zhu et al., 2020). As inspired by Psycharis (2013) argument framework can be divided into five levels as follows.

Level 1: Argumentation was comprised of conflict between simple argument and counter-argument.

Level 2: Argumentation was comprised of conflict between argument and evidence supported argument. But it has no demur.

Level 3: Argumentation was comprised of a set of arguments and data-rich counter-argument, reasonable explanation, or appropriate evidence. But it has insufficient firmness.

Level 4: Argumentation was comprised of an argument with a clear conflict declaration. Moreover, it has many arguments and counter-argument.

Level 5: Argumentation that shows greater than one counter-argument and leads to the next argumentation.

4. Scientific Inquiry

Scientific inquiry is seen as central to science education as an entirety (Hsu, Chiu, Lin, & Wang, 2015). According to Weber et al. (2013), Scientific inquiry comprises of 8 features as follows.

1. Asking questions, defining the problem.
2. Developing, using Models.
3. Planning, doing investigations.
4. Analyzing, interpreting data.
5. Using math, information/computer technology, computational thinking.
6. Constructing explanation, designing solutions.
7. Arguing from evidence.
8. Obtaining, evaluating, communicating information.

Previous research indicates that argument-based inquiry as a learning environment can enhance scientific reasoning (Acar, 2014b). Therefore, scientific inquiry should be collected to strengthen scientific reasoning.

5. Argument-Based Inquiry

In this study, the argument-based inquiry was combined from argument strategy and scientific inquiry. Firstly, argumentation is a model of reasoning based on creating and comparing the arguments (source). Argumentation is the cooperation of evidence and theory that support or argue the inference, model, or prediction (De La Paz, Ferretti, Wissinger, Yee, & MacArthur, 2012). It is a formulation of complex inference unable to be generated from definition or description (source). The argument strategy includes learners 1) able to links propositions with “but” as a way to show disagreement, 2) to define the strengths of those arguments, 3) to claim and give reason (premise) supporting claim, 4) to determine the different conflicts between the arguments, 5) to evaluate the acceptability of the different arguments, and to conclude or define the justified conclusions (Abi-El-Mona & Abd-El-Khalick, 2011; Amgoud & Kaci, 2007; O’Hallaron, 2014; Voss & Means, 1991; Zhang et al., 2015). Secondly, scientific inquiry covers learner’s engagement with a scientific question, concentration in shreds of evidence or evidence that relate to the question, ability to build the explanation from data and gathered pieces of evidence, use of mathematics, ICT or computer technology and computational thinking, learner connect acquired knowledge to scientific knowledge, and learner' s communication and evaluation of reasonable knowledge (Grigg, Kelly, Gamoran, & Borman, 2013; Hodson, 2014; Weber et al., 2013). So, argument-based inquiry is a learning activity that gives an opportunity to learners to use various inquiring methods like a scientist. There is a cycle of the process from asking a scientific question, investigation and evaluation of the evidences or answer of the question. Learners use acceptable methods that can be accepted by scientist community, including realizable knowledge from the scientific report, confirmation of scientific arguments, and awareness of the complicated relationship between science, technology, social and environment. Via activities, the learner has to apply the argument strategy and active self-regulation to investigate knowledge by themselves.

According to literature, the argument-based inquiry seems to be an optimal learning activity for empowering student's scientific reasoning. However, few studies show the current state of teacher practice and the expected state of argument-based inquiry. In this study, we will reveal the gap between the current and expected state.

6. Promoting Scientific Reasoning in School Curriculum

Although the studies about the effect of school curriculum on student's scientific reasoning are very limited, in the case of Thailand, the school curriculum will provide a framework and direction for the procurement of education to succeed in the core curriculum (Seehamat, Sarnrattana, Tungkasamit, & Srisawasdi, 2014). The school curriculum should cater ~~to~~ an opportunity for students to express scientific reasoning skills. Thus, the understanding of the current state and obstacles for practical implementation is needed.

Materials and Methods

This is a descriptive quantitative study with a survey method using questionnaires as the instrument to measure the teacher's viewpoint. The research population was 126 general science teachers who are teaching in secondary education (educational service area 28, Sisaket province). The sample size was defined from the table determining sample size from a given population (Krejcie & Morgan, 1970). The research 105 samples were randomly collected by simple random sampling. Consequently, modified priority need index

(Phanchalaem, Sujiva & Tangdhanakanond, 2016) and descriptive statistics were used for data analysis.

The systematic approach (Yavuz, Parzych, & Generali, 2017) was used to conduct this study. The 4-part questionnaire is shown in Table 1, which was developed by researchers to reflect the differences between the current state of simulation and argument-based inquiring activity, enhancing students' scientific reasoning and the state of expectation. The first section of the survey leads participants to complete background and demographic information such as gender, teaching experience, teaching level, school type, school size, educational background, and teaching subject. Part 2 – 4, each item is closed-end question, with Likert's 5 rating scales (very poor = 1, poor = 2, fair = 3, good = 4, excellent = 5). The participants were asked to check how much they agree with the statement concerning topics shown in Table 1.

Table 1 The key questions of the needs associated with each part.

Part	Items
Basic information of the informant.	7
The state between current and expected learning materials and school curriculum for enhancing student's scientific reasoning.	13
The state between current and expected simulation for enhancing student's scientific reasoning.	5
The state between current and expected argument-based inquiring activity for enhancing scientific reasoning.	16

The questionnaire consists of 4 parts as followings:

Part 1: Basic information of the informant

In this part, informants were asked about the necessary information to describe the sample's demographic.

Part 2: The state between current and expected learning materials and school curriculum for enhancing student's scientific reasoning

In this part, informants will express the different states between existing learning materials and school curriculum for enhancing student's scientific reasoning and expected state should be.

Part 3: The state between current and expected simulation for enhancing student's scientific reasoning

In this part, informants will express the different features between existing simulations for enhancing students' scientific reasoning that teachers have used and expected features should be.

Part 4: The state between current and expected argument-based inquiring activity for enhancing scientific reasoning

In this part, informants will express the different features between existing argument-based inquiring activity for enhancing students' scientific reasoning that teachers have used and expected features should be.

To validate the assertion of 41 items, researchers asked the opinions of five experts (three educational technologists and two science educators) to validate the question's objectives. The Lawshe's content validity ratio (Lawshe, 1975, as cited in Gilbert and Prion, 2016) was used for analyzing the question's validity. The result of the analysis of CVR found that all of the questions could be considered good question because of CVR more than 0.78 (Polit, Beck, & Owen, 2007). Then the questionnaires were distributed to 12 science teachers in Ubon Ratchathani province to evaluate the objectivity. The teachers were asked to share their experiences regarding the length of the survey. Pilot respondents indicated that they were satisfied with quality of the questions (Seechaliao, 2010). Finally, questionnaires were sent to 36 science teachers in educational service area 29, Ubon Ratchathani province, to assess internal consistency. Cronbach's alpha coefficient assessed internal consistency, and the instrument was found to be highly reliable (49 items; α = 0.917). Following the pilot study and validation of the instrument, 105 participants (science teachers in educational service area 28) completed the revised version.

In an analysis of the survey, this study has followed Phanchalaem et al. (2016). The modified priority need index (PNI_{mod}) was used for the analysis of collected data as an intervalist's viewpoint (Harpe, 2015). The priority needs index is presented as a mean point and PNI_{mod} value because PNI could be used for calculation from importance and degree of success (Lane, Crofton, & Hall, 1983, as cited in Wongwanich, Sakolrak, & Piromsombat, 2014).

Results

The questionnaires out of 126, 105 (83%) were responded by 35 (33%) male and 70 (67%) female teachers. Among these, 27 (26%) had less than 5 years of teaching experience, 26 (25%) teachers with 10 – 15 years of teaching experience, 15 - 20 years of teaching experience, and 20 (19%) with more than 20 years of teaching experience. Twenty-five teachers (24%) taught at Mathayomsuksa 1 (level 7), 32 (30%) at Mathayomsuksa 2 (level 8), and 48 (46%) at Mathayomsuksa 3 (level 9). With the number of 27 (26%), employed at Opportunity extension school, and 78 (74%) at secondary school. There were 27 teachers (26%) from small schools, 34 (32%) from middle schools, 19 (18%) from large schools, and 25 (24%) from extra-large schools. These teachers held a bachelor's degree, 48 (46%), 55 (52%) with master's degree, and 2 (2%) doctorates. Among these respondents, 63 (60%) only taught general science and 42 (40%) general science and other subjects (Table 2).

Table 2 Demographic Characteristic of Teachers. (*N* = 105)

Demographic Data		Frequency	Percentage
Gender	Male	35	33
	Female	70	67
Teaching Experience	<5 years	27	26
	5-10 years	26	25
	10-15 years	16	15
	15-20 years	16	15
	>20 years	20	19
Teaching Level	Mathayomsuksa 1 (level 7)	25	24
	Mathayomsuksa 2 (level 8)	32	30
	Mathayomsuksa 3 (level 9)	48	46
School type	Opportunity extension school	27	26
	Secondary school	78	74
School size	Small	27	26
	Middle	34	32
	Large	19	18
	Extra Large	25	24
Educational background	Bachelor	48	46
	Master	55	52
	Doctor	2	2
Teaching Subject	Only general science	63	60
	General science and Others	42	40

Overall of the attitude of teachers towards the problems, the feature (Student makes an understanding of the relationship between multiple variables) is the most expected (PNI_{mod} = 0.23), followed by the allocation of result and feedback (PNI_{mod} = 0.22), the accentuation of evidence or question-based evidence in learning activities (PNI_{mod} = 0.22), the student's presentation of evidence supporting the claim (PNI_{mod} = 0.22), the student's presentation of a count-argument (PNI_{mod} = 0.21), the investigation of model's behavior in scientific phenomena (PNI_{mod} = 0.20), the defining of conflict argument (PNI_{mod} = 0.20), and the use of mathematics, information, information technologies, or computational thinking (PNI_{mod} = 0.19), respectively. Besides, the researcher found the limitation of learning materials and the school curriculum. The existing learning materials (PNI_{mod} = 0.22) and school curriculum (PNI_{mod} =0.21) could enhance student's scientific reasoning sufficiently, as show in Table 3.

Table 3 The priority needs index of the problem in the current state of learning materials, school curriculum, simulations software, and argument-based inquiry activity for enhancing middle school's scientific reasoning ability (*N* = 105)

Features of simulation and argument-based inquiry	I*	D**	PNI***	Rank
The simulation could lead the student to make an understanding of the relationship between multiple variables of scientific phenomena.	4.07	3.30	0.23	1
The simulation could allocate features of results and feedback. For instance, the user interface could show a data table or graph of the experiment result.	4.01	3.29	0.22	2
The existing learning materials could enhance a student's scientific reasoning.	4.13	3.38	0.22	2
The argument-based inquiry could have more emphasis on evidence or question-based evidence.	4.03	3.30	0.22	2
The argument-based inquiry could lead the student to present evidence supporting the claim.	4.13	3.40	0.22	2
The argument-based inquiry could lead the student to present a counter-argument.	4.13	3.41	0.21	3
The current school curriculum could enhance a student's scientific reasoning.	4.03	3.34	0.21	3
The simulation could allocate features of defining of model's behavior in scientific phenomena.	3.98	3.32	0.20	4
The argument-based inquiry could lead the student to define conflict of arguments.	4.11	3.42	0.20	4
The argument-based inquiry could promote the student to use mathematics, information, information technologies, or computational thinking.	4.02	3.37	0.19	5

* I = The Average score of expected state.

**** D = The Average score of current state.**

*** PNI = **I-D/D**

Conclusion and Discussions

In conclusion, this study revealed that northeastern Thailand teacher's aspect rated the deficiency of learning materials and school curriculum for scientific reasoning. Likewise, simulation's features, which could be improved, are displaying a relationship between multivariable, feedback, and result. Similarly, argument-based inquiry features, which could be added to learning activities for scientific reasoning are an emphasis on evidence or question-based evidence, presentation of evidence supporting the claim, presentation of a counter-argument, stipulation of a conflict of arguments, and using of mathematics, information, information technologies, or computational thinking. Therefore, OBEC (the office of basic education commission) should provide a novel instructional simulation, which includes enhanced features, and distribution to distant schools. These insights should be used to inform simulation developers to understand the needs of users better.

Based on the results, this study investigated overall expected views of learning materials, school curriculum, simulation, and argument-based inquiry activity for enhancing middle school's scientific reasoning ability of science teachers in Sisaket province (northeastern Thailand) and explored associated factors. The results reveal the insufficiency competency of existing learning materials and school curriculum that encourages student's scientific reasoning. The results of this study is in line with previous studies that scientific reasoning is a core topic in science education in schools. While a variety of interventions are developed and implemented to deal with the problem, but there are a few learning materials and curriculum that were used for the fostering (Engelmann, Neuhaus, & Fischer, 2016). This is indicative of the demand for novel learning materials and curriculum. Besides, when ranking PNI was pronounced for the needs on more useful features of simulation, e.g., understanding of the relationship between multiple variables of scientific phenomena, results and feedback, and defining of model's behavior in scientific phenomena. This result related to findings of previous studies (Aldrich, 2009; Liu, Kinshuk, Lin, & Wang, 2012) that DLMR (dynamic linked multiple representations) as a result and feedback, such as graph and diagram. They are the efficient tools for learning with courseware. Likewise, the investigation of the model's behavior in the system is the core feature of simulation for learning (Landriscina, 2013).

More importantly, the result of this study shows the deficient positive impact of current argument-based inquiry for scientific reasoning, e.g., emphasis on evidence or question-based evidence, presentation of evidence supporting the claim, presentation of a counter-argument, stipulation of a conflict of arguments, and using of mathematics, information, information technologies, or computational thinking. This result conformed to prior studies (Grigg et al., 2013;

Weber et al., 2013) that scientific inquiry with constructing explanations from evidence is a potent activity for student's learning in scientific topics. Similarly, these results tally with antecedent studies (Abi-El-Mona & Abd-El-Khalick, 2011; Amgoud & Kaci, 2007; O'Hallaron, 2014; Voss & Means, 1991; Zhang et al., 2015) that presentation of reason supporting claim, introducing a counter-argument, and determining of the different conflict between arguments is the crucial process in argumentation.

Suggestions

This study was associated with limitations. The sample size was small, and the data were obtained from a single setting. Other studies should study with larger sample sizes and in different regions. Mixed methods are a better method to conduct future studies.

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