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# Science Teachers' Practical Knowledge of Inquiry-Based Learning

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## ABSTRACT

Science teachers' practical knowledge of inquiry-based learning influence their beliefs about science teaching and learning. The Indonesian Curriculum released in 2013 has required teachers to teach science via inquiry-based approaches. In fact, some previous studies have found that teachers have difficulties in practically implementing the requirements suggested by the curriculum. It is believed that teachers' practical knowledge may influence their real teaching practices. This research aimed to analyze how teachers employed their practical knowledge in teaching inquiry-based science by selecting an appropriate type of inquiry in science topics. 105 science teachers purposefully drawn from the regular meeting of Science Teachers Association of Surakarta City in February 2017voluntarily participated in the survey. A nine-item questionnaire originally developed by W.W. Cobern et al (2104) was administered to measure the most appropriate type of inquiry in various science topics. The teachers' options represent their practical knowledge of inquiry-based learning. It is expected that teachers will choose the best appropriate type of inquiry focusing on student's autonomy, i.e an open inquiry. The results showed that the teachers differently interpreted the inquiry-based learning. Teachers mostly used guided-inquiry (32.8%) and open-inquiry (32.08%) to teach the science topics in the questionnaire. It was elicited that 12.17% of them selected didactic direct inquiry, whilst 22.65% of them chose active direct one. It is recommended that future studies should handle the results of the current study to appropriately formulate in-service curriculum and education for science teachers.

**Keywords:** Inquiry-based learning, practical knowledge, science

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## INTRODUCTION

Science teaching and learning has recently focused on meaningful and contextual learning (Ultay & Calik, 2012, King & Henderson, 2018). That is, learning scientific concepts needs to be linked with the real-life issues or phenomena. Contextual learning gives a chance for students to interpret phenomena, experiment, and inquiry scientific approaches in understanding science concepts (Chinn, 2007). To promote meaningful and contextual learning, inquiry-based learning is recommended as one of the promising methods to understand science concepts properly.

Teachers' practical knowledge of the inquiry-based learning show their capabilities on implementing the inquiry-based learning as well as their comprehensive understanding of student's learning quality on the importance and benefits of the inquiry-based learning. Teacher's practical knowledge helps him to construct his conception of science and to learn about how to teach specific science topic(s)(Ratinen, Viiri, Lehesvuori & Kokkonen, 2015).

Teachers are expected to improve their professional skills by conducting proper pedagogical strategies for effective teaching (Drago &Mih, 2015). Because teachers have to use content knowledge, experimentation skills, and pedagogical knowledge, they need adequate skills to make and implement their lesson plans through pedagogical content knowledge(PCK) (Cobern, Schuster, Adams, Skjold & Mugaloglu, 2014). PCK is the benchmark to assess teachers' specific competencies and abilities portraying how to be a good teacher (Fernandez, 2014).

Teachers sometimes stumble in properly conducting the inquiry-based learning due to lack of practical knowledge and/or practical experience with the inquiry process (Crawford, 2000). In view of Adofo (2017), the inquiry-based learning is relatively inadequate in practicum, because teachers possess limited knowledge of inquiry concepts and processes. Therefore, to develop more effective and efficient practices of the inquiry-based learning, teacher should be equipped with ample skills and knowledge of the inquiry. Since teachers play a crucial role in the teaching and learning processes, their practical knowledge of the inquiry-based learning should be elaborated to drive their students to accomplish the learning goals. Teacher's practical knowledge of the inquiry-based learning may give students a chance to improve students' thinking skills and experiences through inquiries process or science process skills (Castro & Moralez, 2017).

Teachers' high expectations make learning activities more effective and meaningful (Bhengu & Mthembu, 2014). In the inquiry-based learning, teachers act as the bridges to connect their own students with the learning contents to achieve the learning goals. Teachers' conceptions of the inquiry are associated with their teaching practices which will develop their students' competencies/abilities (Wang & Jou, 2016). To successfully support the inquiry-based learning at science classes, science teachers should effectively manage the students' learning activities, look for the need(s) of each action, reconfigure their classes, and prepare better instruction (Harris &Rooks, 2010;Feyzioglu, 2015). Moreover, teachers are required to master the basic knowledge of the inquiry-based learning, particularly planning the learning design, students' activities, and developing the appropriate assessment. The effective learning design and assessment may as sure the students' achievements throughout various student responses and their experiences or psycho-social backgrounds (Hong& Lawrence, 2011).

Various ideas on categorizing the inquiry process in the class are available in the related literature. Tafoya, Sunal and Knecht (1980) divided inquiry into four levels: confirmation inquiry (level 1), structured inquiry (level 2), guided inquiry (level 3), and open inquiry (level 4). Those levels are distinguished from each other based on teacher responsibility and student activities in three main stages, i.e., stating or identifying the problem, selecting the procedure, and formulating the solution. In a similar vein, Cobern et al. (2014) formulated the similar inquiry types (see Table 1).

Teacher is expected to select the open inquiry as the most appropriate model to nurture students' understanding, abilities and autonomies of science concepts. The inquiry-based learning is recognized as an alternative approach to enhance their autonomies (Sierenset al., 2009; Hartingset al., 2015; Silva & Galembeck, 2016).In the framework of open-inquiry, students independently explore the phenomena, generate the hypothesis, and design the experiment(s) to deeply test their hypothesis. Further, they are encouraged to collect and analysis data to formulate their conclusion(s).

**Table 1.** *Pedagogical understanding levels of the inquiry*

| Basic Modes | Variants | Operational Descriptions |
|---|---|---|
| Science as the factual content knowledge | *Didactic direct* | Teachers directly provide and explain the content knowledge through examples and demos without student activities. |
| | *Active Direct* | Teachers directly provide and explain the content knowledge. Students verify teachers' explanations. |
| Science as the developmental products of the scientific inquiry process | *Guided inquiry* | Students explore the phenomena or ideas with teacher guidance. |
| | *Open inquiry* | Students explore the phenomena or ideas. Teachers facilitate the exploration procedure but they do not actively influence on their decisions or concepts. |

(Adopted from: Cobern, Schuster, Adams, Skjold, Mugaloglu, Bentz, & Sparks, 2014)

The inquiry-based learning improves students' abilities to: (a) build the basic knowledge, (b) foster problem-solving skills, (c) interpret the phenomena, (d) explain the interconnection(s) between scientific concepts and facts, and (e) construct the prediction about what happens (Avsec & Kocijancic, 2014). Also, the inquiry-based learning promotes students to explore their abilities to think about the real-life situations. When students are confronted with various tasks and questions that need comprehensive answers or solutions, or require them to change their problem-solving methods, students are able to use their competencies. This regular process trains students to solve their daily life problems and prepares them for long-life learning (Alameddine & Ahwal, 2016). A combination of inquiry and content knowledge can improve students' knowledge through real-life-activities while building their conceptions (Buczynski & Hansen, 2010). The inquiry-based learning, as a part of science teaching and learning, aims to improve students' learning outcomes of science (Abd-el-khalick et al., 2004). Acting as scientists to learn science may also evolve their higher-order thinking skills (Comley, 2009).

This research aimed to identify the science teachers' practical knowledge of the inquiry-based learning. Further, it identified how the science teachers linked the type of inquiry with the certain science topics. It also detected whether the science teachers promoted their student autonomies via open-inquiry, which is seen as the most appropriate type of inquiry in science learning.

## METHODOLOGY

The research design was a case study of introduction of digital teaching material to the social science teachers at junior high schools in Surakarta, Indonesia. Participants in this study were 47-48 years old. The number of participants were 40 social sciences teachers which were selected according to purposive sampling. Data was collected by interview form.

The interview form was developed by considering a conceptual framework that consists of 4 (four) main components of learning process. The first component is included aspects of the ability and performance of teachers. In this aspect, semi-open statements were used to reveal teacher perception on planning for the utilization of digital teaching materials. The second component is to uncover the potential use of digital teaching materials. The third component comprised the pedagogical and technical aspects to reveal the teacher perception on development of teaching materials in relation to the fluency and continuity of teaching and learning activities. The fourth component is about the use of ICT in the social science learning process. The authors emphasized Yin's (2009) framework of the three principle of data collection, which consist of the use of multiple source of evidence, create a case study database, and maintain a chain of evidence, to construct the validity and reliability of data collection tool and data collection procedure. The interviews conducted with purposive sampling according to educational background.

Data analysis was conducted by using coding and categorization on each of words or phrases in the interview form which were relevant to the purpose of this research. Through the coding and categorization, 32 statements were grouped into 4 (four) main components. Interactive analysis including data collection, data reduction and verification to find common patterns were used as data analysis method in this research. Triangulation of methods by interview and questionnaire. The interview through checking selected with the respective respondents to make sure the data is properly written in accordance with reality was used as data validation technique.

**Research Design**

Through a survey research method, 105 science teachers from the Surakarta Middle School Science Teachers Association Meeting held in February 2017 were purposively selected. A 9-itemq questionnaire concentrated on nine science topics (i.e., *temperature and solubility, role of chlorophyll in photosynthesis, animal classification, microbes, water characteristics, air is a matter, power and movement, static electricity, and, light and reflection*) in the middle school curriculum and included four-optional inquiry methods for each topic. The items were selected from the Pedagogy of Science Teaching Tests (POSTT 3 and 4) developed by William Cobern et al. at Michigan University (from http://www.wmich.edu/science/inquiry-items/index.html), and we have asked permission to do translation and some changes, regarding the name of the teacher with more common name for Indonesian and Malaysian students, and match the topics with the suitable grade in both countries. The optional answers were developed in regard to the types of inquiry proposed by Cobern et al.(2014), i.e. didactic direct, active direct, guided inquiry and open inquiry. Sample questions are presented in Table 2.The optional letters were set randomly, in order to reduce the possibility of respondents to guess. For example, according to Q4, the teachers are expected to choose A, as a high level of inquiry, while, for Q8, they are expected to opt C as a reflection of open inquiry.

**Table 2.** *Examples of pedagogy assessment test and expected answers, adopted from Pedagogy of Science Teaching Tests (POSTT)*

| Questions | Didactic direct | Active Direct | Guided Inquiry | Open Inquiry |
|---|---|---|---|---|
| Q4. *Microbiology* Mr. Chong introduces the idea to grade nine students that microbes are minuscule living | D. In the early learning process, I will explain to the students what we will learn today | C. I will explain the microbe can be found almost everywhere in daily life. Then I will use the ideas from | B. I will ask students what conclusion can be drawn from their lists. Based on their ideas I will confirm the | A. I will praise students for their participation, then end the learning session by asking |

| | | | | |
|---|---|---|---|---|
| beings live around us. He asks the students to make a list about the places they think they can and cannot find microbes. Students then read their lists and Mr. Chong writes them on the board.  Based on the aforementioned situation, please choose the alternative that most likely you do on this orientation stage? (POSTT 4-p.5) | before they involved in various learning activities. | their lists as to support the learning goal to connect the learning contents with students' ideas and daily life situation. | microbes can be found everywhere. | the students to write a short paragraph about where we can find the microbes. |
| Q8. *Static electricity* Mr. Maniam taught grade seven students about static electricity. He only wants the students to experience those phenomena by observing some materials can produce static electricity better than others when rubbed to balloon. He brings several balloons and materials to be rubbed, such as wool, plastic bag, feather, glass, cabbage, and newspapers. He asks the students to rub each of the sample materials to the balloon, and test it how strong the balloon will be attached to the wall.  Think about how you will teach this topic. Please evaluate Mr. Maniam's teaching strategy by choosing the answer you think proper (POSTT 3-p.3) | D. Mr. Maniam should explain first the balloon will be attached to the wall if rubbed with certain materials, but not with other materials. Then he demonstrates it to the students, not the students asked to do those activities. | A. Mr. Maniam should explain first the balloon will be attached to the wall if rubbed with certain materials, but not with other materials. He then permits the students to do the experiments themselves. | B. So far the learning activities are good as long as Mr. Maniam can provide a framework about how students' findings are connected with learning goals, thus provide the correct conclusions. | C. In order to push the students to become independent researchers, Mr. Maniam should not provide explicit instructions. But he asks the students to do self-explorations with the balloon and provided materials and observe what will be going on. |

The science teachers were expected to choose the open inquiry as the correct answer since the open inquiry actively engages students in activities and promotes their autonomies. In this process, the teachers acted as the facilitators to help the students explore the science concepts. The percentages of all categories and the instrument's reliability were calculated using Rasch Analysis with Winstep.

**RESULTS and DISCUSSION**

As seen in Table 3,the science teachers considerably chose the open inquiry, especially on Q5 and Q8 (see Table 2). Meanwhile, the science teachers viewed Q4 as the guided inquiry for the most proper method.

**Table 3.** *Type of inquiry preferred by the science teachers*

| Type of Inquiry | Number of responses on each item | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| Didactic direct | 11 | 1 | 13 | 3 | 0 | 12 | 20 | 27 | 28 |
| Active Direct | 29 | 17 | 47 | 39 | 18 | 20 | 21 | 15 | 8 |
| Guided Inquiry | 24 | 46 | 8 | 54 | 44 | 41 | 39 | 11 | 43 |
| Open Inquiry | 41 | 41 | 37 | 9 | 43 | 32 | 25 | 52 | 26 |
| Percentages of responses to open Inquiry | 39.05 | 39.05 | 35.24 | 8.57 | 40.95 | 30.48 | 23.81 | 49.52 | 24.76 |

As observed from Table 3, a few science teachers selected didactic direct, while most of them chose either guided or open inquiry. Whereas they mostly marked didactic direct for Q9 (light and reflection) (n=28), they generally preferred active direct for Q3 (animal classification) (n=47). Meanwhile, they mostly selected the guided inquiry for Q4 (Microbes--n=54), the open inquiry for Q8 (static electricity--n=52).

For Q9 (light and reflection), most of the science teachers thought that the guided inquiry was better than the didactic direct. This means that some teachers tended to implement teacher-centered learning. Some of the science teachers did not give an opportunity for the students to explore their understanding of the 'light and reflection' topic through independent activities. In fact, because this topic has a lot of everyday life connections, an open inquiry is easily applied to this topic. The science teachers gave different responses to Q5 (characteristics of water). None of them chose the didactic direct. Indeed, majority of them selected the guided or open inquiry fostering students to explore and analyze the real-world phenomena. This implies that most of them may have used the inquiry-based learning on this topic. For Q3 (animal classification), active direct learning, in which students have little opportunity for verification stages, or teachers play dominant roles, was the most selected type.

The average percentages of didactic direct, active direct, guided inquiry, and open inquiry were 12.17, 22.65, 32.8 and 32.38 respectively. This means that 65.18% of the science teachers focused on the guided or open inquiry. In view of Wang and Jou (2016), the inquiry-based learning foster students' active participations in decision-making through scientific experiments, findings, and innovations. Hence, they develop their skills integrating and applying various aspects of science. Implementing the inquiry-based learning helps the teachers achieve the learning goals. The science teachers' various responses to each topic indicated that content knowledge or science topic drove the type of inquiry, and the open inquiry was not the only proper one for all science topics.

The lowest percentage in the didactic direct means that a few teachers used factual learning without focusing strongly on their students' autonomies. Phrased differently, the teacher-centered learning seems to have been less desirable.

The fact that 22.65% of the science teachers chose the active direct learning revealed teacher-centered science teaching, with limited student's engagement. This also means that the science teachers may not have enough courage to play a facilitator role of learning. On the other hand, they tended to use one-way learning process by asking a question and waiting for their students' responses. Active direct only makes students active in the verification stage instead of all learning stages of learning, so that student's active engagement is very constrained.

The highest percentage in the guided inquiry pointed to the student-centered learning in which they become more active in all learning processes. The science teachers, who preferred the guided inquiry, tended to explore their students' inquiry skills and only gave the problem-related starting questions. Hence, the science teachers asked them to construct their own methods to solve the problem. Overall, the guided-inquiry intends to develop their skills of experimental work flows, defining and analyzing data, and making conclusions (Lederman, 2008).

The fact that a significant percentage of the science teachers selected the open inquiry as the second alternative method (32.38%) referred to the opportunity for students to explore their knowledge independently. Through the open inquiry, students are very active in deciding and exploring the proper learning resources. Teachers only observe how far students can explore without deciding the boundaries.

Two types of the inquiry (guided and open inquiry), as a part of the inquiry-based learning, afford students to think logically and connect their concepts with their daily lives experiences (Zubaidah, Fuad, Mahanal & Suarsini, 2017).Furthermore, it also promotes creativity, and independence to explore science (Zulfiani & Herlanti, 2018).

*Instrument's Reliability*

The result of Rasch person reliability (r value= 0.66) indicated that the science teachers' response consistency was reasonable. Also the value for Item Reliability (0.86) revealed that the items were good. According to Sumintono & Widhiarso (2014), person reliability co-efficient fell into 'enough or average' category. Item Reliability value, which was between 0.81 and 0.90, was viewed as good. The value for person reliability test may stem from varied levels of the inquiry. It also may stem from a lack of practical knowledge for each inquiry case or given science topic.

As can be seen from Table 4, the values of INFIT MNSQ (means-square), an dOUTFIT MNSQ were between 0.98 and 1.01. Those values ranged from average to good categories because the ideal value is 1.00. The values for INFIT ZSTD (Z-standard) and OUTFIT ZSTD, which were 0.0, changed from average to good categories because the ideal value is 0.0 (Sumintono&Widhiarso, 2014).

**Table 4.** *The characteristics of respondents*

| PERSON | 105 INPUT | | 105 MEASURED | | INFIT | | OUTFIT | |
|---|---|---|---|---|---|---|---|---|
| | TOTAL | COUNT | MEASURE | REALSE | IMNSQ | ZSTD | OMNSQ | ZSTD |
| MEAN | 25.7 | 9.0 | .51 | .45 | .98 | .0 | 1.01 | .0 |
| S.D. | 4.8 | .0 | .79 | .10 | .43 | 1.0 | .45 | 1.0 |
| REAL RMSE .46 | | TRUE SD | .65 1.39 | SEPARATION | | PERSON RELIABILITY | | .66 |
| ITEM | 9 INPUT | | 9 MEASURED | | INFIT | | OUTFIT | |
| | TOTAL | COUNT | MEASURE | REALSE | IMNSQ | ZSTD | OMNSQ | ZSTD |
| MEAN | 299.7 | 105.0 | .00 | .12 | .99 | -.1 | 1.01 | .0 |
| S.D. | 23.2 | .0 | .34 | .01 | .19 | 1.6 | .18 | 1.3 |
| REAL .12 | RMSE | TRUE SD | .31SEPARATION 2.52 | | | PERSON RELIABILITY | | .86 |

The higher separation values mean the better instrument because of identifying respondent groups and item groups. Group separation can be determined with the formula of H = [(4 x Separation) + 1]/3 (Sumintono & Widhiarso, 2014). As observed in Table 4, person separation value of [(4 x 1.39) + 1]/3 = 2.19. If it is converted to 2, the value shows two respondent groups, i.e. direct teaching and inquiry learning groups. Item Separation value was [(4 x 2.52) + 1]/3 = 3.69. If it is converted to 4, it reveals four answer groups: didactic direct, active direct, guided inquiry, and open inquiry. To sum up, these values address that the instrument is good, reliable, and can be used for further/future researches.

## SUMMARY

This research showed that the science teachers' practical knowledge of the inquiry-based science teaching and learning leaned toward the high-level inquiry, i.e., guided inquiry and open inquiry. This finding indicated the readiness of the science teachers on the 21st century skills (e.g., communication, collaboration, critical thinking and creativity). The instrument may be used for an extended scale or a larger sample. To improve the science teachers' practical knowledge of the inquiry-based science teaching and learning, suitable seminars and trainings should be organized and implemented.

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