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Investigating the immersion of inquiry in lecture in improving students' understanding about scientific inquiry

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ABSTRACT

This study aimed to examine the extent to which scientific inquiry procedures during a lecture improve students' understanding of scientific inquiry. The study implemented a one-group pretest-posttest design. Participants were 53 first-year students from the Chemistry Department at a public university in Malang City. Students' understandings of scientific inquiry were assessed before and after the instruction using the Views About Scientific Inquiry (VASI) questionnaire. The participants' responses were analysed descriptively and classified into three categories: informed, partially informed, and naïve, with Cohen's inter-rater reliability value of 0.81. The results showed that (1) before treatment, students' understanding of scientific inquiry was at the level of partially informed and naïve, and (2) the immersion of scientific inquiry procedures in lectures improved students' understanding of scientific inquiry with the improved strength of Cohen's d-effect size was 1.10 (much larger than the typical category) or average normalized gain was 0.3 (medium category).

Keywords: scientific inquiry, scientific inquiry-based lecture, views of scientific inquiry

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INTRODUCTION

Scientific inquiry has become one of the main goals of contemporary science education (J. S. Lederman et al., 2014; Shwartz et al., 2006) and student learning experiences (Kapelari, 2015; MoEC, 2016). The Programme for International Student Assessment (PISA) project places scientific inquiry as a central component of the scientific literacy framework (OECD, 2019), which he calls competencies. Therefore, students must know about scientific inquiry and be able to conduct it.

In the field of science, scientific inquiry refers to the various ways that scientists use to study the natural world to develop scientific knowledge. Whereas in instruction, scientific inquiry refers to the students' activities in which they develop scientific knowledge and the understanding of science, and also an understanding of how scientists generate scientific knowledge (NRC, 1996). In developing scientific knowledge, scientific inquiry combines science processes (e.g., observing, inferring, classifying, predicting, measuring, questioning, interpreting, and analyzing data) with scientific knowledge, scientific reasoning, and critical thinking (Kapelari, 2015; J. S. Lederman et al., 2014; N. G. Lederman et al., 2013). In this view, scientific inquiry can be applied to all branches of science (e.g., chemistry, physics, and biology) that develop students' knowledge based on evidence generated from observations of the natural world.

Regarding instruction, scientific inquiry has three distinct but complementary meanings: as science content that students should understand; as a set of cognitive abilities in which students should develop; and as an instructional approach that can be used by science teachers (Bybee, 2002). In terms of science content, there is a global consensus on the aspects of scientific inquiry that should be learned by students (Strippel & Sommer, 2015). These are the following: all scientific investigations begin with a question and do not always test a hypothesis; there is no single scientific method; inquiry procedures are guided by a question posed; all scientists performing the same procedures may not get the same results; inquiry procedures may influence results; research conclusions must be consistent with the data collected; scientific data are not scientific evidence; and the instrument of assessment used to assess students' understanding of scientific inquiry is developed based on these views.In terms of cognitive abilities, scientific inquiry abilities (Kuo et al., 2015) or scientific competencies (OECD, 2019) or classroom inquiry (Campbell et al., 2010; NRC, 1996) consist of a set of skills needed by students to develop and to understand scientific knowledge. The National Research Council (NRC) formulated five principles of classroom scientific inquiry. These five principles are framing research questions, designing investigations, conducting investigations, collecting data, and drawing conclusions (Singer et al., 2006).

In terms of instructional approach, scientific inquiry has become an essential component of K-12 science education in the USA, England, South Africa, Turkey, and Indonesia. In general, knowledge construction regarding scientific inquiry is conducted via students' engagement with investigation, or generally by "doing" inquiry or by engaging in authentic scientific inquiry activities (Sadler et al., 2010). This implies that knowledge of scientific inquiry is taught as a nurturing effect instead of as an instructional effect. It is assumed that the learners who engage in inquiry activities would probably have an informed conception of scientific inquiry. However, research showed that learners who experienced inquiry-based learning did not automatically have an informed conception of scientific inquiry (Anggraeni et al., 2017; Antink-Meyer et al., 2016b; Gaigher et al., 2014), and learners asking scientific questions do not automatically have informed conceptions about scientific questions (J. S. Lederman et al., 2014). In other words, students experiencing scientific inquiry do not necessarily have informed conceptions of scientific inquiry. Therefore, the knowledge gained through scientific inquiry should be placed as the instructional effect of instruction.

Studies showed that students' understandings (Anggraeni et al., 2017; Antink-Meyer et al., 2016b; Gaigher et al., 2014; J. S. Lederman et al., 2014), as well as the teachers' understandings (Adisendjaja et al., 2017; Muntholib et al., 2019) of scientific inquiry were low. Educators have made some efforts to overcome the lack of understanding of scientific inquiry. However, efforts such as explicit instruction (J. S. Lederman et al., 2014), science camps (Antink-Meyer et al., 2016b), and teacher professional development (Adisendjaja et al., 2017) slightly increase students' understandings of scientific inquiry. This situation indicates that effective instructional strategies in increasing students' understanding of scientific inquiry are still a significant challenge for science education.

Explicit instruction about scientific inquiry (i.e., It is usually implemented in lecturing format) has a limited effect in improving students' understanding of scientific inquiry (J. S. Lederman et al., 2014). Meanwhile, lecture remains the most common instructional method implemented by teachers (Cobern et al., 2010; Lom, 2012; Steward et al., 2010) due to its conveniences. Whereas, Hodson suggests that placing the knowledge of scientific inquiry as explicit curriculum content could enhance the effectiveness of the instruction in increasing students' understanding of scientific inquiry (Hodson, 2014). Therefore, giving a lecture to effectively improve students' knowledge in scientific inquiry is a significant challenge.

Scientific inquiry-based instruction is proven to be one of the most effective instructional approaches in improving students' understanding of the nature of science and of the scientific ways of thinking(Bianchini & Colburn, 2000; Capps & Crawford, 2013), content knowledge understanding (Minner et al., 2010), ability to evaluate scientific data and models (NRC, 2000), motivation to learn science (Palmer, 2009), and overcoming preexisting misconceptions (NRC, 2000). However, most inquiry-based instruction collects data through laboratory activities or field observations, which takes a long time in practice. In addition, inquiry-based instruction only increases the understanding of upper-group students (J. P. Walker et al., 2016). Therefore, developing inquiry-based instruction that is effective and efficient in improving understanding and scientific inquiry abilities is a major challenge for science education. This study seeks to address these challenges by immersing scientific inquiry procedures in the lecture method, aiming to improve student achievement related to scientific inquiry knowledge.

The direct instruction approach is built on the assumption that all students can learn with well-designed instruction (Stockard et al., 2018). In this approach, the instructor conducts well-planned, organized, and highly sequenced lectures and gives guided practice or drills to students (Maandig et al., 2017). The principles of the direct instruction approach are: explicit teaching of rules and strategies; example selection; example sequencing; and conversation (Kinder & Carnine, 1991). One of the most well-known direct instruction-based learning models is the Hunter Direct Instruction Model (HDIM) (Steward et al., 2010). This model emphasizes guided practice that enables students to acquire a set of skills. In this model, the educator explicitly validates that learning has taken place. This instructional approach is also effective in promoting children's ability to design unconfounded experiments (Lazonder & Wiskerke-Drost, 2015). In other words, lectures conducted in a structured, systematic, and explicit manner can increase the students' ability to design unconfounded experiments.

In this study, we embed the scientific inquiry learning activities into lectures to enhance students' achievements related to knowledge of scientific inquiry. We named this instruction the explicit scientific inquiry strategy. This strategy consists of six phases, namely: orientation, conceptualization, investigation, report drafting, validation of scientific inquiry, and enrichment.

The first two phases (orientation and conceptualization) provide students with the knowledge and skills needed to conduct scientific inquiry. This phase is dominated by direct instruction characters. The orientation phase aims to build the lecturer-student relationship, develop curiosity, refresh and strengthen prerequisite knowledge, and formulate problem statements. The conceptualization phase aims to comprehend the key concepts related to the problem statement, identify and formulate the research question(s) or objective(s) in accordance with the problem statement, and organize the hypothesis (if necessary).

The next three phases provide experiences for students to practice scientific inquiry. These phases are investigation, report drafting, and validation of scientific inquiry. This stage is dominated by scientific inquiry learning characters. The investigation phase is carried out in a cooperative learning format. In this phase, learners collectively identify the types of data needed to answer the research questions, how to vary the values of independent variables, how to measure data related to changes in the value of dependent variables; to process the data, to draw conclusions, to create the relationship among variables, to make sense of the relationship, and to generate explanations (Pedaste et al., 2015; Rönnebeck et al., 2016; Joi Phelps Walker & Sampson, 2013). In lectures, data are obtained from secondary sources such as books, research reports, journal articles, or learning materials that have been prepared by lecturers. The report-drafting phase is undertaken by students in group discussions. This phase aims to produce a draft report with scientific argumentation as a focus, consisting of claims (the answers to research questions), evidence that supports the claims, and explanations that describe the relevance of the evidence in accordance with the concepts and assumptions underlying them (Joi Phelps Walker et al., 2011; Joi Phelps Walker & Sampson, 2013). In the validation of the scientific inquiry phase, students present and discuss their scientific inquiry practices, such as giving criticism, evaluating, and revising arguments, and doing a reflection on their learning behaviour and outcomes (Ilie, 2014).

The last phase is enrichment. in this phase, students deepen and extend the scientific knowledge they have constructed in the previous phases. This phase is dominated by direct instruction characters. The enrichment phase is carried out in debriefing to deepen and broaden students' understanding of the essential concepts of subject matter in accordance with the curriculum content. Overall, the explicit scientific inquiry strategy represents cognitive inquiry at the guided level because it provides students with experience in designing investigations, processing data, making claims, and compiling explanations even though the data processed are secondary (Singer et al., 2006).

The science of chemical kinetics has factual, procedural, conceptual, and metacognitive knowledge (Krathwohl, 2002) that allows students to develop their understanding using cognitive abilities or scientific inquiry abilities. There are some phenomena in chemical kinetics that are related to scientific inquiry. The reactions of limestone with hydrochloric acid, sodium thiosulfate with hydrochloric acid, and hydrogen peroxide decomposition with an iron (III) chloride as a catalyst can all be used as instructional content to develop scientific inquiry understanding and abilities. Therefore, this topic and other topics in science with similar characteristics can be taught using an inquiry approach and can be used to develop and assess students' abilities and understanding of scientific inquiry.

The instruction of the chemical kinetics and other topics of basic chemistry courses was commonly carried out using two sections, namely lectures and laboratory work. The lecture section emphasizes the aspect of conceptual understanding, which is carried out using direct instruction strategies. While the laboratory work section emphasizes aspects of psychomotor skills, which are carried out using a verification approach. Both lectures and laboratory work do not emphasize the understanding and ability of scientific inquiry. The purpose of this study was to examine to what extent the explicit scientific inquiry strategy improves students' understanding of scientific inquiry. In a scientific inquiry-based lecture, students carry out all scientific inquiry activities explicitly, except for direct data collection. The used data was collected from secondary sources. The hypothesis of this research was that there was a difference in students' understandings of scientific inquiry after experiencing a scientific inquiry-based lecture compared to their initial understandings.

The learners' (Antink-Meyer et al., 2016a; Gaigher et al., 2014) and even educators' (Adisendjaja et al., 2017; Muntholib et al., 2019) understanding of the nature of science (NOS), which is one of the basic learning goals (Hodson, 2014), especially understanding of scientific inquiry, is relatively low. Inquiry-based instruction is a learning strategy that uses a learning experience to understand scientific inquiry. Meanwhile, the most broadly applied learning strategy, especially in Indonesia, is direct instruction through the lecture method. Therefore, immersion in scientific inquiry in lectures is expected to increase students' understanding of scientific inquiry. This learning innovation is expected to solve the problem of students' low understanding of scientific inquiry.

METHOD

Participants, intervention, and measurement

This study applied a one-group pretest-posttest design with three main steps: pretest, intervention, and posttest (Creswell, 2015). The study examined the changes in students' knowledge of scientific inquiry after instruction using the explicit scientific inquiry strategy. The effects of an explicit scientific inquiry strategy on knowledge about scientific inquiry were assessed after students took a five-week course on the topic of chemical kinetics. The tests on scientific inquiry understanding were administered before and after teaching intervention.

Participants of this study were selected using a convenience sampling technique (Creswell, 2015) in which the research data were collected from participants who were readily accessible to the first author, who is a member of the staff at the university where the undergraduate students were enrolled and has access to high schools through the university's preservice teacher preparation program. They consisted of 53 undergraduate students who took a general chemistry course at a public university in Malang city. Before this study began, permission to conduct the study was received from the Head of the Chemistry Department, and the students were also informed about the purpose of the questionnaire and that they had a choice whether or not to participate.

Students worked in groups of three to four. The groups addressed the same research question prepared in the learning material. The explicit scientific inquiry strategy was applied to chemical kinetics instruction for five weeks, two lessons per week with two hours per lesson. The summary of 10 meetings of lecturing activities and their relationship to the scientific inquiry aspects can be seen in the Appendix. The course began with a pre-test followed by an explanation and debriefing about prerequisite knowledge and how students learn in this strategy. Chemical kinetics instructions were carried out using learning materials that were in line with the explicit scientific inquiry strategy, a learning strategy that immersed scientific inquiry procedures in lectures. The next stage was a review of the lecture process and the strengthening of chemical kinetics knowledge, including the algorithm of reaction rate. The last stage of this research was doing a post-test.

Each cycle of explicit scientific inquiry strategy implementation required two meetings of 100 minutes each. At the first meeting, students were involved in orientation, conceptualization, investigation, and report drafting. The learning output of the first meeting was the report draft of the students' group. At the second meeting, students were involved in the presentation and enrichment. The learning output of the second meeting was an individual report, which was focused on confirming the report draft of the students' group. Individual reports were collected in the first meeting of the next cycle of instruction.

The research instrument was an open-ended questionnaire of views about scientific inquiry (VASI) on chemistry knowledge (Muntholib et al., 2019) (Supplement 1). The questionnaire was modified from a similar questionnaire on biological knowledge (J. S. Lederman et al., 2014). The questionnaire consisted of seven open-ended questions that represented eight aspects of scientific inquiry. These aspects are as follows: there is no single scientific method; scientific investigations all begin with a question; scientists performing the same procedures may not get the same results; inquiry procedures can influence the results; scientific data are not scientific evidence; inquiry procedures are guided by the posed questions; research conclusions must be consistent with the data; and explanations are developed from a combination of collected data and observations.

As in the previous research (J. S. Lederman et al., 2014), the validity of this VASI questionnaire is content validity and face validity, while its reliability is inter-rater. To ensure the instrument's content validity, a judgement of how appropriate items seem to a panel of experts in the subject matter (Wattanakasiwich et al., 2013), four chemistry education experts assessed the instrument. This validity assessment was carried out using an index of item–objective congruence (IOC) technique (Sireci, 1998). The four experts provided valid scores for all VASI items. Therefore, the instrument could be used to collect data.

The participants' responses to the VASI questionnaire were assessed by two raters independently. Each response to the eight aspects of scientific inquiry was coded as an informed, partially informed, or naïve (Supplement 2). If a view of an aspect is consistent with the accepted conception, it is coded as informed view; when a view is partially appropriate to the accepted conception, a partially informed view is used as the rating; and when a view is demonstrated as a misconception or lack of understanding, it is rated as naïve view. For the quantitative analysis, the level of informed view was given a score of 2, the level of partially informed view was given a score of 1, and the level of naive view was given a score of 0.

The reliability of the raters' assessments to the student's response was evaluated using inter-rater reliability, i.e., the level of similarity of the results assessment to a student's work carried out by two or more different raters independently using the same rubric (Leclerc & Dassa, 2010; Stemler, 2004)). The degree of reliability was determined by the consistency categories given separately by two different raters towards the same student's work. The degree of agreement between raters was calculated using the coefficient Cohen-Kappa (Landis & Koch, 2016). The strength of agreement degree between raters was determined using the Cohen-Kappa coefficient (κ) with the following criteria: very less if κ below 0.00; less if $\kappa = 0.00\text{-}0.20$; enough if $\kappa = 0.21\text{-}0.410$; medium if $\kappa = 0.41\text{-}0.60$; high if $\kappa = 0.61\text{-}0.80$; and very high if $\kappa = 0.81\text{-}1.00$. The assessment of student work carried out by two or more assessors is trustable if the value of the Kappa coefficient (κ) is greater than 0.60 (Stemler, 2004).

Data Analysis

Pair-sample inferential statistics Wilcoxon's Signed Rank Test was used to test the differences in students' understanding of scientific inquiry between before and after the implementation of the strategy. The strength of improvement from pretest to post-test was examined using Cohen's d-effect size (Leech et al., 2015) and the mean normalised gain score (Coletta & Steinert, 2020). The Cohen's d-effect size interpretations used in this research are:

smaller than typical if $d < 0.40$, typical if $0.40 \leq d < 0.70$, larger than typical if $0.70 \leq d < 0.90$, and much larger than typical if $d \geq 0.90$ (Leech et al., 2015). While the normalised average gain score is intrepreted as high for $\langle g \rangle \geq 0.7$, low for $\langle g \rangle < 0.3$, and medium for $\langle g \rangle$ in the middle (Hake, 1998). In addition, we also analysed the impact of the explicit scientific inquiry strategy on students' understanding of scientific inquiry aspects.

FINDING AND DISCUSSION

Finding

The effectiveness of the immersion of scientific inquiry procedures in lectures in enhancing students' scientific inquiry understanding was determined by the improvement of students' understanding from the lower (naïve) to the higher (informed) category. The Kappa coefficient values of assessment to the students' understanding of aspects of scientific inquiry vary from 0.68 (high) to 0.93 (very high), with an average score of 0.81 (very high). It means that all Kappa coefficient values for each scientific inquiry aspect, both pre-test and post-test, are more than 0.60. Therefore, the degree of agreement between the two raters was acceptable at a very high level (Stemler, 2004).

This research used the VASI score as the measure of students' scientific inquiry understanding. Table 1 summarises scores in terms of descriptive statistics that include minimum score, maximum score, mean, and standard deviation.

Table 1. Statistics descriptive of students' VASI scores

Statistics	Pretest (%)	Posttest (%)
Minimum	3.00	7.00
Maximum	13.00	16.00
Mean	8.96	11.38
Standard Deviation	2.27835	2.12337

Table 1 shows that students' post-test scores were higher than their pre-test scores. These data suggest that students' scientific inquiry understanding was improved from pre-test to post-test. However, the significance of the improvement needs to be tested statistically.

The Kolmogorov-Smirnov normality test showed that the posttest scores were normally distributed while the pretest scores were not. Therefore, a paired-sample Wilcoxon Signed Rank Test was employed to test the statistical significance of the mean difference between pretest and posttest. The test yielded $t(df = 51) = 5.013$, $p = 0.000$ (two-tailed)' suggesting that the hypothesis is accepted in which the mean difference between the pretest and posttest scores is statistically significant. It can be concluded that the explicit scientific inquiry strategy improved students' understanding of scientific inquiry. The analysis of the improved strength using Cohen's d-effect size gives a value of 1.10 (much larger than the typical category) that indicates a very large difference between the posttest and pretest mean scores. Meanwhile, the analysis using the normalised gain score gives a value of 0.30 (medium category), which indicates that the immersion of inquiry procedures in lectures improves students' scientific inquiry understanding with the strength of moderate.

All VASI questionnaire items are related to each other. However, to facilitate the discussion, the analysis of student responses was carried out aspect by aspect. The brief data of students' understanding of scientific inquiry aspects before and after intervention are shown in Figure 1. The figure shows that before intervention: most of the students had an uninformed (partially informed and naïve) understanding of scientific inquiry aspects; the lowest achievement was the aspect of the same procedures may not result in the same conclusions; and the highest achievement was the aspect of procedures are guided by the question; while the implementation of explicit scientific inquiry-based learning materials improves students' understanding of all aspects of scientific inquiry; the lowest improvement of students' understanding was the aspect of procedures can influence the conclusions; and the biggest improvement of students' understanding was the aspect of explanations are developed from data and what is already known. This means that instruction of chemical kinetics conducted using explicit scientific inquiry-based learning materials improves students' understanding of all aspects of scientific inquiry.

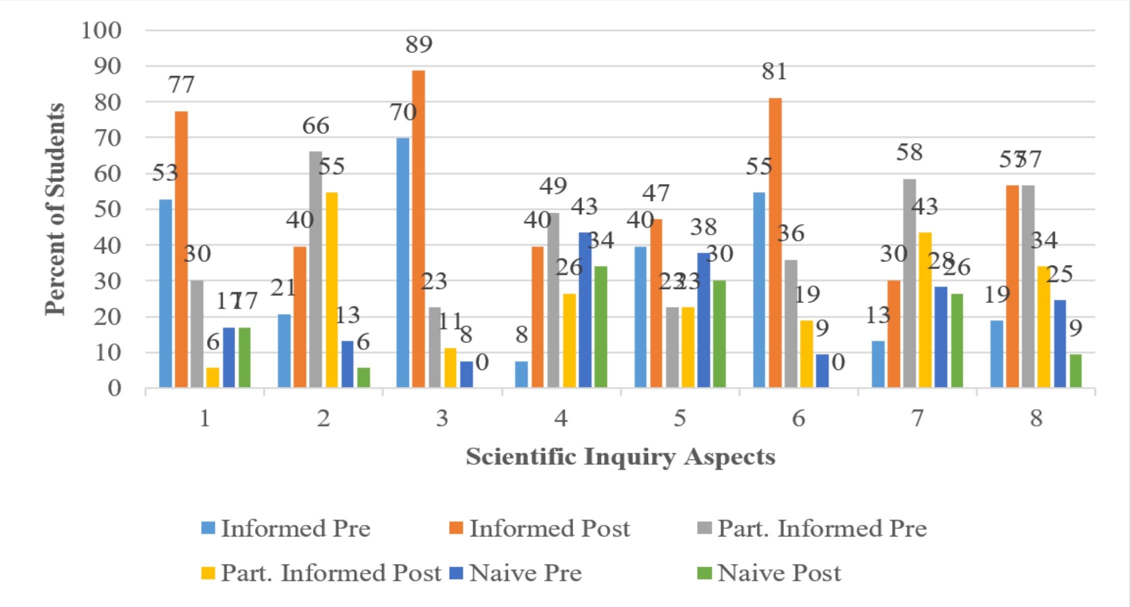

Figure 1. The Shift of Students' Understanding of Scientific Inquiry Before and after the Instruction of Chemical Kinetics Conducted Using Explicit Scientific Inquiry-based Learning Materials.

Discussion

The impact of an explicit scientific inquiry strategy on the students' scientific inquiry understanding

This research examines the impact of applying an explicit scientific inquiry strategy, an instructional strategy that immerses scientific inquiry procedures in lectures, in aims to increase students' scientific inquiry knowledge. According to Lederman et al. (2014), student understanding of scientific inquiry does not need to be quantified and analysed inferentially because numerical score provides a very limited picture of the VASI complex construct and does not provide a detailed description of respondents' conceptions. The researchers afterward (Adisendjaja et al., 201a; Antink-Meyer et al., 2016), who used the VASI questionnaire, did not do the quantification as well. However, quantification and inferential analysis are needed to investigate how the impact of an instructional method/strategy/approach on certain learning outcomes. Therefore, this study used inferential statistics to analyse the impact of the explicit scientific inquiry strategy on students' scientific inquiry understanding.

The analysis showed that the explicit scientific inquiry strategy improved students' scientific inquiry understanding. The strength of improvement was "much larger than the typical category" according to Cohen's *d*-effect size analysis (Leech et al., 2015) and "medium category" based on the analysis of average normalized gain (Hake, 1998). This improvement is higher than what has been achieved by previous instructional strategies such as direct instruction (low category) (Lederman et al., 2014); science camp (low category) (Antink-Meyer et al., 2016); and (3) teacher professional development (low category) (Adisendjaja et al., 2017). This means that the explicit scientific inquiry strategy seemed to be more effective in improving students' understanding of scientific inquiry compared to the previous studies.

The improvement of students' scientific inquiry understanding after receiving the explicit scientific inquiry strategy is related to several issues. First, students' learning experiences in the explicit scientific inquiry strategy are in line with the learning outcomes of scientific inquiry knowledge (Hodson, 2014). Second, students have sufficient prerequisite knowledge and opportunities to practise inquiry activities (Banilower et al., 2010). Third, in this instruction, the aspects of scientific inquiry knowledge are explicit for students (Leblebicioglu et al., 2017). Fourth, the feedback practise carried out throughout the learning process is effective in improving the learning outcomes (Ilie, 2014). Fifth, the repetition of inquiry practise in the lecture reinforces students' understanding (Ilie, 2014). Sixth, the application of positive student-lecturer interactions (Ilie, 2014) creates a pleasant learning atmosphere.

The students' scientific inquiry understanding before and after intervention

In addition to a general discussion about students' scientific inquiry understanding, it is useful to examine students' understanding of scientific inquiry aspects. As shown in Figure 1: the scientific inquiry aspect in which the respondents have the weakest understanding is the same procedures may not result in the same conclusions; whereas the scientific inquiry aspect which is the most understood by respondents is procedures are guided by the question; the scientific inquiry aspect in which the respondents' understanding increases the lowest is procedures can influence the conclusions; and while the scientific inquiry aspect in which the respondents' understanding increases the highest is explanations are developed from data and what is already known. These findings can be explained as follows.

The scientific inquiry aspect of procedures is guided by the question is the most understood by respondents. As many as 70% of respondents understand that inquiry procedure is developed based on the research questions. Moreover, the implementation of explicit scientific inquiry strategy-based learning materials on chemical kinetics lecture reinforces this understanding. An example of a student response that reflects a naive view is the respondent's failure to recognize the relationship between inquiry procedures and scientific questions (line 1) as follows:

Pre-instruction. A respondent was asked, "Which tire is more durable, A or B?" To answer this question, she designed an experimental], "Testing the performance of tire A in various road conditions." (Nanda, naïve view). After the intervention, her understanding changed. Only 11% of respondents have a naïve conception. Nanda's response changed to (line 2):

Post-instruction. The answer of the same respondent to the same question as before, "Testing the performance of both tires (A and B) in various road conditions because the purpose of this experiment is to compare the performance of the two tires." (Nanda, informed view)

In explicit scientific inquiry strategy instruction, students always design an investigation from the research question. Furthermore, students get feedback confirming the role of questions in scientific investigations. Therefore, after instruction, students have an informed view about the aspect.

Most students had an informed view about the inquiry aspect of the same procedure may not lead to the same conclusions. Only 8% of respondents had an informed view about this inquiry aspect. After the implementation of explicit scientific inquiry instruction, the number of respondents who had an informed view about this aspect increased to 40%. Fina's pre- and post-intervention responses reflect those typical of her classmates. The question of "Whether scientists who follow the same procedures may come to the same results?" invites the following responses from Fina on both the pre- (line 3) and post-instruction (line 4) of chemical kinetics conducted using the explicit scientific inquiry strategy.

Pre-instruction. "Yes, because if the research objectives and procedures used to obtain data are the same, they will get the same results even though the data is slightly different." (Fina, naïve view)

Post-instruction. "No, because personal views (interpretations) can be different depending on the breadth and depth of their knowledge as well as their maturity." (Fina, informed view).

Scientists may come to different interpretations of the same data (Lederman et al., 2014). Therefore, two scientists working on the same procedures may end up with different results. Differences may be influenced by their scientific background and mindset. This understanding is new for most students. Most of the students firmly understood that all scientists who performed the same procedure of investigation would also get the same data and draw the same conclusions. This naïve understanding may be firmly stored in students' memories.

The students' understanding to the inquiry aspect of the inquiry procedure could influence the result increases slightly from 40% to 47%. Rico's response below reflects a shift in understanding from partially informed (line 5) to informed (line 6).

Pre-instruction. "Yes, because experiments do not have to be done in one way but in many ways. However, they produce the same conclusion." (Rico, partially informed).

Post- instruction. "No, because different experimental procedures can produce different data, which can lead to different conclusions." (Rico, informed).

This low shift in understanding can be caused by three factors. Firstly, most students hold conceptions that the research conclusions should be in accordance with the question asked. This conception was reinforced by another scientific inquiry aspect; namely, research procedures are developed in accordance with research questions. This statement guided and reinforced students' understanding that performing different procedures of investigation would not affect the outcome because the research procedure was developed using the research question as the guideline. Secondly, all cycles of chemical kinetics lectures are carried out using explicit scientific inquiry instruction that applies to a single procedure. All cycles draw conclusions from the same data, although the claims can be different.

As a result, students do not have the experience of collecting data using different procedures or not receiving feedback that discusses the relationship between different procedures and the result of research. Thirdly, the position of knowledge of the inquiry procedure could influence the result in the learning outcome of instruction. In the instruction, this knowledge position was a nurturant effect, not an instructional effect, so students paid little attention to the knowledge. This result was like Antink-Meyer et al.'s report, which states that learners showed a low understanding of the scientific inquiry aspect of inquiry procedures that could influence the results (Antink-Meyer et al., 2016).

The respondents' understanding of the inquiry aspect of explanation is developed from a combination of data and existing knowledge underwent the most considerable improvement. The chemical kinetics lecture conducted by using explicit scientific inquiry instruction increased the number of students who had informed views from 19% to 57%. In the pre-treatment, most respondents could only make conclusions. They are not accustomed yet to using existing knowledge to make explanations. Myrinda's response below illustrates the shift in respondents' understanding from partially informed (line 7) to informed (line 8).

Pre-instruction. The installation of Rh catalyst in motor vehicle exhaust has the potential to reduce CO gas pollutant emissions into the air] because the installation of Rh in motor vehicle exhaust reduces the concentration of CO gas (emissions) and the installation of Rh in the exhaust filters CO gas thereby reducing the concentration of the gas emissions. (Myrinda partially informed)

Post-instruction. Installing an Rh catalyst in motor vehicle exhaust has the potential to reduce CO gas pollutant emissions into the air because the Rh catalyst reduces the concentration of CO gas pollutants (emission) and the Rh catalyst accelerates the reaction rate (conversion) of CO gas (to CO2gas) (Myrinda informed).

This increase can be explained for several reasons. First, this knowledge is new to most students. This is indicated by the low of students' pretest scores in which only 19% of students who have an informed view of that explanation are developed from a combination of collected data and what is already known. The instructional method that is commonly used in chemical kinetics instruction and other basic chemistry topics is direct instruction. The instruction places great emphasis on mastery (Levine, 1985) of content knowledge and psycho-motor skills but less emphasis on scientific inquiry skills. Generally, students are interested in learning new knowledge about what they can understand. Second, there is a repetition of the same activities in lecture-based inquiry, namely inquiry procedures. The construction of explanations is repeatedly carried out by students at the end of each cycle of scientific inquiry. Third, students receive support from classmates and lecturers in the lecture-based inquiry, especially in preparing explanations. Fourth, students receive feedback from the lecturer, both in the process of construction of explanation and at the end of the lecture. Students use experiences and lecturer feedback as a basis to develop explanations in the next scientific inquiry cycle.

Practical Implication

The current findings provide practical suggestions for lecturers and educators in general. First, the scientific inquiry activities can be immersed in lectures, except for direct data collection activities through measurement and observation. Second, students' achievements are in accordance with their learning experiences. The knowledge, skills, or abilities will be mastered by students if the knowledge, skills, or abilities are relevant to their learning experience. Feedback and the review of student's learning experiences are also strengthened students' understanding. The improvement of students' understanding of all inquiry aspects except “the aspect of how inquiry procedures influence the results” emphasises the importance of conforming the students’ learning experiences to the learning outcomes (Hodson, 2014). An explicit scientific inquiry strategy that provides students with a learning experience of doing and reflecting on scientific inquiry in accordance with the learning outcomes of scientific inquiry aspects therefore, the explicit scientific inquiry strategy can increase students' understanding of scientific inquiry aspects.

Recommendation and Limitation

Recommendation: In accordance with the above practical implications, we recommend immersing inquiry activities in lectures. Inquiry activities provide experiences for students to develop and understand knowledge in depth. While lectures provide insight to students on how to relate their inquiry experience to other knowledge. Inquiry activities can be enriched and strengthened with the critical thinking skills and creativity that students need to live in the 21st century. Immersing inquiry activities in lectures can develop students' scientific literacy; since knowledge about scientific inquiry overlaps with scientific competencies, which are one of the three aspects of scientific literacy (OECD, 2018). Therefore, the results of this research should be transferred to other teachings that has the similar characteristics, whether in chemistry, physics, biology, or other fields. These characteristics are those of inquiry activities including asking questions, designing investigations, collecting data from secondary sources, analysing data, and drawing conclusions (Singer et al., 2006).

Limitations: The immersion of inquiry activities in lectures can only be implemented in teaching that meets two conditions that the first, the content knowledge of the instruction covers factual, conceptual, and procedural knowledge; and the second the learning outcomes of the instruction are limited to knowledge and cognitive abilities and skills, cannot be applied in instruction that places psycho-motor abilities and skills as learning outcomes.

CONCLUSION

Implementation of the explicit scientific inquiry-based strategy in chemical kinetics improved moderately students’ understanding of all aspects of scientific inquiry with various degrees. Students' understanding of inquiry procedures can influence the result had the lowest improvement since this aspect did not appear explicitly during the course. Understanding explanations is developed from a combination of collected data, and what is already known and all scientists performing the same procedures may not get the same results achieved the greatest improvement since both aspects were new knowledge for the students. The scientific inquiry aspects of “inquiry procedures are guided by the posed question, and research conclusions must be consistent with the data collected have been common senses for the research subjects.

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