DIFFERENTIATING INSTRUCTION IN INQUIRY-BASED LEARNING TO ASSESS SCIENCE PROCESS SKILLS

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Abstract

Inquiry-based learning has been widely applied in science education to improve students' Science Process Skills (SPS). Since not all students learn at the same pace or in the same way, Differentiated Instruction (DI) is essential to ensure that all students can access and benefit from inquiry-based science education. Therefore, this paper presented an in-subject study that explores science process skills in a differentiated inquiry instruction setting. The study was conducted in an Indonesian secondary school for grade 10. Students were divided into three groups based on learning readiness. Students then studied electrolyte and non-electrolyte solutions with differentiated inquiry instructions. Data were collected through observations & worksheet assessment. The results showed that most of the students' SPS profiles were nearing mastery level, with the highest average SPS score achieved by the group with high learning readiness, while the lower learning readiness achieved the lowest average. This research contributes new knowledge to understand DI in inquiry-based learning better, resulting in meaningful implications on pedagogy and assessment in the field of SPS.

Keywords: differentiated instruction, inquiry-based learning, observation, science process skills

1 INTRODUCTION

Inquiry-based learning is a student-centered approach in which students construct knowledge by using methods similar to those used by professional scientists (Keselman, 2003). Inquiry has been cited in educational policies (European Commission, 2007; Permendikbud No. 103, 2014; National Research Council, 1996) as one of the most promising approaches for science learning. Many studies have been conducted to determine if inquiry-based learning is beneficial in science classrooms. According to various studies, inquiry-based learning has the potential to increase students' science literacy (Fang & Wei, 2010; Tornee et al., 2017), conceptual understanding of science (Af'idayani et al., 2018; Cairns, 2019; Chang & Mao, 1999; Lati et al., 2012; Öztürk et al., 2022; Supasorn & Promarak, 2015; Taylor & Bilbrey, 2012), science process skills (Af'idayani et al., 2018; Durmaz & Mutlu, 2017; Ekici & Erdem, 2020; Hiğde & Aktamış, 2022; Lati et al., 2012; Mutlu, 2020; Şimşek & Kabapinar, 2010), independent study (Tornee et al, 2017), argumentation skill (Arslan et al., 2023), attitude toward science (Şimşek & Kabapinar, 2010), STEM career interests (Hiğde & Aktamış, 2022), and motivation for STEM (Hiğde & Aktamış, 2022). As a result, even though it takes time, inquiry-based learning is a useful learning approach for the twenty-first century that can boost learning skills and encourage enthusiasm in science.
The notion of inquiry-based learning is to engage students in an actual scientific discovery process (Pedaste et al., 2015). It is important for students to understand that scientific knowledge is generated through processes of scientific inquiry. In inquiry-based learning, the goal of science education is to emphasize science as a way of thinking (Cansiz et al., 2015). Consequently, inquiry enhances science process skills (SPS). Inquiry includes a variety of science process skills such as asking questions, formulating hypotheses, planning an investigation, experimenting to collect data, and interpreting it to build arguments and coherent explanations that can help answer the questions addressed (Solé-Llussà et al., 2021).

SPS are skills that can reflect scientific attitudes in a person (Mutmainah et al., 2019). These skills are also essential for students to become scientifically literate and succeed in science-related fields. SPS are divided into basic and integrated SPS. The prerequisites for the integrated process skills are the basic science process skills. It is linked to the ability to perform empirical-inductive reasoning or Piaget's concrete operational reasoning and serves as the intellectual foundation for scientific inquiry (Beaumont-Walters & Soyibo, 2001; Germann & Aram, 1996). SPS at the basic level include observing, classifying, predicting, measuring, and communicating. Meanwhile, the integrated science process skills are used to solve problems while conducting scientific experiments, which are attributed to hypothetico-deductive reasoning or Piaget's formal operational reasoning (Beaumont-Walters & Soyibo, 2001; Germann & Aram, 1996). Identifying variables, making predictions, designing inquiry plans, graphing and interpreting data, also describing interactions among variables are examples of integrated level.

Fostering science process skills in inquiry-based learning can be challenging due to its open-ended nature and the diverse backgrounds of students. Teachers must customize learning to meet the needs of diverse students. This is due to the fact that not all learners progress at the same rate or with the same learning techniques, behaviors, or interests (Ismajli & Imami-Morina, 2018). Differentiating instruction (DI) in inquiry-based learning can help address these challenges by tailoring learning experiences to students' individual needs and interests.

The trend in education is to implement full inclusion for both students with and without disabilities (Ferguson, 2008). This trend requires teachers paying attention to the diversity of students in the classroom and responding to the needs of each learner. Since full inclusion recognizes that each person is unique, the classroom will be much diversified. Diversity in the classroom can result from a variety of factors, including diverse backgrounds and differences in learning styles, motivation, abilities, needs, and interests (Suprayogi et al., 2017)

DI believes that in order for students to learn effectively, they have to be challenged and successful (Tomlison, 2007). Thus, an appropriate challenge can be provided only when teachers pay attention to the needs of each learner in the classroom by providing differentiated instruction. This distinction is a result of teachers providing equal opportunities for learners to receive instruction that meets their needs, allowing them to maximize opportunities for growth. The development of learners' abilities or growth in a class that uses differentiated instruction is a result of providing challenges that are appropriate to the learners' circumstances. Hence, this study explored science process skills in different inquiry instruction environments.

2 METHOD

This research implemented differentiated inquiry instruction with 19 participants of senior high school students. The framework consists of three stages: (1) pre-assessment, (2) differentiated inquiry instruction (DII), and (3) post-assessment. Pre-assessment was used to identify students' prior knowledge. DII was designed to cater to student's needs based on pre-assessment data. Post-assessment was used to assess students' SPS.

The DII was given in electrolyte and non-electrolyte topics. According to Tomlison (2007), there are several foundations for designing differentiated instruction, including learners' readiness, interest, and learning profile. These three bases can be used to modify the four elements of the curriculum (objectives, content, process, and assessment). In this study, we focused on the different levels of learner readiness by differentiating the classroom learning process with three levels of inquiry. There were three tiers of instructions. Tier 1 was scaffolded instruction for groups of learners with a low readiness to learn electrolyte and non-electrolyte solutions in the inquiry environment. Tier 2, with moderate difficulty, was designed for groups of learners with a moderate level of readiness. Tier 3, with a high level of complexity, was designed for groups of learners who demonstrated a high level of learning readiness, identified by high scores on prerequisite materials. Table 1 shows the differentiating instructions in detail.
The constructivist ideas and critical phases of the learning cycle were considered when creating these worksheets. Students were exposed to the case in the first phase through some news articles regarding electrocution cases during floods, rain, and others. Then, as they reflected on their understanding, the students created questions and hypotheses. The following stage involved the design of experiments and the gathering of information from various viewpoints and sources. Students considered and analysed the data gathered. At this stage, the facilitator offered limited support to the students while they worked independently. Students then encountered novel phenomena during concept application that could challenge their initial observations. Finally, assessments were used to evaluate learning outcomes once the students had finished the worksheets.

In this study, both basic and integrated SPS were measured. Basic SPS involves observation, classification, inference, prediction, and communication. Meanwhile, integrated SPS includes interpreting data, forming questions and hypotheses, and experimenting. SPS was observed by four observers during the class and scored on the student's worksheet. The SPS's profile was interpreted verbally based on the SPS rating in Idul and Caro (2022), as shown in Table 2.

### Table 1: Differentiated Inquiry Instruction Design

<table>
<thead>
<tr>
<th>Instructions</th>
<th>Characteristic of Students</th>
<th>Differentiated Inquiry Instruction</th>
</tr>
</thead>
</table>
| Tier 1       | Students who need support in designing measurement tool to test conductivity, developing research question, its procedure to answer, and how to analyse data. | 1. An example of a research question is provided.  
2. Guided questions and circuit electricity graph are provided to design conductivity measurement.  
3. Students are assisted in analysing the data by guided questions, tables, graphs, and examples of how to fill them in. |
| Tier 2       | Students who understand how to collect data but struggle with how to interpret and analyse data require a less scaffolded version of the guided-inquiry activity. | 1. Guided questions are provided to design conductivity measurement.  
2. A table, a graph, and guided questions are provided to analyse data. |
| Tier 3       | Students who have a good understanding in electricity concept, chemical bonding, and scientific method. | Guided questions are provided to design conductivity measurement & analyse data. |

### Table 2: Science Process Skills Rating

<table>
<thead>
<tr>
<th>Score</th>
<th>Mean Range Interval</th>
<th>Descriptive Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-10</td>
<td>8.20 – 10.00</td>
<td>Mastered</td>
</tr>
<tr>
<td>7-8</td>
<td>6.41 – 8.20</td>
<td>Nearing mastery</td>
</tr>
<tr>
<td>5-6</td>
<td>4.61 – 6.40</td>
<td>Moving toward mastery</td>
</tr>
<tr>
<td>3-4</td>
<td>2.81 – 4.60</td>
<td>Low mastery</td>
</tr>
<tr>
<td>1-2</td>
<td>1.00 – 2.80</td>
<td>No mastery</td>
</tr>
</tbody>
</table>
3 RESULT

As indicated in Table 3, all students had average SPS at the near-mastery level. Meanwhile, when looking at each group, the groups working on Tier 2 and 3 were nearing mastery, while those working on Tier 1 were nearing mastery.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Verbal Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1</td>
<td>6.27</td>
<td>0.45</td>
<td>Moving toward mastery</td>
</tr>
<tr>
<td>Tier 2</td>
<td>6.56</td>
<td>0.30</td>
<td>Nearing Mastery</td>
</tr>
<tr>
<td>Tier 3</td>
<td>7.69</td>
<td>0.33</td>
<td>Nearing Mastery</td>
</tr>
<tr>
<td>All students</td>
<td>6.84</td>
<td>0.72</td>
<td>Nearing Mastery</td>
</tr>
</tbody>
</table>

There are 8 SPS measured in this study. Based on Figure 1, the observation skills in Tier 2 and 3 are nearing mastery level while Tier 1 is still moving toward mastery level. The low score of students in Tier 1 is because they did not repeat the observation to increase reliability.

The classification ability for the three groups is the same, which is at the mastery level. All three groups could identify similarities and differences between a group of solutions and use familiar categorization schemes to identify solutions. However, Tiers 1 & 2 only used observational characteristics to categorize solutions, while Level 3 used observations & concepts (degree of ionization) to classify the conductivity of solutions.

The inference ability for all groups was the same, nearing mastery level. The scores were not maximized in these three groups because they needed to set the limits of inference and provide suggestions for making further observations using inference.

Prediction ability for all groups was the same, at the level of near mastery. Based on initial observations (news about electrocution when it rains & floods) and the inferences they made, students predicted that ‘water can conduct electricity.’ At this first stage of the inquiry, students referred to water in rain and floods at the macroscopic level as a pure substance rather than a mixture, regardless of whether or not they realized that there were solutes in it.

The communication skills for all groups were the same, at a level close to mastery. However, there were slight differences in the mastery of communication skills, such as female students in all groups performing better in report writing by writing more detailed experimental procedures that would allow others to conduct similar experiments.

Tier 1 and 2 data interpretation skills are still at the no mastery level, while Tier 3 is nearing mastery. The interpretation skills that Tier 3 mastered but were not yet mastered by other groups were (1) selecting data relevant to the question being asked, (2) establishing criteria for assessing the validity, accuracy, and usefulness of data, (3) comparing similar data sets to assess the credibility of conclusions and generalizations, and (4) choosing the most acceptable interpretation among various interpretations of the same facts.

Skills in formulating questions and hypotheses Levels 1 and 2 are at the almost master level while level 3 is still at the level towards mastery. No group tried to check the effect of concentration on electrical conductivity. Tier 3 scored lower because they did not break down the broad question into components that, if explained, would add to the detailed answer.

Tier 1 experimental skills were at the Low mastery level, Tier 2 at the Moving toward mastery level, and Tier 3 at the Nearing mastery level. The low level in Tier 1 and 2 was due to the low indicator of being unable to maintain precise records of experimental methods and results, identify the factors of experimental error, and explain the experimental design's constraints.
4 DISCUSSION

This study aimed to investigate science process skills in various inquiry instructions. Result in Table 3 shown that, despite working on the most challenging worksheets, the Level 3 group got the highest average score. This highest score implies that learners are still challenged to finish the worksheet, even though inquiry aid is limited. Meanwhile, the other two groups received lower scores due to unsatisfactory data interpretation and experiment skills. According to some studies (Algiranto et al., 2019; Turiman et al., 2012), analyzing data (mainly) and experimental skills received lower scores than other skills in SPS.

Some possible explanations for the 'unsatisfactory' results in groups 1 and 2 on developing interpreting data and experiment skills are now discussed. Several students may not have been familiar with the types of tasks explored in this study (Beaumont-Walters & Soyibo, 2001). In this case, students are not used to inquiry-based learning. It is recommended that teachers refrain from expecting significant increases in experimentation abilities after only a few trials. (Lati, et al., 2012). The skills of understanding data and experimentation are integrated SPS, where basic scientific process skills must be acquired before one may regulate abstract thinking in integrated science process skills (Turiman, et al., 2012). Students in Tier 1 & 2 can accomplish fundamental SPS because of scaffolding aid. As a result, they have not fully learned basic SPS and are having problems completing performance at the integrated level. Moreover, a study reveals that more practice on simple experiments can improve integrated SPS ((Çakıroğlu, et al., 2020). In addition, scaffolding in the experimentation phase and data interpretation may still be insufficient in specificity, causing students to struggle to finish the task. This scaffolding insufficiency was obvious at data collection phase. Some learners in Tiers 1 and 2 had already given up and excused themselves to the restroom when the data-gathering stage began. This behavior supports Barker's claim (Barker, 2020) that learners are generally intelligent, but their confidence is weakened when teachers fail to provide teaching that meets their needs.

Despite the lower average SPS score, students in these two groups felt supported by the scaffolding on the worksheet they got during the learning process, allowing them to finish the learning without falling behind students in the tier 3 group. This means that the purpose of differentiated learning has been reached, which is that differentiated activities are designed to create opportunities for students to advance in terms of understanding relative to where they started (Whitwort, n.d.). This is demonstrated by the fact that students in Tier 1 have achieved nearing mastery in five SPS (classification, inference, prediction, communication, and forming questions and hypotheses). Meanwhile, students in Tier 2 have achieved nearing mastery in six SPS (observation, classification, inference, prediction, communication, and forming questions and hypotheses). While students in Tier 3 have nearly mastered seven SPS (observation, classification, inference, prediction, communication, interpreting data, and experimentation).
5 CONCLUSION AND RECOMMENDATION

Differentiated instruction (DI) in inquiry learning reveals that most students’ SPS profiles are nearing mastery, with students in the high learning readiness group achieving the highest average SPS and students in the low learning readiness group achieving the lowest average. The majority of students excelled at basic SPS over integrated SPS. The lower score in integrated SPS demonstrates that researchers must grasp students’ initial conditions to ensure that the DI prepared can optimize the entire SPS. As a result, more study on the practical diagnostic test is required before developing DI learning.

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REFERENCE LIST


