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Alternative approaches to practical work in a biology classroom – meeting the needs of our students

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Abstract: Most science teachers regard practical work as an essential requirement for science teaching. There is, however, research-based evidence suggesting that how practical work might best be assessed and carried out in high school science was still ineffective and controversial. Here, the conceptual and procedural knowledge of 110 secondary students as they carried out the practical work in science courses are explored. Regardless of the amount and details of prior instruction that the students get, the descriptive analysis method was used to investigate the extent to which students at the secondary level can both explain biological concepts and perform practical procedures after participating in practical work. A total of 30 open-ended questions were given to students after completing four practical works on the topics of cells, food testing, photosynthesis, and urine testing. Students performed slightly better in procedural knowledge (65) compared to conceptual knowledge (64), with both scores out of 100. The results thus far are consistent with findings from previous studies, which indicate that practical work lacks emphasis on the minds-on aspects. It also shows that procedural knowledge, which is not currently, summatively assessed in Indonesian school science, has not been fully mastered by students even after carrying out practical work. To address this issue, the alternative to a practical test as an indirect assessment of practical skills (IAPS) from England has been adapted to the assessment of practical work in an Indonesian classroom setting. The considerations and limitations are discussed.

Keywords: practical work; high school science; procedural knowledge; classroom assessment

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Introduction

Practical Work is an essential part of science learning. Science or Natural Sciences essentially seeks to expand students' knowledge about the natural world and, at the same time, develop their understanding of ideas, theories, and models considered important and useful by scientists to explain and predict the behavior of the natural world (Millar dan Abrahams, 2009). Teaching science is fundamentally an effort to "show" students 'something' or bring them into a situation where they can see and experience 'something' themselves.

Most science teachers view work practice activities as a crucial part of science teaching that gives meaning to science lessons. Many science teachers believe that individuals find it easier to understand and remember something they have done compared to something that has been told to them. In other words, learning by doing is more meaningful than learning by listening. Moreover, the results of the TIMSS 2007, with a sample of students from England, for example, further reinforce that students aged

13-14 mostly prefer spending their time conducting science experiments compared to other learning activities (Sturman et al., 2008; Woodley, 2009). This indicates that work practice activities play a crucial role and have significant potential as an effective way to teach science to students.

However, the beliefs of science teachers and the positive responses of students to work practice activities contrast with research findings suggesting that work practice activities in science learning are not effective and do not contribute significantly to students' conceptual mastery. Wiemans dan Holmes (2015) found that the conceptual mastery of students taking basic physics courses with laboratory work practice activities did not differ significantly from the conceptual mastery of students taking the same course without laboratory work practice activities. This fact has long been identified and has been a focus of attention for educational researchers but remains unresolved. Osborne (2015) argued that work practice activities have only a limited role in science learning and that role contains little educational value. Hudson (1996) claimed that, as in some countries, laboratory work practice activities are unproductive and confusing. For many students, what happens in the laboratory contributes little to their science learning. The fact is that students often do not learn anything – the concepts that teachers want them to learn – from laboratory work practice activities. Even several days after the practice, they are unable to explain what they have learned and the purpose of the laboratory activity (Abrahams dan Reiss, 2012; Millar dan Abrahams, 2009; Abrahams dan Millar, 2008).

The main objectives of work practice activities in science learning can be grouped into three categories: type A: illustrating ideas, type B: practicing procedures, and type C: the inquiry process (Millar dan Abrahams, 2009). Type A helps students build their knowledge of the real world and their understanding of the main ideas, theories, and models that science uses to explain phenomena in the real world. Type B helps students learn how to use scientific equipment and/or follow some standard scientific procedures. Finally, type C develops students' understanding of the scientific approach to discovery (i.e., how to design an investigation, assess and evaluate data, and process data to draw conclusions). Based on previous research findings, it can be noted that work practice activities still face difficulties in achieving type A: illustrating ideas and type C: the inquiry process goals (Wiemans dan Homes, 2015; Osborne, 2015).

Based on the above presentation, this research is conducted to determine the extent of procedural knowledge and conceptual knowledge of students after engaging in work practice activities in Biology subjects at the Junior High School (SMP) level. This research is a preliminary study to determine the appropriate design of work practice activity programs in science learning at the SMP level. Through this research, the author also wants to see if the results obtained show the same patterns as previous research when using the education setting in Indonesia (Wiemans dan Homes, 2015; Osborne, 2015).

Procedural knowledge refers to knowledge about scientific procedures or strategies for scientific inquiry and the basic thinking in doing science, such as keeping one factor constant while changing another when controlling variables, deciding how many measurements to take, and how to interpret patterns in research data and evaluate the overall investigation (Osborne, 2015; Abrahams dan Reiss, 2015).

This study presents the profile of procedural and conceptual knowledge of students after conducting laboratory practices, not just the extent to which both develop as an impact of a pedagogical learning implementation. It also proposes a form of assessment test in the form of an alternative to practical, adapted from the International General Certificate of Secondary Education (IGCSE) test, to explore students' procedural knowledge. Further explanations about the form of the alternative to practical test and its usage are discussed in the results and discussion section of this article.

Method

This research is an analytical descriptive study that depicts conceptual knowledge, procedural knowledge, and practical skills of students after engaging in laboratory practical activities. The practical activity topics covered include topics on cells, food testing, photosynthesis, and urine testing. The research subjects consist of 110 ninth-grade students from the 2015/2016 academic year who took the final practical exam in the Biology subject during the 2017/2018 academic year at a private school in Bekasi City.

For data collection purposes, four sets of essay-type tests were constructed to assess students' procedural and conceptual knowledge. Each test set contains different items. There are 7 items, 9 items, 7 items, and 7 items sequentially for the cell, food testing, photosynthesis, and urine testing topics. Some of the test items, apart from being developed by the author, were taken and/or adapted from alternative to practical questions from Cambridge checkpoint past papers as anchoring questions. Procedural knowledge indicators used to compose the test include: using tools procedures (K1), predicting/formulating hypotheses (K2), designing variations in measuring the same quantity (K3), conducting repeated measurements and averaging (K4), deciding the number of repeated measurements needed (K5), and evaluating the validity of data from two investigations of the same phenomenon (K6). Meanwhile, items for conceptual knowledge consist of basic knowledge tests on related topics (Basic Knowledge, BK) using cognitive process indicators at the understanding level (C2) ((Anderson dan Krathwohl 2001). The test was administered after students completed four practical activities on the topics of cells, food testing, photosynthesis, and urine testing. The time allocated for each test set was 30 minutes, and four test sets were given in two sessions lasting 120 minutes. The constructed sample questions are presented in Figure 1. The tests aimed to assess the extent of students' conceptual and procedural knowledge after engaging in practical activities. Additionally, students' completed lab reports for the four practical activities were also analyzed to understand the extent of students' conceptual understanding during the practical activities. The four practical activities were conducted simultaneously as the final practical exam set by the school. The collected data were analyzed both quantitatively and qualitatively. Quantitative analysis was used to calculate the average percentage scores obtained by students for each indicator, while qualitative analysis was based on the interpretation of trends indicated by the percentage for each indicator.

Akram is testing a leaf for starch.

a. What items should he select from this list of apparatus? Circle your answer.

• Beaker	* Liebig condenser	* Bunsen burner
• Test tube	* gauze (*kasa*)	* conical flask
• Microscope	* heat-proof mat	* Petridish
• Tripod	* filter funnel	* crucible

b. He will need water to perform three tasks. What are they? List them in order.

i. ______________________________

ii. ______________________________

iii. ______________________________

c. Akram is using ethanol in his test. What does he need it for?

____

d. Akram completed the first part of the test and the leaf is ready for testing for starch. What chemical reagent does Akram need to see if starch is present?

____

e. What colour is the reagent in the bottle? ______________________________

f. What colour does the reagent go if starch is present in the leaf?

____

____

g. Jamila points out to Akram that he has used a leaf from a plant that has been in a cupboard for 2 days.

What result does Jamila predict for Akram's test?

____

Explain your answer.

____

Figure 1. Sample questions constructed to test procedural knowledge

Results and Discussion

Students conducted four practical activity topics, with each topic having a duration of 30 minutes for practical work and report preparation. The four practical topics were completed within 120 minutes, covering cell topics, food testing, photosynthesis, and urine testing. Students' conceptual knowledge was assessed using two instruments: practical reports created simultaneously with the students' practical activities and a conceptual knowledge test instrument administered several days after the practical activities. The average scores for students' conceptual knowledge from the reports and the conceptual knowledge test instrument were 78 and 64, respectively, out of a maximum score of 100. A summary of the average comparison for each knowledge indicator is presented in Figure 2.

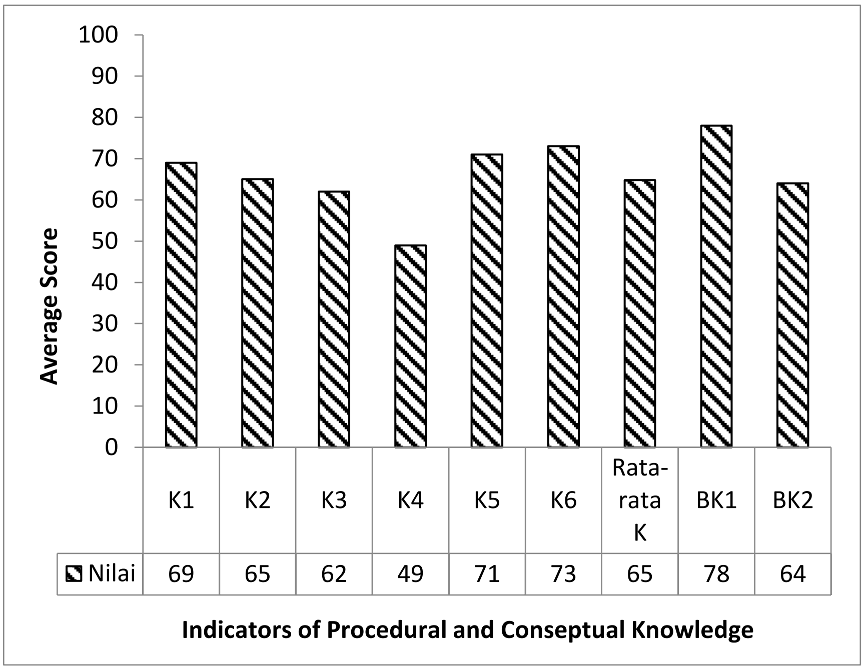

Figure 2. Summary of students' conceptual knowledge during (BK1) and after (BK2) practical activities and procedural knowledge (K) for each indicator

Students' conceptual knowledge during and after practical activities showed differences, with the test scores after the practical activities being lower. The comparison indicates that after conducting practical activities, students' test scores on basic knowledge actually decreased by 18%. Besides indicating that students' conceptual knowledge is still not optimal, this finding also provides evidence that practical activities are not fully effective and do not significantly contribute to students' conceptual mastery. This result aligns with previous research findings (Wieman and Holmes, 2015; Holmes *et al.*, 2017). However, the low attainment of students' conceptual knowledge scores and the observed decrease can be explained in relation to the form of the test assessment used to evaluate students' knowledge after the practical activities.

Before engaging in practical activities, students received assistance first. Assistance is a pre-practical activity where students are given the opportunity to try and learn the practical activity topics under the guidance of the teacher. During the practical activities, students were only given a sheet of paper containing sections of the report, such as the title, background, equipment-materials, procedure, results and discussion, and conclusion. The score for this report was taken as the students' conceptual knowledge score. After the practical activities, students were given questions about the activities they had previously undertaken. The question format was adapted from the Cambridge Past Paper, with each question constructed to be valid and reliable to meet the assessment targets set.

The unfamiliarity of the question format — previously not received or trained to students — may be a cause for the low scores in the post-practical test. Students were not accustomed to the open-ended alternative to practical questions constructed using the context of laboratory practical activities. Additionally, this result also affirms that students' procedural knowledge is not adequately trained in daily classroom learning. Further investigation is highly needed to delve deeper into this aspect.

The average procedural knowledge displayed by students was at 65, which is still considered low. The overall low average of procedural knowledge indicators is undoubtedly a consequence of the low average attainment for each indicator. This indicates that students' procedural knowledge is still low even after engaging in practical activities on the same topic. After the practical activities, many students were unable to explain what they had learned and the purpose of the laboratory activities they had undertaken (Abrahams dan Reiss, 2012; Millar dan Abrahams, 2009; Abrahams dan Millar, 2008). Thus, the results of this study align with previous research reports and further emphasize that practical activities do not significantly contribute to students' conceptual mastery (Wiemans dan Homes, 2015; Osborne, 2015; Hudson, 1996). The average indicators for each procedural knowledge are presented in Figure 2.

Figure 2 shows the highest average achievement of procedural knowledge indicators in assessing the validity of data from two investigations of the same phenomenon (K6), while the lowest average achievement is in the indicator of conducting repeated measurements and averaging (K4). All the presented results in Figure 2 explain that all procedural knowledge indicators, even after engaging in practical activities on the tested topic, show low scores because they are not explicitly and intensively trained continuously. The lack of follow-up after practical activities and/or the absence of summative tests for procedural knowledge make this knowledge not well-trained. Students are likely to forget what they learned and did during practical activities without reinforcement and repetition as follow-ups to those activities. The research results indicate that providing assistance and guidance to students during or outside class hours and providing repeated reinforcement have a significant impact on student understanding and performance (Coletta, 2014; Adey & Shayer, 2016).

Previous research reports explain the significant benefits and learning opportunities gained by students through writing laboratory report activities (Lemons, 2021; Thompson et al., 2021); Hoehn & Lewandowski, 2020). The findings of Buggé's research (2023) further support its application for high school students, stating that implementing formative assessment in the form of asking students to revise their laboratory reports can have a positive impact on the development of scientific skills (including procedural skills) for high school students. Additionally, the Indirect Assessment of Practical Skills (IAPS) from the Cambridge curriculum has the potential to be adapted. This form of assessment is a written exam that tests students' understanding of how to conduct a hypothetical experiment described with the help of diagrams and data (Ngozi, 2012). Students are required to read the measurement results presented in the diagram, tabulate, analyze, and draw conclusions. This activity can also be given as a formative assessment after students have completed a practical activity. The purpose is to assess students' understanding of the procedures and scientific reasoning at each stage of the experiment they have conducted. Based on this rationale, the activity of writing a laboratory report accompanied by formative or summative assessment testing procedural knowledge after conducting practical activities holds potential that is worthy of further investigation.

Conclusion

From the discussion presented, it can be concluded that overall, students' conceptual and procedural knowledge is still low. Procedural knowledge about assessing the validity of data from two investigations of the same phenomenon is the indicator with the highest achievement, while the indicator of conducting repeated measurements and averaging is the lowest achievement. The low level of students' conceptual knowledge is also related to the low level of procedural knowledge. This research result aligns with previous research reports and further emphasizes that practical activities do not significantly contribute to students' conceptual masteryh.

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