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The Development of a Resource Guıde in Assessıng Students' Scıence Manıpulatıve Skılls at Secondary Schools

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ABSTRACT

Manipulative skills and abilities include skills in the handling and manipulation of materials and apparatus in the context of scientific investigation. Science teachers appeared to be struggling with the mode of assessment in making authentic evaluation of manipulative skills in laboratories. One of the contributing factors is due to the lack of instrument developed to assess these skills. This paper explains the development of a resource guide in assessing students' manipulative skills at secondary schools. This study employed a qualitative research methodology. The development of a resource guide in assessing students' manipulative skills involved three phases; (i) analysis, (ii) design and development, and (iii) implementation and evaluation. The evaluation of this guide was conducted qualitatively with 40 science teachers. Findings showed that the development of this resource guide is advantageous and beneficial to facilitate teachers in determining students' manipulative skills competency during practical work so that students can be more prepared for the implementation of the upcoming science practical examination. The findings may contribute towards enriching research on assessment of manipulative skills at the secondary school level. Science educators, either pre-service or in-service, may use this resource guide to improve their instruction during practical work.

Keywords: Assessment of scientific skills, rubric development, secondary science, practical work, science manipulative skills.

INTRODUCTION

Science subject requires practical training as well as theoretical studies. Practical work is an essential part of science education and is considered as the most distinctive features of science that can ignite students' interest. Practical work in this context can be defined as any scientific activity in which learners need to be actively involved, hands-on and minds-on, to observe physical phenomena (Adlim, Nuzulia, & Nurmaliah, 2018; Allen, 2012). The aims of

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the practical work contain developing practical skills that include science manipulative skills. In this study, manipulative skills are psychomotor skills that enable students to use and handle science apparatus and specimens correctly in the approved manner. In schools, these skills are interwoven throughout the science curriculum and include diverse activities in practical laboratory work. Manipulative skills play an important role in science education, especially in higher level sciences, and these skills can only be obtained through 'hands-on' practical work. According to past studies, manipulative skills are generally given the least amount of attention in the course of academic instruction even though important aspects of learning can occur in this area (Abrahams, Reiss, & Sharpe, 2013; Ferris & Aziz, 2005; Fuccia, Witteck, Markic, & Eilks, 2012; Fadzil & Saat, 2014; Tesfamariam, Lykknes, & Kvittingen, 2015; Trowbridge, Bybee, & Powell, 2000). Students' involvement was still low in conducting experiments, and teachers do not effectively guide students (Chua & Karpudewan, 2017; Fadzil & Saat, 2014).

In order for the teaching and learning of manipulative skills to be effective, it is necessary to know what are the criteria to be assessed. One particular feature of the current assessment of manipulative skills in many countries (e.g., Malaysia) is the limited amount of direct assessment of students' practical skills. Thus, there is less inclination amongst teachers to devote time and effort in developing students' manipulative skills (Campbell, 2002; Hamza, 2013; Fadzil & Saat, 2014, 2017; Tesfamariam et al., 2015). Furthermore, a study conducted with 40 Grade 6 and Grade 7 science teachers found that teachers still have difficulties in assessing students' manipulative skills due to the lack of information (Fadzil & Saat, 2014).

The issue of practical work will become more substantial due to the comeback of the practical component of science at a national exam (*Malaysian Certificate of Education)* taken by Grade 11 secondary school students. In this practical exam, students will have to carry out experiments individually based on given instructions, and their marks will be reduced when they receive help from the invigilators. Practical science tests were carried out in the national exam until 1999 when they were replaced by written tests and continuous school-based practical science assessments in Malaysia. The reintroduction of science practical examinations have seen as an appropriate move because studies conducted on the implementation of the continuous school-based practical science assessments (Fadzil & Saat, 2014a, 2014b; Ishak, 2014; Ng, 2014) showed many weaknesses in the program which need to be given more attention. Studies also found that the factors that hinder the effective implementation of the continuous school-based practical science assessments in schools were related to the teachers' lack of competence and skills in assessment activities (Ishak, 2014; Ng, 2014). Thus, the findings of this study can be significant in providing information on the competency level of students for the implementation of the upcoming science practical examination in Malaysia, and to those nations that have similar interest.

Therefore, the purpose of this research was to develop an instrument, in this case, a resource guide to assess students' manipulative skills and find out the appropriateness of the instrument from the perspective of experienced science teachers. This research focuses on the following research question: Can the resource guide be used to determine students' manipulative skills competency during practical work based on the feedback from the experienced science teachers?

METHODOLOGY

a) Development of the Resource Guide

This paper discussed the development of a resource guide in assessing secondary school students' manipulative skills during practical work. The rubric developed in this resource guide emerged from the first part of this research, which explored students' manipulative skills in 8 schools in Selangor, Malaysia (Fadzil & Saat,2017). During the data collection phase of the research, laboratory observations of students' practical work were conducted and each student's required four individual experiments were video recorded. The students were also interviewed at least four times. The findings of the previous research showed that the majority of participants responded positively toward the practice of using and handling scientific apparatus in the science laboratory. They were cooperative in every session conducted at primary and secondary schools. However, the majority of students did not display sufficient manipulative skills during the transition from primary to secondary schools. The gap can be detected when students show no progress or even regressed in manipulative skills during the study. The findings from this qualitative research revealed that the main problem arising from the research was that most of the students were unable to master the manipulative skills in using four basic apparatus in the science laboratory, namely the measuring cylinder, thermometer, Bunsen burner, and microscope.

Responses from science teachers from the previous research have prompted a need to prepare some form of guide to be used in assessing students' manipulative skills. Thus, the researchers strongly felt that there was a necessity to prepare this rubric based on the emerging findings in order to facilitate teachers and students in establishing effective manipulative skills. Like with the preparation of any instructional materials, this resource guide was constructed based on the analysis of three instructional design (ID) models. The term ID can be defined as the systematic and organized process for analyzing, designing, developing, evaluating and managing the instructional process efficiently (Dick, Carey, & Carey, 2001; Isman, Abanmy, Hussein, & Al-Saadany, 2012). In this study, three ID models were reviewed for ideas in preparing the materials for the resource guide. The reviewed ID models were the Isman, ADDIE, and ASSURE ID models. From the analysis of the three ID models, the researchers found that ADDIE model serves as a basic framework for most of the design models and it provides an organized way to develop learning activities and instructional programs to ensure competent performance by the learners. Thus, a modified framework of the ADDIE model was implemented in this research, and then the resource guide was revised based on the evaluation process feedback. The three (3) phases of preparing the resource guide are shown in Figure 1.

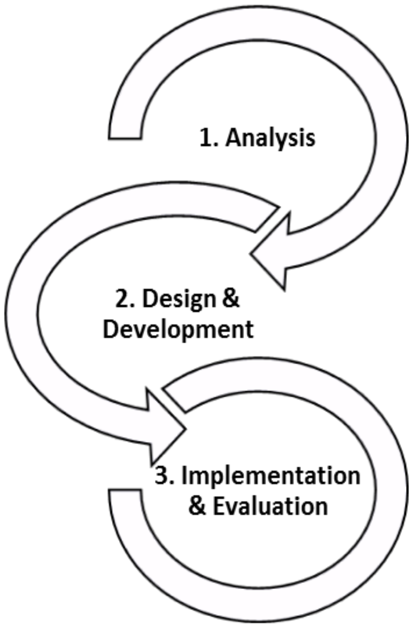

Figure 1. Modified ADDIE model implemented in the development of resource guide

The modified ADDIE model was implemented in developing the resource guide. The involved three phases were (i) analysis, (ii) design and development, and (iii) implementation and evaluation.

Phase 1: Analysis

Analysis phase was the pre-planning phase where all the related information for this research was gathered. In this research, a needs analysis was conducted in order to get a comprehensive understanding of the phenomenon. Issues related to the assessment of science manipulative skills were analyzed during the literature review. The information also emerged from the analysis of data from the first part of the research where findings showed that students confronted with difficulties in acquiring manipulative skills (Fadzil & Saat, 2017). From the understanding of the phenomenon, potential solutions for the problem can be identified. Based on the needs analysis, a resource guide was prepared.

Phase 2: Design and development of resource guide

The objectives in preparing this resource guide were to provide science teachers with an appropriate method in identifying students' level of competency in manipulative skills and a systematic rubric for the teachers in identifying students' proficiency in manipulative skills. The analysis phase indicated that there is a need to gauge the students' level of competency so that once the students' competency is determined, teachers can enhance their manipulative skills accordingly.

The resource guide has been prepared in the Malay language because the Malay language is the medium of instruction in teaching and learning of science at most of the secondary schools in Malaysia. The resource guide comprised of three main parts, which were (i) diagnostic tests, (ii) manipulative skills rubric, and (iii) description of competency level in manipulative skills. The diagnostic tests served as an instrument for systematic identification of students' problems in manipulative skills. Four activities were proposed (see Table 1). Activity A involved the use of measuring the cylinder, the thermometer, and the Bunsen burner. Activity B involved the use of a microscope, which included the preparation of slide. The apparatuses were chosen from the analysis of the related documents including the science practical textbooks, science curriculum specification, science textbooks, and science teaching and learning materials in secondary schools. The information such as learning objectives, learning outcomes, apparatus, and materials needed for the experiment, experiment procedures, and table for results were provided in the activity sheet for each diagnostic test.

For example, in Task 1, students were required to conduct an experiment to understand how the presence of salts affects the boiling point of water. The learning outcome was to measure the water temperature when impurity such as salt was added to the solution. Students' skills in using the measuring cylinder, the thermometer, and the Bunsen burner can be observed during the execution of this experiment. The apparatus and materials needed for the experiment were beakers, thermometers, Bunsen burners, measuring cylinders, tripod stands, spatulas, glass rods, lighters, candles, tongs, distilled water, and salt. A guide depicting simple procedures of the experiment for students to follow were provided. The students had to write their results in the given space and state the safety procedures they used for this experiment.

Table 1. *Activities for the diagnostic test*

Activity	Learning Outcome
Activity A: Understanding water	Activity 1: To measure the temperature of the water when it is heated Activity 2: To understand how the presence of salts affects the boiling point of water
Activity B: Science under the microscope	Activity 3: To observe the movement of microorganisms Activity 4: To understand that organisms are built from the basic units of life

The second section consists of an analysis of the manipulative skills rubric. As mentioned earlier, the criteria and categories in the rubric were based on the findings of the first part of this study which explored students' manipulative skills in using and handling scientific apparatus during the activities (Fadzil & Saat, 2017). The main categories include (a) systematic operation of a task, (b) management of time and workspace, (c) safety and precautionary measures, (d) numeracy, (e) scientific drawing, (f) technical skills in using measurement of the cylinder, thermometer, Bunsen burner, and microscope, as well as (g) the slide preparation for a specimen. There were two rubrics provided in this resource guide: rubric for Activity A and Activity B. During the execution of Activity A and B, teachers were required to observe the students' ability and give points for each criterion: low = 0 mark, intermediate = 1 mark, and high = 2 marks. The total score will reflect a student's ability in manipulative skills for each category. Table 2 summarizes the criteria for the categories in rubric A and rubric B.

Table 2. *Criteria for the categories in rubric A and rubric B*

Category	Criteria
A. Systematic operation of tasks	1. Following instructions in performing an overall operation of a task 2. Checking the functionality of apparatus 3. Communication with group members to ensure a systematic operation of a task
B. Management of time and workplace	1. Using time 2. Condition of the working area before, during, and after the

	experiment 3. Cleaning and storing of apparatus and materials
C. Safety and precautionary	1. Safety procedure during the experiment 2. The technique in using apparatus in order to prevent unwanted damage
D. Numeracy	1. Making assumptions 2. Skill in reading meniscus of measuring the cylinder 3. Skill in reading meniscus of the thermometer
E. Scientific drawing	1. Use a pencil to draw 2. Production of neat line drawing 3. Appropriate title of the drawing 4. Correct label of scientific drawings 5. Magnification of drawing is indicated 6. Authentic drawing – based on observation
F. Technical skills in using apparatus	(i) The use of measuring cylinder to measure the volume 1. Ability to recognize apparatus, their features, and functions 2. Using appropriate measuring cylinder in measuring the volume of solution 3. Placement of measuring the cylinder 4. Eye position when reading the meniscus 5. Efficiency in measuring the cylinder 6. The need for guidance (ii) The use of the thermometer to measure temperature 1. Ability to recognize apparatus, their features, and functions 2. The technique in holding the thermometer 3. Using the correct part of the thermometer to measure temperature 4. Ensuring the thermometer bulb does not touch the bottom or the wall of the beaker 5. Waiting for the temperature to be stable by stirring the solution before taking the temperature 6. Eye position when reading the meniscus 7. The appropriate way of taking the measurement of the water temperature (did not take the thermometer out from the solution) 8. Efficiency in using the thermometer 9. The need for guidance (iii) The use of the Bunsen burner 1. Ability to recognize apparatus and their functions 2. Ability to identify parts and features of apparatus and their functions 3. Manipulation of the gas hole before lighting the Bunsen burner (the collar of the Bunsen burner should be turned so that the air-hole can be closed) 4. Light up the candle/lighter before turning on the gas 5. Manipulation of air hole after lighting up the Bunsen burner (Open the air-hole, so that the flame changes to the non-luminous blue flame) 6. Efficiency in using the Bunsen burner 7. The need for guidance

	(iv) Slide preparation 1. The use of correct stain in an appropriate amount 2. The technique in using the slide cover (v) The use of the microscope 1. Ability to recognize apparatus and their functions 2. Ability to identify parts and features of apparatus and their functions 3. Handling the microscope (techniques in holding it and placing on a flat surface) 4. The use of stage clips to secure the specimen slide 5. The use of the lowest magnification power objective lens by rotating the nosepiece 6. Ability to coordinate the mirror, condenser, and diaphragm in order to get a sufficient source of light. 7. Adjustment of the coarse adjustment knob until the specimen is in focus. 8. Adjustment of the fine adjustment knob until the focused specimen is well-defined. 9. Efficiency in using the microscope 10. The need for guidance

Each of the criteria was divided into three main levels (i.e., low, intermediate, and high) of acquisition. For example, the first criteria in category A, “Systematic operation of tasks” is on student ability to follow the instruction in performing an overall operation of a task. When a student is unable to follow overall instructions and the given procedures for the experiment, the student should be considered in the “low” level of acquisition. If a student can follow the instruction and procedures but not as effective as a student in the “high” level, the student should receive the “intermediate” level. Teachers must determine the students’ level of acquisition for each of the criteria in this category and give the appropriate points: “0 mark” for students with a low level of acquisition, “1 mark” for intermediate, and “2 marks” for students in the high level. This procedure needs to be followed by the second category of “Management of time and workspace.”

The cumulative score for each category will determine students’ level of competency. This score can provide a guide for teachers in determining students’ ability in every category of manipulative skills. For example, Student A scores a cumulative of 1 mark in the first category, systematic operation of tasks. From the score guide, under this first category, “0-1 marks” is categorized as “basic level” competency, “2-4 marks” as “intermediate level” competency, and “5-6 marks” as “high level” competency. Student A can be categorized under the “basic” level of competency for this particular category. However, in using the thermometer the student may score 16 out of 18 marks which is categorized under the “high level” of acquisition of skills. From this information, student A’s secondary school teacher should acknowledge Student A’s difficulty in performing the systematic operation of tasks and can continue to improve the student’s skills in this specific category. In using the thermometer, Student A can be considered as proficient, but the teacher can analyze the criterion as there is a possibility that Student A did not stir the solution using the glass rod. From the score, the teacher can determine the student level of competency for each category and summarize the student’s level of competency.

The third section of this resource guide contains a description of each level of competency of manipulative skills. The guide describes the general criteria of a student with “low,” “intermediate,” or “high” competency of manipulative skills. It was constructed based on the research findings and the theories underpinning this research. For example, students with a high level of competency of manipulative skills demonstrate smoothness and efficiency in manipulative skills, display high skills to achieve the learning objectives and can adapt their skills to new situations. The skills can also be applied with minimum supervision. At this level, the movement is ingrained to the students' minds and most of the action is natural, where practices can enhance the students' precision and accuracy of manipulative skills.

Phase 3: Implementation and Evaluation

The following phase focuses on the implementation and evaluation of the prepared resource guide. In the evaluation phase, there was a need to critically consider the appropriateness of the resource guide to implement in the local context. The resource guide was implemented and evaluated by a group of teachers. For this purpose, a two-day workshop in a teacher training institute in Kota Bahru, Kelantan was organized. The implementation and evaluation phase were conducted in Kelantan after obtaining approvals to collaborate with the Kota Bahru Teacher Training Institute and the Kelantan State Education Department to conduct the workshop. Initially, 40 school teachers agreed to participate in a two-day workshop. However, only 39 teachers (female=24, male=15) participated in the workshop. The participated teachers' teaching experience average was 14 years in science subjects at schools. The two-day workshop included an introductory session, brainstorming session, and the evaluation of the resource guide session by the school teachers. In the introductory session, the objectives, overall procedure, and the findings of the previous study were introduced. This allowed the teachers to get a clear picture of the study and their important roles in evaluating the resource guide. In the brainstorming session, the teachers were divided into eight groups to discuss related issues and problems in teaching and assessing manipulative skills at their respected schools. After the brainstorming session, the teachers admitted that their students' manipulative skills were weak and much guidance was needed as found in the previous study. The teachers also raised the issues and challenges in teaching manipulative skills. The issues included time constraint, lack of laboratory apparatus, students' attitudes, and safety issues. During the evaluation of the resource guide session, the teachers were requested to go through the complete resource guide, conduct all activities. At the end of the session, they were asked to give feedback on the appropriateness of the resource guide during the interview sessions. The following questions were asked to each participating teacher during the evaluation phase:

1. Can you share your thoughts about the clarity of the explanations given in the resource guide? Please explain.
2. Can the suggested activities be used to determine the level of manipulative skills acquisition among the student?
3. Are the criteria for each proposed category relevant in the context of science learning at school? Please describe.
4. Are the criteria for each proposed category easy to understand?
5. Are the forms in this resource guide easy to use or do you see any difficulty in using it? Please explain.
6. Can the resource guide be implemented at schools? Why?
7. What is your suggestion to make this module more effective?

(b) Analysis of Data

In this study, data were collected from observations of teachers' in performing the activities from the resource guide and also from individual interviews. The data were collected and organized into a manageable format. All video and audio data were transcribed. These data were then analyzed qualitatively, which involved the process of coding and categorizing from information that emerged from the collected data (Strauss & Corbin, 2008). The validity and reliability of the interview protocol were done through members check where all the participants agreed to the transcribed data. Categories that emerged during the data analysis were also checked by peer review. Two science education experts were involved in the peer review. Peer review is regarded as one of the most reliable techniques used to enhance the credibility and trustworthiness of qualitative research because of its use of external experts in a given field of study (Merriam, 2009).

FINDINGS

The analysis of answers that emerged from the interviews is discussed in this subsection.

a) Clarity of the explanations

During the design and development phase, among the issues to ponder was the suitability of word and sentence structure used to construct the materials in the resource guide. The experiments should be easy to understand for students, whereas the rubrics and instruction for teachers should be well-defined so that teachers can get a clear picture of their role. As seen in the written responses, the teachers agreed that the instruction and explanations in the resource guide were clear, systematic, and suitable for the students. The following excerpts show some of the related responses.

Yes, the given explanations (in the resource guide) conform to the student's ability. (ST3)
Clear and satisfying, can assist teachers in teaching and learning of manipulative skills. (ST11)
Yes, it is systematic and helpful for teachers to identify what is to be evaluated during practical. (ST9)
The structure of the sentence and language used are simple and clear. (ST12).

b) Suitability of the activities or tasks

The teachers who participated in this evaluation phase were experts because of their vast and wide experience in teaching science, and all of them were the examiners for national examination in a science subject at the time of this study. Thus, the teachers played an important role in validating the suitability of the given tasks in determining students' level of competency. All the responses from the teachers regarding this aspect were constructive. They admitted that the activities were suitable to be used for basic experiments. From the observation of the activities, teachers were able to determine students' level of competency in manipulative skills.

c) Relevancy of the represented criteria in the rubric

The third aspect focused on the relevancy of the criteria in the rubrics in the context of science learning. The criteria were constructed based on the earlier research findings. The following excerpts illustrate the teachers' responses to the third question.

Yes, it can be used as a guide (to a teacher) and it follows the students' appropriate level of competency. (ST1)
It is relevant to the science curriculum for secondary school. (ST13)
Yes, it is relevant and follows the curriculum of secondary school. (ST4)

d) Clarity of the underlined criteria in the rubric

The science teachers' feedback as "*it is easily understood*" (ST27) and "*simple criteria, easily understood*" (ST36) indicated that the teachers had no problem in comprehending the criteria.

e) The usability of the Manipulative Skills Competency instrument

As an instructor, it is important for a teacher to be able to follow the instruction in the resource guide. The important aim of the resource guide is to determine students' ability or level of competency in manipulative skills. Thus, the appropriateness of the instrument needed to be determined. Most of the teachers found this instrument practical in term of its usability. For example, ST25 responded that "*it is suitable, systematic and can be used to determine the students' level of competency, in accordance with the criteria proposed in the rubric*". ST9 said that "*It can also guide the teachers to identify what needs to be evaluated during practical work* and ST28 indicated that the instrument was critical "*to determine which categories of skills that need improvement*" in students' ability or level of competency in manipulative skills.

f) The suitability of the resource guide to be implemented in schools

The teachers gave a warm response towards the resource guide as it *"can assist the teachers in identifying the students' competency of manipulative skills at secondary school"* (ST1). It is also "*systematic and comprehensive"* (ST9) and "*can help teachers and students to understand the concepts of manipulative skills based on the criteria proposed in the rubric"* (ST13). The resource guide can also be used to "*assist teachers in school-based assessment"* (ST32) and "*facilitate students to increase their proficiency in manipulative skills"* (ST22).

g) Improvement of the resource guide

The final question needed the teachers to give some recommendations for the improvement of the resource guide. Among the recommendations are shown below.

To add more safety measures (ST2)
To use the resource guide to support PEKA assessment (ST8)
Come out with a certificate or a form of students' manipulative skills competency at the end of every school year (ST1 & ST14).

The evaluation phase with the experts was followed by a revision of the resource guide. Most of the modifications and adjustments focused on the structure and arrangement of the resource guide to facilitate its use by science teachers. The instruction was clarified to avoid any difficulties in implementing all the resource guide materials. The workshop received positive feedback from the experts. The experts agreed that this resource guide should be implemented as it can facilitate science learning at secondary school. It is hoped that this resource guide can serve as an important instrument in bridging the gap in science practical work. Once teachers can identify the student level of competency, weaknesses, and strengths in manipulative skills, their focus can become clearer and be further improved until the students achieve the autonomic stage of performing manipulative skills.

DISCUSSION

This study explored the appropriateness of a developed resource guide in assessing secondary school students' manipulative skills from the perspective of experienced science teachers. Developing a resource guide takes a lot of effort, time, and consideration. After much deliberation, the researchers decided to use a modified framework of the ADDIE model. The ADDIE model is the systematic instructional design model that serves as a basic framework for almost all instructional design models (Isman et al. 2012). The ADDIE model provides an organized way to develop learning activity and instructional strategy to ensure competent assessment instruments can be created for the teachers.

Previous studies found that Malaysia science teachers lack competence and skills in the assessment of manipulative skills during practical work (Ishak, 2014; Ng, 2014). This is in agreement with the findings from this study where the teachers agreed that they had difficulties in assessing students' manipulative skills due to the lack of information about what skills needed to be observed during the laboratory work. The excessive number of students in the science classrooms complicates the matter. It is difficult for teachers to control the classroom. At the same time, the teachers have to ensure that each student acquires the intended manipulative skills.

Moreover, the current assessment guide for Science Practical Work Assessment (PEKA) for UPSR examination (Malaysia Examination Board, 2008) has been seen as not comprehensive enough in assessing students' skills. The current assessment guide only assesses five "constructs" of students' science manipulative skills which are (i) ability to use and handle science apparatus and substances correctly, (ii) ability to handle living and non-living specimens carefully, (iii) ability to draw specimen, apparatus, and substances correctly, (iv) ability to clean apparatus using the correct method, and (v) ability to store apparatus and substances correctly and safely (Ishak, 2014). The instrument developed in this study was based on the extensive analysis of related documents in the assessment of manipulative skills in the primary and secondary school levels. The tasks were not created to evaluate students' knowledge on the science concepts but specifically prepared to understand their manipulative skills in using and handling of the apparatus. The criteria and categories in the instrument were based on the dimensions and elements that emerged from the findings of students' manipulative skills in using and handling scientific apparatus (Fadzil & Saat, 2017). The main categories in the assessment of manipulative skills include (i) systematic operation of tasks, (ii) management of time and workspace, (iii) safety and precautionary measures, (iv) numeracy, (v) scientific drawing, (vi) technical skills in using measuring the cylinder, the thermometer, the Bunsen burner, and the microscope, and (vii) the preparation of slide for the specimen. The categories are more specific and involved more detailed criteria to guide teachers in assessing the students individually.

To address the aforementioned issues, a rubric was developed based on the emerging findings from the first part of this research. Rubrics are well known in the pedagogical plateau. Rubric are advantageous in providing teachers with a guideline to envision what is perceived as effective teaching (Sato, Wei, & Darling-Hammond, 2008) as they serve as a medium that can provide concrete evidence of what needs to be achieved. Jonsson and Svingby (2007) argued that rubrics offer teachers a roadmap to engage with what is perceived as excellent assessment behaviors and practices. According to Allen and Tanner (2006), rubrics not only can be designed to formulate standards for levels of accomplishment but can also be used to guide and improve students' performance. Teachers from this research agreed that the manipulative skills rubric that developed in this study was relevant and practical to be implemented in the context of secondary school science learning. In other words, this rubric can be used to make the appropriate standards of manipulative skills clear and explicit, not only for teachers but appropriate for the students as well. Students can get a clear sense of what the expectations are for a high level of performance and how they can be met as suggested by Huba and Freed (2000), and Luft (1999). The teachers agreed that the resource guide could be extremely beneficial in enhancing their understanding of how manipulative skills can be assessed. Moreover, the resource guide can provide information on the competency level for each student so that students can be more prepared for the implementation of the upcoming science practical examinations.

CONCLUSION

In light of the findings, it can be concluded that the development of this resource guide is advantageous and beneficial to facilitate teachers in revealing students' manipulative skills competency during practical work. Based on the positive feedback from the experts, this guide can also serve as a powerful instrument for teachers in enhancing the acquisition of science manipulative skills. The research found that minimal research attention has been directed toward exploring the appropriate assessment method in manipulative skills and issues relating to it. Teachers must be aware of the students' different abilities in manipulative skills. This means that the approach in teaching manipulative skills has to be appropriate in order to address the students' competency in handling apparatus. Innovative pedagogical approaches and effective instructional materials may be used to improve teaching and learning to enhance student learning and facilitate the acquisition of manipulative skills. Thus, more research is needed to follow up on the numerous issues raised in this study. For example, a quantitative measure can be conducted to examine the dimensions and elements transpired from this study. The validity of the findings can also be established by carrying out studies with a larger sample of students.

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