Eurasia Journal of Mathematics, Science & Technology Education, 2014, **10**(3), 209-218

Enhancing STEM Education during School Transition: Bridging the Gap in Science Manipulative Skills

Hidayah Mohd Fadzil & Rohaida Mohd Saat
University of Malaya, MALAYSIA

Received 08 August 2013; accepted 26 December 2013

The lack of exposure to practical work in primary schools leads to incompetency in manipulative skills and students may carry this problem with them to secondary school. To address this issues, an in-depth qualitative study was conducted during transition from primary to secondary school. The research involved 10 primary school students (grade 6) who were interviewed again in secondary school (grade 7). Manipulative skills during transition can be described by understanding of technical skills and functional aspects of performing laboratory tasks. Findings indicated that students' cognitive knowledge did not reflect their true ability in manipulative skills. Further collaboration between primary and secondary schools should be considered in order to bridge the gap during transition.

Keywords: experiments, functional aspect, science manipulative skills, STEM education

INTRODUCTION

In line with Malaysian aspirations to be a fully developed and industrialized nation by 2020, much emphasis has been placed on the importance of science and the effective teaching and learning of science in schools. The creation of a scientific and progressive society that is innovative, creative, and able to contribute to future technological development is high placed on the national agenda. Under the Tenth Malaysia Plan (2011-2015), the Malaysian government continues its effort toward attaining the status of K-economy (knowledge-based economy) advancing from P-economy (production-based economy). With the advent of information technology and a knowledge-based economy, the mastery of science and technology among school students is vital to produce knowledgeable and competent human capital with adequate capabilities and creativity to lead this nation in attaining developed nation status by 2020. Through science, technology, engineering and mathematics (STEM) education, technological development can be further upgraded to meet the present challenges.

Correspondence to: Rohaida Mohd Saat,
University of Malaya, 50603 Kuala Lumpur
Malaysia.
E-mail: rohaida@um.edu.my
doi: 10.12973/eurasia.2014.1071a

Science education in Malaysia is facing a great challenge. In regard to international studies, for example, the trends in International Mathematics and Science Study (TIMSS) have shown disturbing trends among Malaysian students. The findings from ~~the~~ TIMSS suggest that the declining attitudes toward science education constitute an international crisis. In Malaysia, the TIMSS science score in 2007 has decreased radically to 471 points, 40 points lower than the score of TIMSS 2003. Amongst 59 countries taking part in TIMSS 2007, the cumulative score of science achievement for Malaysia Form 2 (grade 8) students show the most significant decline compared to other countries. TIMSS 2011 revealed the same trend with science decreased to 426 points, 45 points lower than the score in 2007 (IEA, 2012).

Besides the poor performance in international studies, we also have not achieved the 60:40 policy. The Higher Education Planning Committee aims for 60% science stream and 40% art stream students at upper secondary school. This issue is clearly evident when only 20% of the 472,541 students who sat for the Malaysian Certificate of Education or commonly known as SPM (a national examination taken by all grade 11 students in Malaysia) in 2012 were science-stream students. The decrease in the number of students in the science stream is alarming. At tertiary education, statistics indicated that

ISSN: 1305-8223

State of the literature

- The common objectives of science education are to provide students with competent knowledge and scientific skills that enable them to solve problems and make decisions on scientific issues.
- Many benefits accrue from engaging students in science-practical activities. However, generally in Malaysian science classrooms, practical work is limited.
- There is consensus throughout the literature that Malaysian students have difficulties using and handling scientific apparatus proficiently.

Contribution of this paper to the literature

- The aforementioned gap in the literature is addressed in this paper by critically examining teachers' views through the lens of contemporary theories of learning
- This study provides insight on students' manipulative skills during transition from grade 6 at primary school to grade 7 at secondary school.
- Students' manipulative skills during early and late transition can be illustrated by an understanding of components and elements in technical skills and functional aspects of performing the experiment.
- Findings indicated that the progression skills demonstrated during transition was inadequate for smooth transition to learning science at the secondary school level.
- To develop manipulative skills progressively, students should be given ample opportunities to practice their skills continuously.

the inclination of students' interest is toward the social sciences, business, and law courses (Ministry of Higher Education, 2011). This trend will somehow impede our national aspirations toward "establishing a scientific and progressive society" (Mahathir Mohamad, 1993). To address this declining enrolment in STEM-related fields, science education needs to be more relevant and the program should be able to adapt to the changes in the development of science and technology. One of the most distinctive features of science that may ignite students' interest is practical work (Sorgo & Spernjak, 2012). Practical work in this context is defined as any scientific activity in which learners are needed to be actively involved to observe physical phenomena, hands-on and minds-on (Allen, 2012).

Practical work has developed tremendously over the years and has been given increasingly important emphasis around the world (Allen, 2012; Hofstein & Mamlok, 2007). Practical work emphasizes learning through inquiry-discovery in which students are encouraged to learn through the discovery of phenomenon that occurs in the environment to facilitate the acquisition of scientific knowledge and understanding of scientific theories. Through practical work, students get an opportunity to investigate phenomenon, draw conclusions, and practice the scientific skills in handling apparatus that lead to meaningful science learning and development of critical thinking skills (Yakar & Baykara, 2014).

The scientific skills in using and handling of apparatus are also known as manipulative skills. Manipulative skills are psychomotor skills that relate individual cognitive function with corresponding physical movement (Kempa, 1986). In science, it emphasizes the usage and handling of scientific apparatus and chemical substances during scientific investigation in the laboratory. In addition, students are exposed to the proper technique for using, cleaning, and storing scientific equipment safely. However, manipulative skills are generally given the least amount of attention in the course of academic instruction though important aspect of learning can occur in this area (Trowbridge, Bybee & Powell, 2000).

Laboratories can be considered as the best place to learn manipulative skills and these skills are learned as part of formal instruction in science. However, teaching and learning of science at primary level was more on retention of knowledge where students have to involve themselves with too much writing and too little practical (Campbell, 2002; Saat, 2010). In Malaysia, research in science manipulative skills is still limited and much can be done to improve students' laboratory skills, as done in many countries (Abrahams & Millar, 2011; Fuccia, Witteck, Markic, & Eilks, 2012).

This present study focuses on understanding students' manipulative skills during transition. School transition is a process of moving from the familiar to the unknown environment, something experienced by every student in their educational journey. It is an on-going process that requires time and effort for students to adjust to. In this paper, transition refers to the moving process at the end of grade 6 in primary school (early transition) to early grade 7 in secondary school (late transition). According to OECD (2006), students' interest in Science and Technology subjects may appear very early in primary schools and this phenomenon remains stable between the ages of 11 to 15. Conversely, studies have shown a significant negative impact on students' attitudes and attainment in science learning during the phase of transition from primary to secondary school (Braund, Crompton, Driver, & Parvin, 2003; Diack, 2009; Thurston et al., 2010) and the increased tendency to be negative about school were manifested in the middle of transition to secondary school. In science, this phenomenon can be exhibited by the decline in achievement and eroded interest in learning science in the middle of the school year following transition (Braund et al., 2003; Galton, Gray, & Ruddock, 2003).

Issues that arise during transition have been considered as global phenomena. Substantive progress has been achieved by developed countries in formulating and implementing specific programs to ensure a smooth progression during transition. In the United Kingdom, Galton, Gray, and Ruddock (2003) reported that a decline in the work rate and erosion of student interest rooted from the high expectation for science prior to transfer to the lack of curriculum continuity and non-harmonisation of teaching approaches. In New Zealand, Hawk and Hill (2004) reported that students found school transition very stressful and it got worse along the process. Campbell (2002) found that U.S. students reflected less positively on their experience in science learning because their expectations of learning science through the practical approach were not fulfilled. Primary school students were enthusiastic about science because of its distinctiveness and the exciting experiments. Students' expectations of science in secondary school were of using specialist facilities and apparatus, and this is what they looked forward to the most. Due to lack of practical work in science during transition, students may have to deal with problems obtaining specific skills in manipulating scientific apparatus and equipment in the laboratory.

There is an issue of backwardness or gaps in the literature on the transition process from primary to secondary school from the perspective of this country (Noraini, 2009). These issues related to transition need to be examined further and analysed in detail. Hence, scientific research needs to be done with an appropriate methodology as an eye-opener to the relevant stakeholder in the local education context. The purpose of this study is to explore and investigate the acquisition of students' manipulative skills during transition from primary school (end of grade 6) to secondary school (early grade 7) by employing a qualitative research approach. This study will therefore address the following research questions:(a) What are the students science manipulative skills during transition, and (b) What are the differences in the aspect of manipulative skills that could be identified among the students during transition?

Theoretical Framework

The theoretical framework of the present study is based on two theories: (1) the Anderson theory of skill acquisition, also known as the adaptive control of thought-rationale (Anderson, 1982) and (2) Bandura observational learning theory (1977). The acquisition of manipulative skills is associated to student's cognitive development. According to Anderson's (1982) framework of skill acquisition (ACT-R theory), there are two major stages involved in the development of cognitive skills known as: (1) declarative stage, and (2) procedural stage. These stages are based on long-term memory, declarative memory, and procedural memory. When a learner receives instruction and information about particular skills, the instruction will be encoded as a set of facts about skills. These set of facts will be interpreted further to generate desirable behaviour. The declarative stage is a cognitive stage in which processing of information is deliberate, slow, and requires complete attention. The procedural stage involves performing skill and the generation of particular behaviours that reflect knowledge from a declarative stage. In this study, the students' ability to handle scientific apparatus will be manifested in the procedural stage. During this stage, students should have the ability to apply certain skills, such as using a thermometer, appropriately based on the theoretical knowledge of using a thermometer constructed in the earlier stage.

In performing manipulative skills, observation of the skills is an essential component of learning. The teacher plays the role as a model that demonstrates and explains the appropriate skills that students should acquire in using and handling laboratory apparatus. The behaviour enacted by the teacher is coded and retained by students. This is the primary mechanism of social cognitive learning (Bandura, 1977), which stated that each individual learns from their observation of other behaviours.

Although this study is related to students' psychomotor abilities, the skills cannot be separated from students' cognitive development. The processes of learning and acquiring psychomotor skills depend on the development of cognitive abilities. ACT-R theory in this framework explains how skills are generated and acquired while Bandura's observational learning explains students' ability to process observed events.

METHODOLOGY

Participant and Context

The present study was conducted in two primary schools and two secondary schools in the Gombak district. Ten participants were purposively selected by their science teachers. The main criterion for selecting these schools is based on typical case sampling in which these schools were not unusual in any way and it reflects the average phenomenon of interest (Merriam, 2009; Patton, 2002). Students were followed from late grade 6 in primary school right through early grade 7 in the secondary level. Over these 11 months, each student conducted four individual experiments and they were video recorded while performing the tasks. They were also being interviewed at least four times.

For easier identification, the transition phase will be referred to as early transition to denote Grade 6, and late transition to denote early of grade 7 in secondary school. Preliminary study was conducted to refine the instruments (Manipulative Skills in Transition Tasks) before implementation of the instruments in the actual study and to test the MSTT for it appropriateness and usability.

Manipulative Skills in Transition Tasks (MSTT)

MSTT is a set of tasks constructed to understand students' manipulative skills during the transition from primary to secondary school. It is developed based on analysis of related documents, specifically the science practical manuals, science curriculum specification, science text books, and science teaching and learning materials for both primary and secondary level. The tasks require students manipulate four basic scientific apparatus: thermometer, measuring cylinder, Bunsen burner, and light microscope. The researchers construct these tasks because the main objective of this practical activity was to understand the students' ability in using the scientific apparatus rather than focusing on the result of the practical activity. The procedures of the experiments in MSTT have been simplified, as compared to the procedures in the text book. For example in the text book, detailed instructions was given such as 'measure 100 ml of water by using measuring cylinder' and 'stir the solution by using glass rod'. However in MSTT, the instruction; 'measure 100 ml of water' and 'stir the solution from time to time' was given instead. The MSTT consisted of two sets of activities. The first set of activities was developed for grade 6 students and the second set was for grade 7 students. The content of these tasks was based on the science curriculum specification for the respective grade. The tasks were not created to evaluate students' knowledge on the scientific concepts, but specifically developed to measure students' mastery of manipulative skills in using and handling of the apparatus.

DATA ANALYSIS

In this study, data was collected from individual observations of students performing MSTT tasks, interviews, and analyses of students' scientific drawings. Data were collected and organized into manageable format. All video and audio data were transcribed. These data were then analysed inductively using the constant comparative method of analysis, which involves the process of coding, categorizing, and the development of themes from information that emerges from the collected data (Strauss & Corbin, 2008). The detailed analysis started with the process of open coding where every transcribed observation is studied and coded to generate initial categories and to suggest relationship among categories. This is to determine the students' technique in manipulative skills during the execution of the tasks. The consistency of the observation was examined as a whole. The researchers began the analysis on small part of the data in order to generate a set of initial categories. For instance if one excerpt is given the label 'accuracy', the researchers examined the observation data for other relevant excerpts that should be given the similar code. If reference was made to the same category again, the excerpt relating to the 'accuracy' were compared and contrast in order to find out what the commonalities, differences, and the dimension of the highlighted code. During this stage, it was kept in mind on the issue of suitability of the codes used for the observation data. During analysis, questions such as, what are the characteristics of each excerpt in the same categories? What characteristics do excerpts with the same code have in common? How are all the excerpts related? Were the excerpts constantly addressed? (Boejie, 2002).

General patterns were identified to make a robust conclusion of the findings. Initially seven categories and 18 sub-categories emerged from the first level of analysis. After deliberations, the second level of analysis was constructed, comprising five categories and 11 sub-categories. The emerging categories and sub-categories were compared and refined until they were mutually exclusive.

Refining the thematic framework involves logical and intuitive thinking in ensuring that the research objectives are addressed appropriately (Ritchie & Spencer, 1994). For example, to get a general trend of technical skills required for each apparatus, this category had to be re-analysed by segregating and dissecting the data according to the apparatus, i.e., measuring cylinder, Bunsen burner, thermometer, and microscope. Again, these emerging sub-categories were compared and contrasted to identify the general trend for each apparatus. This resulted in the identification of sub-categories or elements under the component of "technical skills". The reliability or better known as dependability in qualitative paradigm of the tasks (MSTT) and interview protocols was determined by peer review and through multiple processes during preliminary study of this research. Themes and categories identified during data analysis were also judge by panel of experts. Peer review as such is regarded as one of the techniques used to enhance the credibility and trustworthiness in qualitative research, i.e. through the use of experts (Merriam, 2009). A detailed audit trail was also constructed which explain the procedures and methods conducted in this study as a way to enhance the reliability of research.

RESULTS AND DISCUSSION

Two main themes emerged as follows: (1) technical skills and (2) functional aspects of performing laboratory tasks, as represented in Figure 1. Each theme comprises components and elements of manipulative skills acquired during transition. Students' ability in mastering components and elements serve as a strong basis for them to further enhance these skills at upper secondary school. Of the two themes, this paper will only focus on the functional aspect of performing experiments. Functional aspects of performing scientific experiments can be defined as specific procedures (apart from the technical skills) which were related to the operation of manipulative skills while performing the experiments. This theme comprises four (4) components and they are (a) operation of tasks during practical work, (b) management of time and workplace, (c) safety and precautionary measures, and (d) numeracy and technique of drawing specimen.

Operation of Tasks during Practical Work

The systematic operation of tasks was characterized by the organized manner that the students illustrated during the execution of tasks in the laboratory. Systematic in this context focuses on students' methodical abilities and act as one of the most important aspects of manipulative skills to ensure a smooth execution of task. However, during transition, students displayed difficulties in following instruction and checking the functionality of apparatus before executing the task.

(a) Following instructions in performing overall operation of task

Difficulty to follow instruction in this context can be defined as the students' problem in following the experimental procedure methodically. The common mistake that most students demonstrated during transition was using the unmeasured volume of water when the instruction clearly required them to do so. The problem with following instructions also occurred in the context where students were supposed to stir the solution before taking the temperature so that the heat would be evenly and uniformly distributed. In primary school, only one student was able to follow this step every time she took the water temperature during heating, and she continued the practice through secondary school. Some of the students followed the instruction, however, they used the thermometer to stir the liquid. In using the microscope, the students again did not follow the instruction given in MSTT. Some of the students overlooked the step, especially when it involved staining of the specimen on the microscope slide so that it could be better viewed. For example during observation of the third task in MSTT, Student 4; placed the glass slide cover on the specimen. It seemed as she forgot to put the iodine solution. She pressed the glass slide with her finger. She read the given worksheet and realized that she had skipped the important step (Obs.3, Ep1, S4b)

(b)Checking the functionality of apparatus

Scientific apparatus are tools that are used to measure, observe, and gather scientific data in experiments. One of the feature of manipulative skills that emerged during this study was that most of the students were unable to ensure the functionality of apparatus before, during, and after using them. The inability to check the functionality of the apparatus brought undesirable consequence during the execution of tasks. For instance, Student 2 used the thermometer without checking it thoroughly before she started the task. She realized that the mercury column was separated when she had already immersed the thermometer into the heating water. Such ignorance jeopardized her experiment's result because she had to replace the thermometer, while at the same time she had to record the temperature of the heating water at a given time interval. Of all the students during early transition, only Student 11 was able to perform the good practice in using thermometer. He "picked up the thermometer, took a glance at the stem and examined it closely before he immersed it into the beaker to take the initial temperature of the water" (Obs.1, Ep.2, S11a). A different scenario was observed when students entered secondary school. Students displayed good practice by ensuring the functionality of thermometer. Most of them were capable of checking the functionality of the Bunsen burner during the heating of the solution, and they made efforts to adjust the flame accordingly. In manipulating the microscope, not much difference was observed during transition. Students did not bother to check the functionality of the apparatus before using it.

Management of Time and Workplace

The second component focuses on students' ability to complete tasks within the specified time frame and students' attitude in making sure that the appearance of their working area was orderly and neat, especially in the placement of apparatus.

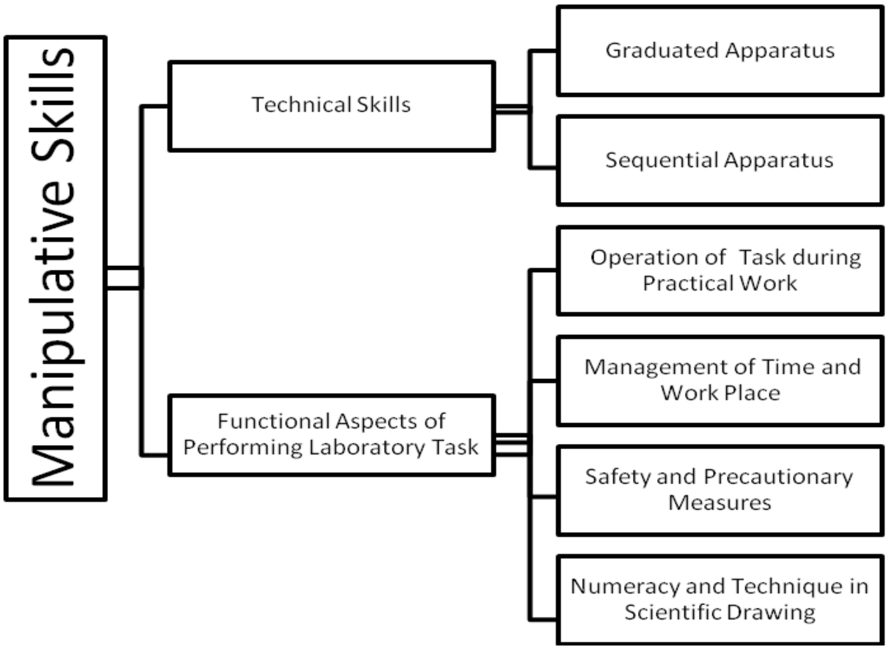

Figure 1. The themes and components of manipulative skills

(a) Efficiency in using time

Efficiency in this context can be defined as students' ability to complete the experiment methodically within the given time frame to get the best result. Someone who is efficient works well, fast, and is good at organizing his or her work. During transition, students demonstrated lack of this criterion during the performance of tasks, especially when these tasks involved the use of the Bunsen burner. This may be because of the lack of practice in using this apparatus. The following examples exhibited the observation of primary school students during the execution of tasks. They have to repeat the same procedure to achieve their target.

There was no flame. The gas was not sufficient enough to light the burner. She lit the candle again and brought it closer to the top of the barrel of the Bunsen burner. She turned the gas knob more than she did before and this time it worked. (Obs.1, Ep.2, S4a)

(b) Condition of working area

To ensure the execution of tasks to be in conducive conditions, students should make sure that their working area appearance is orderly and neat. Good utilization of available working space is one of the criteria of appropriate manipulative skills (Kempa, 1986). The disorganized placement of apparatus during experiments may impede students' work flows during the completion of a task, as illustrated in the following excerpts,

Student 1 placed the beaker on the top of the tripod stand, in the middle of the table surface, quite far from the end of the table where he stood. (Obs.1, Ep.1, S1a)

"How can I read this?" he mumbled to himself. It was difficult for him to read the thermometer because the apparatus was set quite far from the end of the table where he was standing. (Obs.1, Ep.3, S1a)

Based on the observation during late transition, it was noticed that students had improved and become more aware of employing effective management of the workplace, as demonstrated in the following excerpt,

Cautiously he poured the measured water into an empty beaker. He placed the beaker on the tripod stand. He moved the measuring cylinder, empty beaker, and the salt container further from his working area. (Obs.4, Ep.1, S7b)

Cleaning and Storing of Apparatus

The ability to clean and store apparatus after using them is one of the important elements under the effective management of workplace. It is interesting to note that during the period of transition, most students were capable of cleaning and storing apparatus after using them even though there was no clear guideline given as to how they should carry out the procedure. However, there were still some cases of ignorance in the aspect of cleaning and storing apparatus as illustrated in the following video transcript.

She left the slide on the microscope, submitted her worksheet to the teacher and started packing her belongings. (Obs.4, Ep.3, S14b)

Figure 2. Placement of thermometer after taking initial temperature of solution

Figure 3. Student 6 harshly pressed the slide cover

Safety and Precautionary Measures

This component focuses on students' safety and precautionary techniques in science laboratory during the execution of MSTT. From the analysis, two elements have been identified, the technique in using the apparatus and the handling of the apparatus and specimen.

(a) Technique in using the apparatus

Findings from the phase of early transition revealed that most of the students performed the dangerous technique of handling the apparatus, especially using the Bunsen burner; for instance, students should not have turned the gas on before lighting the candle which was used to light the Bunsen burner. Progress was observed with students in the late transition phase. Almost all of the students displayed acceptable skills in manipulating the Bunsen burner, although none of them could adjust the air hole correctly. Practically, they should close the air hole by adjusting the collar of Bunsen burner before lighting the burner and open it back up after lighting it for complete combustion to occur. In handling the thermometer, some dangerous techniques were displayed by the primary school students as illustrated in Figure 2 and the following excerpt:

He took the thermometer and placed it in the beaker. The thermometer seemed unstable but it did not bother him. (Eps.2, Obs.1, S7a)

This unsafe technique was also observed during late transition. It was clear that the students were not aware of the danger during the execution of the task. In using the microscope, most of the problems occurred during the slide preparation. During early transition, students tended to press hard on the glass slide cover instead of placing it gently when preparing the specimen (refer Figure 3). This action could also be observed during late transition.

(b) Handling of apparatus and specimens

The second element highlighted students' rough handling of scientific apparatus. Such practice can be damaging to the apparatus and the students themselves. From the observation on the conducted tasks, students had a tendency to do it unintentionally, for example, while waiting for the water to boil. The students were not aware of the danger of such actions. The notion is evident in the following excerpt,

He waited for the water to boil. Once in a while he touched the surface of the hot beaker. (Eps.2, Obs.3, S12b)

She went out to get something from her bag and left the boiling water unattended. (Eps.2, Obs.3, S14b)

Safety and precautionary measures are important aspects of manipulative skills; these measures ward off impending danger to the individual and damages to the surrounding area. Findings from the research revealed that most of the students neglected safety procedures while they were busy executing the given tasks. Students failed to foresee the consequences of the erroneous techniques. These inappropriate techniques may lead to the occurrence of unwanted incidences in the laboratory, which could be damaging not only to themselves but also to the people around them.

Numeracy and Techniques of Drawing Specimens

The findings showed that during early and late transition, the students' portrayed difficulty in numeracy and lack of proper practice in drawing specimens. Three elements emerged during the analysis of the observation transcripts and documents, as follows: the tendency to make assumption, measuring, and the skills in drawing specimens.

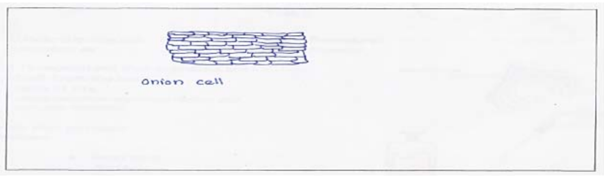

Figure 4. Student 14's actual scientific drawing

Figure 5. Student 1's actual scientific drawing

(a) Making assumptions

Based on observations of the first task, almost all of the primary school students assumed that the initial temperature of water was 0°C, whereas in reality, the temperature should be around 27°C. From the interview, they admitted that it had been a common practice for them to consider the initial reading of any measurement as "zero" without taking the initial temperature of the water.

(b) Measuring

Based on the analysis of the curriculum specification of the Malaysian Science syllabus, the technique of measuring the volume of liquids had been introduced in grade 4 under the topic of "measurement." Students had been trained on the appropriate usage of the beaker and measuring cylinder, two of the basic apparatus in the laboratory for measuring the volume of liquids. Findings from the class observation during transition indicated that students still encountered difficulty in reading the meniscus of graduated apparatus. They tended to read the upper meniscus of the liquid. In using the thermometer, some students were not able to give the correct reading of the water temperature. They recorded the water temperature as 3.0°C instead of 30°C, 3.8°C instead of 38°C. In another case, the students recorded the water temperature as 30.3°C, 50.7°C, and 60.7°C. This showed that the students were unable to connect the basic concept of heat and temperature as learned theoretically.

Although some may argue about the appropriateness of 'measuring' to be categorized as manipulative skills, the literature shows that the measuring skills in science process skills are inseparable from manipulative skills. Moni, Hryciw, Paronnik, Lluka, and Moni (2007) asserted that "to perform accurate measurement" was a component of manipulative skills in the laboratory. Doran, Fraser, and Giddings (1995) listed measuring and manipulating as specific skills in the same category as "performing."

(c) Scientific drawing

Scientific drawing helps students develop ideas and share their ideas and observation with others (Holt, 2002). There are standards as to what constitutes an acceptable scientific drawing, thus all drawings should adhere to this specific standard. However, from the analysis of related documents during the pre-research phase and the interview conducted with students and teachers, this standard had not been put forward and presented specifically in the syllabus. Thus an analysis framework was developed and used to assess the students' scientific drawings. This framework was based on a few principles in scientific drawing found in science practical manuals and criteria listed in PEKA (Assessment of Laboratory Work) by the Ministry of Education (2008).

The framework consists of seven main criteria that act as key elements in scientific drawing. The criteria include: (1) the use of a pencil, (2) the use of line drawing, (3) neatness, (4) appropriate title for the drawing, (5) indicate the magnification, (6) use of correct labels, and (7) authenticity. Line drawings in this context can be defined as drawings that consist of distinct single lines without gradations in shade or hue to represent the observed scientific specimen. Analysis of the student drawings during the phase of transition revealed that students showed different abilities and inconsistencies in drawing specimens. Findings during late transition indicated that there was not much of a progression during transition. Students used line drawings to portray their observations as presented in Figure 4 and 5. However, most of the drawings were not labelled with specimen names and magnification power. Some students used pens to draw their observations and did not label the drawings (Figure 4). They also tended to draw not proportionate drawings with reference to the drawing paper.

CONCLUSION

Manipulative skills include technical skills and functional aspects of performing laboratory tasks. The functional aspect consists of components; the operation of tasks during practical work, management of time and workplace, safety and precautionary measures, and efficiency numeracy and techniques in scientific drawings.

Findings from this study revealed that during early transition the students developed a gap in relating the theory of handling of apparatus during scientific experiments they had learned in classroom with their actual skills and abilities in performing the experiment. The gap in the functional aspects of performing laboratory tasks did not seem to get narrower during late transition. By mere knowing how to manipulate scientific apparatus theoretically will not assist students' acquisition of manipulative skills and scientific concepts as argued by Campbell (2002) that the understanding of science is achieved in the first place not by reading about theories but by performing experiments and creating concepts first-hand in the laboratory. Anderson (1982) emphasized the importance of practice as a medium for converting knowledge into procedural form. Students lack of exposure to hands-on and minds-on activities during transition could lead to the lack of the acquisition of manipulative skills during this period. To address these issues, bridging programs in science should be initiated between primary school and secondary school as done in some countries such as New Zealand and the United Kingdom (Galton, Gray, & Ruddock, 2003; Hawk & Hill, 2004). Intervention programs such as introduction to the science laboratory should also be considered as an initiative to facilitate a smooth transition in learning science.In conclusion, the results of this study have provided valuable information that supports the importance of practical work that can improve the acquisition of manipulative skills. Students' competency in manipulative skills can enhance STEM education in Malaysia. Further studies can be conducted as a follow up to this research which includes using quantitative measure to examine the dimensions and elements transpired from this study and research in other aspects of science process skills for example in communicating or measuring and using numbers.

ACKNOWLEDGEMENT

This study is supported by Fundamental Research Grant Scheme (FRGS), grant number FP077/2010A by the Ministry of Education Malaysia and University of Malaya.

REFERENCES

Adey, P., Hewitt, G., Hewitt, J., & Landau, N. (2004). *The professional development of teachers: Practice and theory.* Kluwer Academic Publishers. New York, USA.

Adler, J. (1998). Resources as a verb: Reconceptualising resources in and for school mathematics, *Proceedings of the 22nd Conference, Psychology of Mathematics Education, Vol. 1*, University of Stellenbosch, South Africa, pp. 1-18.

Allen, M. (2012). Editorial. An international review of school science practical work. *Eurasia Journal of Mathematics, Science and Technology Education*, *8*(1), 1-2.

Abrahams, I. & Millar, R. (2011). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education,* 30, 1945-1969.

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review, 89*, 369-406.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2)*,* 191-215.

Braund, M., Crompton, Z., Driver, M., & Parvin, J. (2003) Bridging the key stage 2/3 gap in science. *School Science Review, 85*(310)*,* 117-123.

Boejie, H. (2002). A purposeful approach to the constant comparative method in the analysis of qualitative interviews. *Quality & Quantity, 36*(4), 391-409.

Campbell, B. (2002). Pupils' perceptions of science education at primary and secondary school. In H. Behrendt, H. Dahncke, R. Duit, W. Gräber, M. Komorek, A. Kross, P. Reiska (Eds.)*Research in Science Education- Past, Present and Future.* Netherlands: Springer. p. 125-130.

Diack, A. (2009). A smoother path: Managing the challenge of school transfer. *Perspective in Education, 2,* 39-51.

Doran, R., Fraser, B. J., & Giddings, G. J. (1995).Science laboratory skills among grade 9 students in Western Australia. *International Journal of Science Education, 17*(1)*,* 27-44.

Fuccia, D., Witteck, T., Markic, S., & Eilks, I. (2012). Trend in practical work in German science education. *Eurasia Journal of Mathematics, Science and Technology Education*, *8*(1), 59-72.

Galton, M. Gray, J. M., & Ruddock, J. (2003).*Transfer and transitions in the middle years of schooling (7-14).Continuities and discontinuities in Learning.* Research Report, Department of Education and Skills, Cambridge, UK.

Hawk, K., & Hill, J. (2004, April).*Transition traumas, traps, turning points and triumphs: Putting student needs first.* Paper presented at The Way Forward for Secondary Education Conference, Wellington, New Zealand.

Hofstein, A., &Mamlok., R. (2007). The laboratory in science education: the state of the art. *Chemistry Education Research and Practice,8*(2)*,* 105-107).

Holt, R. W. (2002). Communicating skills: Science drawing. *Holt Science and Technology.* Retrieved from http://go.hrw.com/hrw.nd/gohrw_rls1/pKeywordResults?HS5%20SW-TOC

International Association for the Evaluation of Educational Achievement (IEA). (2012). *TIMSS 2011 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grade.* Boston, MA.

Kempa, R. F. (1986). *Assessment in Science.* Cambridge: Cambridge University Press.

Mahathir Mohamad. (1993). Malaysia: the way forward. In A. Hamid (Ed.), *Malaysia's Vision 2020: Understanding the concept, implications and challenges* (pp. 403-420). Petaling Jaya: Pelanduk Publications.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation.* San Francisco, CA: Wiley.

Ministry of Education of Malaysia.(2008). *Assessment guide for Science practical work assessment (UPSR).* Ministry of Education of Malaysia: Malaysia Examination Board.

Ministry of Higher Education Malaysia (2011).*Statistics of Higher Education of Malaysia.* Kuala Lumpur.

Moni, R. W., Hryciw, D. H., Paronnik, P., Lluka, L. J., & Moni, K. B. (2007). Assessing core manipulative skills in a large, first-year laboratory. *Advances in Physiology Education, 35*(1), 266-269.

Noraini, Z. A. (2009). *What do we mean by transition at secondary school for students with special educational needs: A case study in the Federal Territory, Kuala Lumpur, Malaysia.* Unpublished doctoral thesis, University of Warwick, United Kingdom.

OECD. (2006). *Assessing Scientific, Reading and Mathematical Literacy: A Framework for PISA 2006*. Paris, France: OECD.

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks, CA: Sage.

Ritchie, J., & Spencer, E. (1994).Qualitative data analysis for applied policy research. In A. Bryman & R. G. Burgess (Eds.), *Analyzing qualitative data*. London, UK: Routledge.

Saat, R. M. (2010). Issues in maintaining continuity and progression of students' science learning. In A. Hussain & N. Idris (Eds.), *Dimensions of education* (pp. 275-291). New Delhi, India: Gyan.

Sorgo, A., & Spernjak, A. (2012). Practical work in Biology, Chemistry and Physics at lower secondary and general upper secondary schools in Slovenia. *Eurasia Journal of Mathematics, Science and Technology Education*, *8*(1), 11-19.

Strauss, A., & Corbin, J. (2008).*Basics of qualitative research: Grounded theory procedures and techniques* (3rd ed.).Newbury Park, CA: Sage.

Thurston, A., Christie, D., Karagiannidou, E., Murray, P. Tolmie, A., & Topping, K. (2010). Enhancing outcomes in school science for pupils during transition from elementary school using cooperative learning. *Middle Grades Research Journal, 5*(1), 19-32.

Trowbridge, L. W., Bybee, R.W & Powell, J. C. (2000). *Teaching secondary school science*. Englewood Cliffs, NJ: Prentice Hall.

Yakar, Z., & Baykara, H. (2014). Inquiry-based laboratory practices in a science teacher training program. *Eurasia Journal of Mathematics, Science and Technology Education, 10*(2), 173-183.

◈◇◈