Exploring pre-university students' manipulative skills and understanding on mitosis

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Abstract

This study aimed to explore pre-university students' manipulative skills and their understanding on mitosis concept. This qualitative study was divided into two parts, the laboratory practical observation and followed by think-aloud interview protocol. Five students aged 18 to 19 years old from a matriculation college in Penang, Malaysia participated in this study. The findings revealed the participants were well equipped with manipulative skills with a very few exceptions on certain skills. The participants were also found to employ various strategies while solving the mitosis question in which reflecting their excellent understanding and solid comprehension on mitosis concept.

Keywords: pre-university, manipulative skills, mitosis, cell division

Abstrak

Kajian ini bertujuan untuk meneroka kemahiran manipulatif dan kefahaman pelajar kolej pra-universiti terhadap konsep mitosis. Kajian kualitatif ini dijalankan dalam dua bahagian iaitu pemerhatian semasa amali di makmal dan diikuti dengan protokol temubual berfikir lantang. Seramai lima orang pelajar kolej matrikulasi di Pulau Pinang berusia 18 hingga 19 tahun mengambil bahagian dalam kajian ini. Hasil kajian mendapati peserta kajian mempunyai kemahiran manipulatif yang sangat baik dengan terdapat beberapa pengecualian kepada kemahiran tertentu. Selain itu, peserta kajian juga menunjukkan kefahaman yang mantap terhadap konsep mitosis dengan menggunakan pelbagai strategi ketika menyelesaikan soalan berkaitan mitosis.

Kata kunci: pra-universiti, kemahiran manipulatif, mitosis, pembahagian sel

INTRODUCTION

Science education curriculum in Malaysia emphasised on thoughtful learning that involve scientific and thinking skills through inquiry as the main approach in scientific knowledge acquisition (Curriculum Development Division, MOE 2016). The curriculum was developed based on 3 domains which are knowledge, values and skills. To narrow it down, the skills domain comprises scientific skills, communication skills, collaboration skills, and critical and creative thinking skills. Furthermore, the scientific skills can be further classified into science process skills and science manipulative skills as shown in Figure 1.

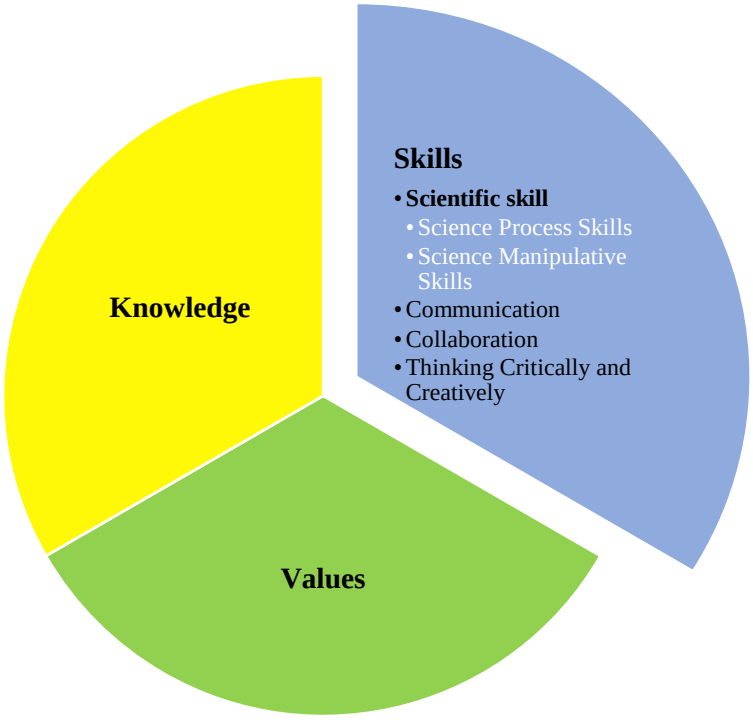


Figure 1 The science curriculum framework

From these two skills, the presence study will be discussing only on the science manipulative skills in particular. Manipulative skills by definition are psychomotor skills that relate individual cognitive function with corresponding physical movement (Kempa (1986), as cited in Hidayah & Rohaida, 2014a). The Curriculum Development Division of Ministry of Education Malaysia (2016) however defined manipulative skills as psychomotor skills that enable students to perform specific task as outlined in Table 1.

Table 1 The science manipulative skills

	SCIENCE MANIPULATIVE SKILLS
i.	Use and handle science apparatus and substance correctly
ii.	Handle specimens correctly and carefully
iii.	Draw specimens, apparatus and laboratory substances accurately
iv.	Cleans science apparatus correctly
v.	Store science apparatus and laboratory substances correctly and safely

Hidayah and Rohaida (2014b) stated manipulative skills play a critical role in science education especially in biology, chemistry and physic subjects that being taught in higher education. They also stressed these skills can only be obtained through 'hands-on' practical work. On the other hand, practical work can be defined as any type of teaching and learning activity that require students to work individually or in groups which involve manipulating and observing real objects and materials (Abrahams, Reiss, & Sharpe, 2013).

In Malaysia, most of the research related to manipulative skills are heavily concentrated on primary and secondary school students (Hidayah & Rohaida, 2013, 2014b, 2014a, 2017; Zainudin, 2015). However, research on pre-university students' manipulative skills is still limited. Thus, this present study is developed to achieve the following research objectives.

Research Objectives

i. To examine pre-university students' manipulative skills in 'Cell Division' experiment.
ii. To explore the understanding of pre-university students on the mitosis concept.

METODOLOGY

Research Design

This study employed a qualitative approach with a case study design in order to observe students' acquisition of manipulative skills during practical session and their understanding on mitosis concept.

Participant

Five pre-university students volunteered to participate in this research. They are 18 to 19 years old pre-university students that enrolled in Biology course in semester 1 of the matriculation programme.

Instrumentation

In order to examine students' manipulative skills during the mitosis experiment, an observation checklist was developed. The checklist is based on the procedure of experiment 4 (cell division) from the laboratory manual of semester I & II (Matriculation Division, 2017). The checklist consists of three parts as the following:

i. Part A : Preparation of onion root tip slide.
ii. Part B : Observing the specimen using light microscope.
iii. Part C : Cleaning up procedure and storage of microscope.

Each part consists of several steps in which represents specific manipulative skills. The participants conducted the experiment within 90 minutes time.

Right after the practical work, the participants were given a task that require them to solve a mitosis question to test their understanding on the concept of mitosis. A think-aloud interview protocol was conducted to determine strategies used by participants in solving the task. The interview protocol was video recorded for further analysis. Moreover, the participants' answer scripts were also collected at the end of the session. The recorded videos were then transcribed individually forming 5 separate transcripts. Atlas.ti 8 software was used to code the transcript and find the emerging themes across the participants.

Expert Validation

Both observation checklist and think-aloud interview protocol were sent to two experts for validation. One of the experts is an experienced biology lecturer in matriculation college with more than 10 years' teaching experience and another expert is a lecturer at School of Educational Studies in Universiti Sains Malaysia (USM) whose also previously worked as a biology lecturer in matriculation college for more than 10 years. A necessary adjustment was then made to the observation checklist and interview protocol based on the comments issued by the experts.

RESULTS AND DISCUSSION

Observation of Manipulative Skills

As mentioned before, the observation of the manipulative skills was performed using an observation checklist. Part A consist of 14 steps (labelled as A1 to A14), part B consist of 6 steps (B1 - B6) and part C consist of 7 steps (C1 - C7) (see Appendix A for the detail information). All 27 steps demonstrating 5 different skills. Table 2 show the steps involved in demonstrating different manipulative skills.

Table 2 Steps in the checklist with the associated manipulative skills

Manipulative Skill	Steps
Use and handle science apparatus and laboratory substances correctly.	A1, A4, A5, A11, A12, A13, B1, B2, B3, B4, B5 (11) *
Handle specimens correctly and carefully.	A2, A3, A6, A7, A8, A9, A10, A14 (8)
Draw specimens, apparatus and laboratory substances accurately.	B6 (1)
Clean science apparatus correctly.	C1, C3 (2)
Store science apparatus and laboratory substances correctly and safely.	C2, C4, C5, C6, C7 (5)

Notes:
***Number in bracket in the step's column (e.g. (11)) refer to total number of steps for each manipulative skill.*

The outcome from the observation of the participants during the experiment is best summarised in Table 3.

Table 3 Frequency of manipulative skills performed by all participants

	Frequency of Manipulative Skills Performed				
Manipulative skills	***P1**	**P2**	**P3**	**P4**	**P5**
***M1**	1.00	0.91	0.73	1.00	1.00
***M2**	1.00	1.00	1.00	1.00	1.00
***M3**	1.00	1.00	0.00	1.00	1.00
***M4**	1.00	1.00	1.00	1.00	1.00
***M5**	1.00	1.00	1.00	1.00	1.00

Notes:
*P1-5 stand for participant 1-5
*M1 = Use and handle science apparatus and laboratory substances correctly
*M2 = Handle specimens correctly and carefully.
*M3 = Draw specimens, apparatus and laboratory substances accurately.
*M4 = Clean science apparatus correctly.
*M5 = Store science apparatus and laboratory substances correctly and safely.

Most participants (P1, P4 and P5) exhibit excellent practice of manipulative skills during the experiment. However, participant 2 and 3 showed a slightly lower performance compared to their peers. Both experienced difficulties in using and handling the light microscope. In addition, participant 3 could not draw the correct scientific drawing as she failed to produce a clear image using the light microscope.

Think – Aloud Interview Protocol

To explore participants' understanding on the concept of mitosis, a think-aloud interview protocol was employed. From the interview, the understanding of the participants on mitosis is gauged based on the strategy utilised to answer the question. It is found that the participants shared few common strategies in solving the mitosis question.

Keyword identification

Most of the participants begin to answer the question by identifying the main keywords in the questions. Participant 1, upon reading the question had the following response;

> 'Okay, I underline the percentage of cells. Then, the chromosomes are visible and consist of two sister chromatids joined together'

Participant 5 also had a similar response as in the following transcription;

> 'Okay, I underline the percentage, visible and two sister chromatids'

Drawing idea

However, some participants were initially not sure how to begin the task, hence require some assistance from the interviewer. Eventually, interviewer led the participants to identify the keywords, and later some of them managed to draw the idea as demonstrated by Participant 5;'

> 'We need to identify the stage where the chromosomes are visible and have two sister chromatids joined together. Should I draw?'

Applying knowledge

In addition, participants exhibit the ability to recall and apply their existing knowledge that suit the requirement of the question. For an instance, Participant 5 in her response showed that;

> '(In) Metaphase (chromosomes) visible and have two sister chromatids. Anaphase (chromosome) also visible but do not consist of two sister chromatids as they are separated and move to the opposite pole. (Chromosomes in) Telophase are also visible but only consist of one sister chromatid. Oh... meaning that the percentage can be calculated by taking into account prophase and metaphase only'

Besides, by recalling and applying the existing knowledge, the participants were able to notice and correct the mistake they made. Participant 4 initially include anaphase in her answer but later correct her answer after second thought.

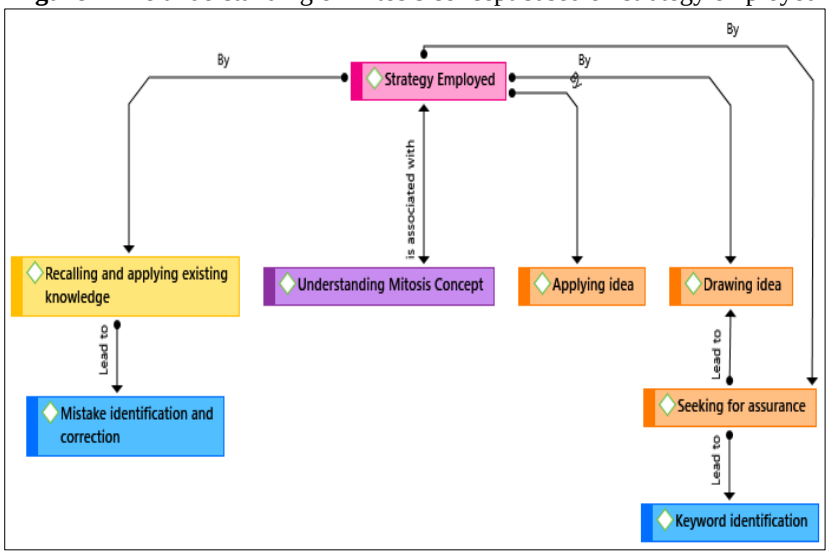
> 'Anaphase no longer has two sister chromatids as they are already separated become one sister chromatid. Okay, I need to remove 10 chromosome and calculate again'

As the interview was progressing, they began to apply the idea they had from the previous steps. For an example, Participant 3 had the idea of calculating the percentage after she identified prophase and metaphase as the stages where chromosomes are visible and consist of two sister chromatids;

> '74 (number of chromosome) plus 18 divides by total number of cells, times 100'

The emerging code from the interview is best summarised in Figure 2.

Figure 2 The understanding of mitosis concept based on strategy employed



CONCLUSION

All in all, it is found that the pre-university students in this study exhibit a well-equipped manipulative skill except for few skills that relate to the usage of light microscope. Besides, in term of pre-university students' understanding in mitosis concept, the participants in this study comprehend an excellent understanding in mitosis concept. This study successfully captured variety of strategies used by them that finally lead to the correct answer. Finally, to seek deeper understanding in this area of research, future research might replicate this study for different experiment that cover all manipulative skills adequately and also use more complex question to map students' cognitive ability.

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APPENDIX A

Observation Checklist: Steps and Associated Manipulative Skills

Procedure	Manipulative Skills
Part A: Preparation of onion root tip slide.	
1) Student excises 1-2 mm of onion root tip using a knife / scalpel on a white tile.	Use and handle science apparatus and laboratory substances correctly.
2) Student places the root tip on a watch glass.	Handle specimens correctly and carefully.
3) Student adds: a. 3 drops of aceto-orcein and; b. a drop of HCl onto the watch glass.	
4) Student light up the spirit lamp using matches/ lighter.	Use and handle science apparatus and laboratory substances correctly.
5) Student holds the watch glass using test tube holder.	
6) Student gently heat the preparation by moving the watch glass above the flame for 30 seconds.	Handle specimens correctly and carefully.
7) Student adds another 2-3 drops of aceto-orcein.	
8) Student allow the preparation to cool for 1 minute.	
9) Student transfer the root tip onto a clean slide.	
10) Student adds another 2-3 drops of aceto-orcein.	
11) Using the tip of a needle, student teases the root tip on the slide.	Use and handle science apparatus and laboratory substances correctly.
12) Student place a cover slip on the preparation.	
13) Student removes the excessive stain on the slide by pressing a filter paper on the preparation.	
14) Student heats the slide for 4 seconds at the end.	Handle specimens correctly and carefully.

Procedure	Manipulative Skills
Part B: Observing the specimen using light microscope.	
1) Student ensure: a. the stage of the microscope is at the lowest position. b. The 4x objective lens is in focus.	Use and handle science apparatus and laboratory substances correctly.
2) Student place the prepared slide on the stage.	
3) Student moves the stage upward using the coarse focusing knob.	
4) Student adjust the stage slowly using coarse focusing knob and focus the image using fine focusing knob.	
5) Student continue to focus the image using 10x and 40x objective lens.	
6) Student records the observation by drawing the image of cells at different phases of mitosis.	Draw specimens, apparatus and laboratory substances accurately.
Part C: Cleaning up procedure and storage of microscope.	
1) Student washes the watch glass and used slide carefully.	Clean science apparatus correctly.
2) Student returns back the materials and apparatus into the provided basket.	Store science apparatus and laboratory substances correctly and safely.
3) Student cleans up the working area.	Clean science apparatus correctly.
4) Student switch off the microscope.	Store science apparatus and laboratory substances correctly and safely.
5) Student ensure: a. the stage of the microscope is at the lowest position. b. The 4x objective lens is in focus.	
6) Student wrap the wire cord around the base of the microscope.	
7) Student store the microscope in the cupboard.	