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Students' Understanding of the Basic Concepts of Matter and Particle in Malaysian Science Education

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ABSTRACT

Background: Although the concepts of matter and particle are learnt throughout the schooling years, students have been found to have difficulties in grasping these scientific concepts and many regard science as one of the most difficult subjects in school. While the reasons for this phenomenon vary from the abstract nature of science's various concepts to the difficulty of the language of science itself, educators around Malaysia are beginning to worry that if nothing is being done to improve this troubling matter, it shall only worsen with time. Objective: This quantitative study aims to identify the level of understanding of the basic concepts of Matter and Particle (i) between male and female students and (iii) among Malay, Chinese and Indian students in Penang, Malaysia. Results: It was found that, in general, students have a good level of understanding of the basic concept of matter. However, their level of understanding of the basic concept of particle is rather weak. Results also showed that there was a significant difference in the level of understanding of basic concepts of matter and particle between male and female students. However, there is practically no difference between the level of understanding of the concepts of matter and particle amongst Malay, Chinese and Indian students. Conclusion: Students, as well as teachers, need to be aware of the concerning issues so that they can play active roles to improve these situations.

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INTRODUCTION

The concepts of matter and particle at the secondary level of Malaysian education system are embodied in the theme of 'Substance and Nature', and is one of the nine major themes highlighted in the school science curriculum in Malaysia (Ministry of Education, 2001). It is taught as a singular subject called "science" from the form one level, right through to the end of school, which is normally at the form five level. The theme provides a framework of concepts that enables the student to understand the world around them. This includes the study of the structure and properties of matter and particle, as well as various materials (Ministry of Education, 2001).

Although the theme is learnt throughout the schooling years, students have been found to have difficulties in grasping these scientific concepts and many regard science as one of the most difficult subjects in school (Tsai, 2009; Jonathan & Hsin, 2003; Liu, 2006; Ozmen, 2009; Nurdiana, Syuhaida & Johari, 2013). Although the reasons for this phenomenon vary from the abstract nature of science's various concepts to the difficulty of the language of science itself, educators around Malaysia are beginning to worry that if nothing is being done to improve this troubling matter, it shall only worsen with time. School science learning is expected not only be able to produce a scientifically literate generation, but also dedicated and innovative professionals (Ministry of Education, 2001).

Problem Statement:

Teachers have always felt that the concept of matter and particle is an important component to be mastered at both the primary and secondary school science curriculums (Snir, Smith & Raz, 2003; Treagust *et al*., 2010). However, even if students have studied the formal concepts of matter and particle in the classroom, they still encounter huge difficulties in using these concepts in real life situations (Jonathan & Hsin, 2003; Liu, 2006; Tsai, 1999). Students are generally found to have difficulties in grasping the idea that matter is composed of fine particle (Mohd Bilal Ali & Norida, 2010). Other frequent problems encountered by students in learning this

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concept include the concept of formation of matter and particle as well as the existence, difference and change of the three states of matter (Nakhleh, 1992; Lee *et al*., 1993; de Vos and Verdonk, 1996; Ozmen, 2009; Nurdiana, Syuhaida & Johari, 2013). Generally, students fail to master this concept due to their inherent weakness in understanding that most of what they know as 'the world' cannot be seen with just the naked eye (Ben-Zvi *et al*., 1987). To cater these problems, it is important for teachers to explore how much students understand this concept as this will assist teachers and educators to plan a better teaching strategy. Since students are different in many ways, the crucial initial step is to look at the difference between gender and ethnic.

Literature review:

A matter is a substance that has mass and fills a void (or space). In other words, matter has mass and also volume. All living and non-living things on Earth are considered as "matter", because each and every one of them has mass and fills a certain void/space. Humans, animals, plants, stones, books, desk are examples of matter because they all have mass and fill a void. Matter exists in three main states: solid; liquid; and gas. Solid has a fixed volume and shape, while liquid has only a fixed volume but no specific shape, and gas does not have any specific shape or volume. The arrangement, movement and energy particle can explain the phenomenon involving 'Three States of Matter'.

According to the kinetic theory, matter consists of small and discrete particle. These small particle, commonly known as atoms, are the basic units of matter. In daily life, there are many circumstances which can cause matter to change from one state to another. For instance, water exists in liquid state at room temperature. When it is cooled down to a certain temperature, for example 0 degrees Celsius, water then turns into ice. When it is heated to a temperature of 100ºC, it will turn into steam. Ice is water in the solid state, while steam is water in the gas state. The concept of particle is important to explain the changes that occurs in three states of matter, such as the movement of the particle in the solid, liquid and gas states. In everyday life, it is important to understand these phenomena.

Matter and particle are one of the most important topics taught in secondary schools in Malaysia (Mohd Yusof *et al*., 2002). To better understand science concepts, students should have a solid knowledge of these concepts first (Douglas, 1996). Therefore, in the Malaysian education system, students are introduced to the basic concepts of matter and particle from form one right through to form five. Matter and particle are also taught to the science stream students in the subjects of Physics and Chemistry. They serve as basic explanation for further science-related concepts (Haidar & Abraham, 1991; Gabel, 1993; Harrison & Treagust, 2002). Therefore, it is crucial for students to master the basic concepts of matter and particle. Failure to understand the basic concepts of matter and particle at the early stages of their studies will affect their future education in science (Snir, Raz & Smith, 2003).

Students in general have also been found to hold misconceptions about the concept of matter and particle. Studies showed that their existing knowledge of the concept is a lot different from the accepted scientific knowledge (Feynmen, 1995). According to Osborne and Whittrock (1983), these misconceptions have been built based on students' perceptions and experiences before they enter the school, as well as learned formally in the class. Most of the alternative concepts built by students are consistent and hard to change, if students are still taught via the common methods practiced in schools (Helm & Novak, 1983; Driver *et al*., 1985). The dispute between the alternative ideas and scientific ideas have created difficulties for students to master these concepts. For that reason, the majority of students tend to choose the easy way to learn these concepts, i.e. via memorizing, without understanding it (Syarifah Maimunah, 2003).

Table 1 shows the characteristics of matter and particle according to the scientific framework and students' alternative framework extracted by Adadan (2006).

Table 1: Characteristics of matter and particle - the scientific framework versus students' alternative framework.

Scientific framework	Alternative framework
Matter is made up of small particles and discrete gates.	Matter does not consist of small particles and discrete gates.
Particles are in a state of continuous movement or vibration in all the three state of matter.	Particles are static, especially in the solid state.
There is no other materials exist between particles of matter.	Students commonly believe that air exists (or other material) between the particles.
The distance between solid and liquid particles are the same.	The distance for liquid particles are between the distance of solid particles and gas particless.
There is an attraction between the particles.	There is no attraction between the particles.
The macroscopic characteristics among the three states of matter are different and cannot be associated with the microscopic characteristics	Students tend to describe the macroscopic characteristics in the microscopic features.

Source: Adapted from Adadan, 2006

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There are also several other factors that influence students' understanding of the basic concept of matter and particle. Studies showed that in general, students possess a good conceptual understanding of matter (Ross & Munby, 1991; Nakhleh, 1992; Sisovic & Bojovic, 2000; Ozmen & Kenan, 2007) but have difficulties in learning the concepts of particle (Ben-Zvi, Eylon & Silberstein, 1987; O'Conner, 1997). They normally hold alternative conceptions about the microscopic and submicroscopic level of particle such as the arrangement and relative spacing between the particle in three states of matter, the movement of water particle and solid particle in a liquid and the movement and uniform distribution of liquid molecules in another liquid (Ozmen, 2009; Nurdiana, Syuhaida & Johari, 2013).

World trends reveal mixed results with regards to students' gender and ethnic gap in science achievement. Most previous studies showed that female students underperform male students in learning science (Hedges & Nowell, 1995; Burkam, Lee & Smerdon, 1997; Hyde, Lindberg, Linn, Ellis & Williams, 2008; Lindberg, Hyde, Peterson & Linn, 2010). Gender differences were found to be related to (a) subject matter (life versus physical science), (b) student ability level, and (c) frequency of hands-on lab opportunities (Burkam, Lee & Smerdon, 1997). However, recent studies have shown that there is, in fact, a limited influence by gender on students' performance in science, which is in contrast to previous studies that show that the difference among ethnics is still pronounced (Greenfield, 1998; Caygill, 2008; Quest, Mineo & Higgins, 2013; Garrison, 2013). In many cases, certain ethnic groups have been found to outperform the others in the matter of science achievements. (Greenfield, 1998; Quest, Mineo & Higgins, 2013; Garrison, 2013).

A study done in a local context by Siti Zubaidah (2010) found that there is no significant difference between the level of understanding of the science concepts among male and female students, as well as among Malay, Chinese and Indian students. The results are in-line with the findings of Mohd. Yusof *et al*. (2002), who found that there is no significant difference between the level of understanding of scientific concepts by gender (Mohd Yusof *et al*., 2002). However, Esah (2003), found that the ability of students in understanding scientific concepts are influenced by the background of the students, such as gender and ethnic. Students of different gender and ethnicity have been found to hold different logical intelligence and visual levels. These differences contribute to the difference in the achievement of students' in understanding of scientific concepts, where students who have a higher level of visual intelligence are more likely to have a higher level of logical intelligence, and are also more likely to better understand a learned concept.

In a broader context, a study done in Hawaii by Greenfield (1998) found that there is no consistent difference in science achievement with respect to a student's gender. Results obtained, however, showed that ethnicity did affect students' science achievement. The study found that Caucasians and Japanese-American students outscored Hawaiians and Filipino Americans at all grade levels tested, which in-line with Kelly's (1998) findings, which revealed that students' ethnic backgrounds does exert an influence on students' science achievement, in a study conducted in Britain. The similar results were obtained in TIMSS's five-year trend analysis among its participating countries. It was found that there was no significant difference in mean science achievement between male and female students in TIMSS 2006/07, but when the student's ethnicity was taken into account, the difference was well pronounced (Caygill, 2008). To the same extend, Quest, Mineo & Higgins (2013), in their study conducted in America, found that male and female students earned similar end-of-year grades, whereas Asian-American students outperformed students from the other ethnic groups in learning science.

Objective:

The objectives of this research are to determine:

- The level of understanding of male and female students of the basic concepts of matter.
- The level of understanding of Malay, Chinese and Indian students of the basic concepts of matter.
- The level of understanding of male and female students of the basic concepts of particle.
- The level of understanding of Malay, Chinese and Indian students of the basic concepts of particle.
- Whether or not the level of students' understanding of the basic concepts of matter and particle is influenced by their prior knowledge of these concepts.

Methodology:

This study adopted a survey method to collect the required data. The study sample consists of 100 students from several secondary schools from one district in Penang to represent the population of Penang students. Cluster sampling technique was used to select the targeted sample. The instrument used in this study is a set of questionnaire known as 'The Questionnaire of Students' Understanding of Basic Concepts of Matter and Particle'. The questionnaire was constructed based on the contents of science textbooks (form one, two, three and four), as well as adapted from the instrument developed by Adadan (2006). The questionnaire was prepared in a bilingual form, in Malay and English, so that students are free to select the language of their preference. The questionnaire has been revised and evaluated by a panel of three professionals, who specialize in the related area, to improve the validity and clarity of it's content. The validity and clarity of the questionnaire were then

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assessed through a pilot study conducted on 30 students with the same characteristics of the targeted sample. The final questionnaire covered 20 objectives and multi-level items, designed to explore the level of understanding of the respondents on the basic concepts of matter and particle, as well as the influence of their prior knowledge towards their scientific framework. Descriptive, inferential statistical analysis (independent samples t-test and one-way Anova) was then performed to analyze the level of students' understanding of the concepts, whereas qualitative analysis technique was used to determine whether or not prior knowledge influence students' understanding of the concepts.

Findings:

The level of understanding of male and female students of the basic concepts of matter:

Results obtained are showed in Table 2a and Table 2b showed that the mean score of the level of understanding of basic concepts of students in general was 77.40. The mean score of male students was 73.10 (SD = 6.023), while the mean score of female students was 82.40 (SD = 5.691). The results showed that female students hold a better level of understanding of the basic concepts of matter than male students.

Table 2a: Mean score of the level of understanding of the basic concepts of matter between male and female students.

	Gender	N	Mean score	Standard error
Basic concepts of matter	Male	52	73.10	6.023
	Female	48	82.40	5.691
	Total	100	77.40	

Table 2b: Independent t-test analysis of the level of understanding of the basic concepts of matter between male and female students.

Levene's Test for Equality of Variances		T-test for Equality of Means								
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Upper	Lower
Equal variances assumed		0.67	0.44	3.12	98	0.001	4.161	1.181	6.481	1.821

Independent t-test analysis conducted (see Table 2b) showed that there was a significant difference between male and female students mean scores (t= 3.524; $p<0.05$). The results confirm that that there was a significant difference in the level of understanding of the basic concepts of matter between male and female students. Female students were found to have a significantly higher level of understanding of the basic concepts of matter, compared to male students.

The level of understanding of the basic concepts of matter among Malay, Chinese and Indian students:

Results obtained are showed in Table 3a, Table 3b and Table 3c. Table 3a showed that the mean score of the level of understanding of Malay students was 80.50 (SD = 65.543), Chinese students was 76.50 (6.713) and Indian students was 75.60 (SD = 5.832). The results showed that Malay students have a slightly better level of understanding of the basic concepts of matter than Chinese students, followed by Indian students.

Table 3a: Mean score of the level of understanding of the basic concepts of matter among Malay, Chinese and Indian students.

Ethnic	N	Mean score	Standard error
Malay	34	80.50	5.543
Chinese	38	76.50	6.713
Indian	28	75.60	5.832
Total	100		6.220

Table 3b: Levene's Test of Equality.

F	df1	df2	Sig.
0.697	2	97	0.501

Table 3c: One Way ANOVA analysis of the level of understanding of the basic concept of matter among Malay, Chinese and Indian students.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	143.92(b)	2	71.96	1.90	0.155	.038
Intercept	121033.28	1	121033.28	3194.76	0.000	.971
Ethnic	143.92	2	71.96	1.90	0.155	.038
Error	3674.83	97	37.88			
Total	125062.00	100				
Corrected Total	3818.76	99				

Dependent variable: basic concepts of matter

a *Computed using alpha* = .05

b *R Squared* = .038 (*Adjusted R Squared* = .018)

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One way ANOVA test analysis conducted (see Table 3b and 3c) showed that there was no significant difference among Malay, Chinese and Indian students' mean scores (F (2, 97) = 1.900, p>0.05). The results confirm that that there was no significant difference in the level of understanding of the basic concepts of matter among Malay, Chinese and Indian students. Students from different ethnic groups were found to have the same level of understanding of the basic concepts of matter.

The level of understanding of the basic concepts of particle between male and female students:

Results obtained are showed in Table 4a and Table 4b. Table 4a showed that the mean score of the level of understanding of the basic concepts of particle of the students in general was 29.50. The mean score of male students was 28.00 (SD = 2.813) while the mean score of female students was 31.30 (SD = 2.569). The results showed that female students hold a better level of understanding of the basic concepts of particle than male students.

Table 4a: Mean score of the level of understanding the concept of particle between male and female students.

	Gender	N	Mean score	Standard error
Basic concepts of particle	Male	52	28.00	2.813
	Female	48	31.30	2.569
	Total	100	29.50	

Table 4b: Independent t-test analysis of the level of understanding of the basic concepts of particle between male and female students.

Levene's Test for Equality of Variances			T-test for Equality of Means						
	F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Upper	Lower
Equal variances assumed	2.96	0.09	2.412	98	0.02	0.789	0.352	1.512	0.212

Independent t-test analysis conducted (see Table 4b) showed that there was a significant difference between male and female students' mean scores (t= 2.412; p<0.05). The results confirm that that there was a significant difference in the level of understanding of the basic concepts of particle between male and female students. Female students were found to have a significantly higher level of understanding of the basic concepts of particle compared to male students.

The level of understanding of the basic concepts of particle among Malay, Chinese and Indian students:

Results obtained are showed in Table 5a, Table 5b and Table 5c. Table 5a showed that the mean score of the level of understanding of Malay students was 30.00 (SD = 2.602), Chinese students was 29.30 (2.803) and Indian students was 29.40 (SD = 2.879). The results showed that Malay, Chinese and Indian students acquire almost similar mean scores of the level of understanding of the basic concepts of particle.

Table 5a: Mean score of the level of understanding of basic concepts of particle among Malay, Chinese and Indian students.

Ethnic	N	Mean score (%)	Standard error
Malay	34	30.00	2.602
Chinese	38	29.30	2.803
Indian	28	29.40	2.879
Total	100		2.761

Table 5b: Levene's Test of Equality.

F	df1	df2	Sig.
0.858	2	97	0.431

Table 5c: One Way ANOVA analysis of the level of understanding of the basic concepts of particle among Malay, Chinese and Indian students.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	0.500(b)	2	0.250	0.079	0.924	.002
Intercept	5013.574	1	5013.574	1580.543	0.000	.942
Ethnic	0.500	2	0.250	0.079	0.924	.002
Error	307.690	97	3.172			
Total	5335.000	100				
Corrected Total	308.190	99				

Dependent variable: basic concepts of particle

a *Computed using alpha* = .05

b *R Squared* = 0.002 (*Adjusted R Squared* = -0.019)

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One way ANOVA test analysis conducted (see Table 5b and 5c) showed that there was no significant difference between the Malay, Chinese and Indian students' mean scores ($F(2, 97) = 0.079$, $p>0.05$). The results confirm that that there was no significant difference in the level of understanding of the basic concepts of matter among Malay, Chinese and Indian students. Students from different ethnic groups were found to have almost similar levels of understanding of the basic concepts of matter.

The Influence of Students' Prior Knowledge:

Qualitative analysis of the data obtained from the questionnaire administered showed that more than 60% of the students are more inclined to provide answers that related to their everyday real-life experiences than that which contain scientific explanations. The misconception was most significant for the concept of particle than that of matter. For instance, most students tend to stick to the answer that particle are static in solid form and believe that air exists between particle. These alternative frameworks, in general, are consistent with Adadan's (2006) framework. The findings portray that the level of students' understanding of the basic concepts of matter and particle have actually been influenced by their prior knowledge of these concepts. The existence of these alternative frameworks, therefore, does influence the development of scientific framework, as well as the students' science learning process.

Discussion:

Results showed that, in general, students possess quite a good level of understanding of the concept of matter, but have a lower level of understanding the concept of particle. Further analysis showed that students were able to provide proper definitions of matter, described the three states of matter, and identified matter and non-matter materials. The results of this study were consistent with the previous research findings conducted in this area (Ross & Munby, 1991; Nakhleh, 1992; Sisovic & Bojovic, 2000; Ozmen & Kenan, 2007; Ozmen, 2009; Nurliana, Syuhaida, Johari, 2013), where students have been found to respond well to the concept of the three states of matter, examples of matter, and classification of matter and non-matter materials, but have a weaker knowledge of the concept of particle and its properties, particularly in drawing its arrangements as well as explaining the distance between particle, its number, size and movement.

The results also showed that there exists significant differences between male and female students' level of understanding of the basic concepts of both matter and particle. Female students were found to have a significantly higher level of understanding of the basic concepts of both matter and particle, compared to male students. The results of this study supported Esah (2003) findings, which suggested that female students showed more dominance towards the skills of understanding the concept, whereas male students showed a higher inclination towards problem-solving skills.

These findings support the notion that males possess a higher predisposition on quantitative and visiospatial abilities, which necessarily results in more males at both high-and low-ability extremes, whereas females tend to excel in verbal abilities, with large differences found between females and males during the time when assessments include writing samples (Halpern, Benbow, Geary, Gur, Hyde & Gernsbacher, 2007). High-level achievement in science requires the ability to communicate effectively and comprehend abstract ideas, and so the female advantage in writing should be more helpful in the academic domains (Halpern, Benbow, Geary, Gur, Hyde & Gernsbacher, 2007). Although many literature reviews showed that, in general, female students are underrepresented by male students worldwide, a slightly contrastive situation occurs in Malaysia, where overall, female students were found to outperform male students.

With respect to ethnicity, although Malay students scored slightly better than the Chinese and Indian students in the questionnaire administered, the results, however, showed that there was no significant difference of the level of understanding of the basic concepts of both matter and particle among students with different ethnic backgrounds. The results supported Siti Zubaidah's findings (2010), which found that there was no significant difference between students' ability, with reference to their ethnic background. The results of this study are also in-line with Tan's (2007) findings, which found that most students, regardless of their background, were having difficulties in mastering the concept of particle. However, the results contradict with the findings of Greenfield (1998), Esah (2003), Caygill, (2008), Quest, Mineo and Higgins (2013) and Garrison (2013), which found that students' background factors, such as ethnicity, do influence students' ability to understand the learned concepts.

The results showed that students' ethnic backgrounds have a limited influence on their science learning processes. This may be due to the reason that these students have quite similar social backgrounds, as they were selected from the same district. As previously argued, these findings confirmed that it was actually the interaction of social background which plays the important role in shaping the students (Kelly, 1998).

In addition, the study found that the existence of an alternative framework also influenced their understanding of the basic concepts of matter and particle. Students were found to have the tendency to use their own notions and reasons to explain the basic concepts of matter and particle, rather than using scientific reasons, which is corraborated by Adadan's (2006) study and findings. The results comply with the fact that most of the

alternative concepts built by students are consistent, and is rather hard to change, if students are continually taught using the common methods currently practiced in school (Helm & Novak, 1983; Driver *et al*., 1985).

Conclusion:

The study found that the level of students' understanding of the basic concepts of matter was quite high, whereas the level of students' understanding of the basic concepts of particle was rather low. There exist a significant difference in the level of understanding of the basic concepts of matter and particle between male and female students. There is no significant difference between the level of understanding of the basic concepts of matter and particle among Malay, Chinese and Indian students. Students' prior knowledge do exert a significant amount of influence on the development of their scientific idea. Students, as well as teachers, need to be aware of the concerning issues so that they can play active roles to improve these situations.

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