Students' Biotechnology Literacy: The Pillars of STEM Education in Malaysia

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Biotechnology has been widely applied in various products throughout the 21st century. Malaysia selected the biotechnology sector as one of the key strategic technologies that would enable Malaysia to transform into a fully developed nation by the year 2020. However, to date, there has been very little research on the level of biotechnology literacy amongst school students in Malaysia and the aim of this study is to determine the presence of biotechnology literacy, based on knowledge, perception, and attitude. Besides, this study also determines the factors affecting the students' attitude towards biotechnology. This study is a quantitative study involving 292 secondary school students from science and non-science classes. The findings showed that overall students have what we describe as a medium level of knowledge, perception, and attitude towards biotechnology. It is anticipated that this pattern of findings can help teachers, the Ministry of Education and the media to strategically plan ahead so that improvements in the national curriculum can be proposed and implemented.

INTRODUCTION

In the 21st century, biotechnology is a knowledge-based economy that will drive the world economy and is listed as one of five key technologies to transform Malaysia into a high-income nation by 2020 (RMK9, 2006). Biotechnology is the fastest growing industry in the production of commercial applications and products throughout the world. With the launch of the National

Biotechnology Policy (NBP) in 2005, Malaysia has pledged to provide a strong commitment to develop this industry. In the Ninth Malaysia Plan (RMK-9), concerted efforts have been devoted to the implementation of the DBN with the active participation of the private sector. Institutional, regulatory and financial frameworks have been developed to promote biotechnology as a key driver of sustainable economic growth. Moreover, the development of 'BioValley' has strengthened and supported the local biotechnology infrastructure and new approaches, such as BioNexus also applies leverage to existing institutions bringing them into line with the development of the industry (MOSTI, 2010). These efforts are made to ensure the success of the government's aspiration to prepare Malaysia as an ideal

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State of the literature

- Public knowledge and awareness is very important because community acceptance, ability of society to make informed judgments and be able to relevantly and rationally evaluate the pros and cons of this technology contribute for the success of biotechnology industry in Malaysia.
- Biotechnology education is a relevant component of general education in Malaysia to produce students that is well informed and aware of this technology.
- But awareness and knowledge alone are not sufficient in helping the community to make wise decisions and to critically evaluate the issues. Scientific literacy is an important element enabling people to think and critically evaluate these issues, to make wise decisions and to develop a proper attitude

Contribution of this paper to the literature

- In this paper, the authors asses the existence of scientific literacy towards biotechnology among Malaysia high school students
- The paper also assesses the factors affecting students' attitude towards biotechnology from the aspects of knowledge and perception towards biotechnology.
- This research is done in aligned with previous literature that emphasis on the lack of research on biotechnology literacy assessment among students in developing countries.

location for biotechnology players and foreign investors. In addition, millions of dollars has been allocated to achieve the goal of creating 280,000 jobs in this sector with a contribution of five percent to the Gross Domestic Product (GDP) by 2020 (Arujanan, 2007).

It was essential to develop the capacity and capability of human resources and research institutions to create a biotechnology literate society. By reporting the RMK-9 (2006-2010) higher education institutions have produced more than 4,000 graduates with a bachelor's degree, masters and doctoral programs in various specializations such as molecular biology, genetic engineering, plant biotechnology, bioprocess engineering, bioinformatics and marine biotechnology. In conjunction, the National Science Fellowship Scheme (NSF) has provided scholarships to 156 students for master's degrees and doctorates in biotechnology-related fields. In addition, in-service training programs to develop human resources in science and technology also provide scholarships to serving officers in research institutes and universities to pursue postgraduate studies in the field of biotechnology.

In Malaysia it is hoped the industry will contribute not only to the field of medicine and the environment but also produce significant contributions in food production. Various types of animal-based food or plants that went through the process of genetic modification will increase substantially in the market (Arujanan, 2007; Sturgis et. al 2005; Kok & Kuiper, 2003). On the other hand, as with any emerging field, biotechnology is clouded by controversies and public concerns. Research on stem cells, cloning, gene therapy, and genetically modified crops raised various concerns among stakeholders and the debate is fuelled with issues related to intellectual property rights, ownership, patents, religion, ethical implications, and trade monopolies. The scientific community and other supporters of biotechnology are concerned that the benefits of biotechnology can be overshadowed by the large potential risks that are shown in the media and espoused by the anti-technology league (Arujanan, 2007). The need to create public knowledge and awareness on this matter is very important because the success of the industry in Malaysia depends largely on community acceptance and the ability of society to make informed judgments (Bowling et. al 2008; and Rota & Izquerdo, 2003) and be able to relevantly and rationally evaluate the pros and cons of this technology because the nation will be flooded with biotechnology-based products (Arujanan, 2007; Sturgis et. al 2005; and Kok & Kuiper, 2003). Thus, the community, regardless of age and status will also be involved in the decision making process and this includes children and school students. However, according to Klop et. al (2010), Miller (2004), and France (2003), awareness and knowledge alone are not sufficient in helping the community to make wise decisions and to critically evaluate the issues. Scientific literacy is an important element enabling people to think and critically evaluate these issues, to make wise decisions and to develop a proper attitude. Biotechnology is enclosed by a variety of issues - ethical, social, political, and economic (France, 2003) – which can only be properly addressed by scientific literacy.

In Malaysia biotechnology related education is being inserted into the Biology curriculum. The goal of biology education in Malaysia is to prepare students to understand their responsibilities as environmental managers. In addition, this subject also provides students with the basic biology education in order for them to further their studies in biology and fields that require biology knowledge and skills (Pusat Perkembangan Kurikulum, 2005). The integration of modern biotechnology elements in the Form 4 Malaysian Biology curriculum includes discussions on the chemical composition of the cell, which involves the profile of carbohydrates, proteins, and lipids. These are the elements that are located under the biochemistry

construct in the biotechnology taxonomy (Wells, 1994). Modern biotechnology integration into the biology syllabus also involves the insertion of cell division discussions focusing on cloning techniques, tissue culture and breeding which are crucial in the field of agricultural biotechnology. Even the teachers were encouraged to organize forums in classrooms to discuss the ethical issues related to biotechnology, for example, the effects of uncontrolled cell division and the introduction of chromosomes and functions in meiosis. All of these elements are essential for the introduction of genetic engineering to students.

In the Form 5 Malaysian Biology syllabus modern biotechnology integration can be seen in the discussions regarding roles in the transportation system of the body's defense mechanism. It contains discussions on human antibodies and immunity which are elements that are categorized under the medical construct in the biotechnology taxonomy (Wells, 1994) In addition specific and detailed discussions are emphasized on genetic therapy, genetically modified organism (GMO), and genetically modified food (GMF) (Pusat Perkembangan Kurikulum, 2005). In addition to the role of the national school curriculum to educate, to disseminate information and raise awareness of students the National Biotechnology Division, Ministry of Science and Technology (MOSTI). They have taken the initiative to organize biotechnology promotional and awareness sessions to students and teachers in Malaysia since year 2001.

The biotechnology education in Malaysia is in synergy with the Science, Technology, Engineering and Mathematics education or commonly known as STEM education. STEM education can promote understanding of scientific concepts in the actual context, can stimulate innovation and creativity, and also at the same time encourage the mastery of 21st century skills the much needed ability for the 21st century economy.

Previous research by Klop et. al (2010), Miller (2004) and France (2003), clearly shows that education providing students with knowledge and information solely is not enough to help people to make decisions and critically evaluate the issue. The research states that scientific literacy is an important element to allow people to think and critically evaluate these issues and make wise decisions, particularly on technology that is surrounded by a variety of ethical, social, political, and economic issues (France, 2003)

Scientific literacy in biotechnology

Various definitions have been put forward to explain the concept of scientific literacy. Among these was the explanation by Miller (2007) that defined scientific literacy as the level of understanding of science and technology needed by an individual to function as

citizens in a modern industrial society. Additionally, Murcia (2007) referred to scientific literacy in an individual or a community as a common, broad, and useful understanding of science, which can contribute to the efficiency and the tendency to use science to meet the demands of their personal and social lives. Bybee (2008) had referred to scientific literacy in his research as individual's scientific knowledge and use of that knowledge to identify scientific questions, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues. In addition, the definition includes the understanding of the characteristic features of science as a form of human knowledge and inquiry; an awareness of how science and technology shape our material, intellectual, and cultural environments; and a willingness to engage in science-related issues. On the other hand, scientific literacy that exists in the community is required for the purpose of learning something scientific. From the definitions given it can be concluded that scientific literacy is the ability of an individual to use their knowledge and understanding of basic science to make rational reasoning on the issues and problems that encircle their daily lives and form their own attitude base on their knowledge-base perception. Scientific literacy also helps how to understand and think about science that influences actions and decisions to be made.

Elements in scientific literacy

It is essential to note down the elements in scientific literacy in order to measure the existence of it amongst the community. Numerous elements have been highlighted by previous researches; Jon Miller's (1983) article on a conceptual and empirical review of scientific literacy was influential because he not only proposed a multidimensional definition of scientific literacy; importantly he also suggested ways of measuring scientific literacy. Miller's definition of science-literate individuals has been commonly accepted and adapted in several studies and consists of three dimensions: i) understanding of the norms and methods of science (i.e., the nature of science); ii) of key scientific terms and concepts and; iii) awareness and understanding of the impact of science and technology on society".

In 1989 the American Association for the Advancement of Science's (AAAS) and the establishment of their reform initiative, Project 2061 extended the definition of scientific literacy to include "habits of mind." According to the AAAS (1989) science literacy includes: i) being familiar with the natural world and respecting its unity; ii) being aware of some of the important ways in which mathematics, technology and the sciences depend upon one another; iii) understanding some of the key concepts and

principles of science. In addition, elements of science literacy also includes iv) having a capacity for scientific ways of thinking; v) knowing that science, mathematics, and technology are human enterprises, and vi) knowing what that implies about their strengths and limitations; and vii) being able to use scientific knowledge and ways of thinking for personal and social purposes. Laugksch and Spargo (1996) explained that this model attributes importance not only to "knowledge of science, technology, and mathematics" but also to "values, attitudes and thinking skills" connected with those subjects.

OECD (The Organisation for Economic Co-operation and Development) in a report entitled "Assessing Scientific, Reading and Mathematical Literacy: A Framework of PISA 2006" state that scientific literacy components include: i) scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues; ii) an understanding of the characteristic features of science as a form of human knowledge and enquiry; iii) an awareness of how science and technology shape our material, intellectual, and cultural environments; and iv) attitudes towards science-related issues as a reflective citizen. An important study in 2010 (Klop et. al) assessed students' scientific literacy by their ability to apply knowledge and perception in developing their attitude towards biotechnology. Based on this theory a persons' attitude is influenced by knowledge and perception and throughout this relationship, the existence of scientific literature can be assessed.

A shift towards long-term view of scientific literacy does not mean that it is a single entity. At the school level, Bybee (2008) has proposed that a scientific literacy can be considered at four levels of functionality. The first level is the nominal level, in which a literate individual is seen to be able to recognize individual scientific terms but do not have a clear understanding of its meaning. The second stage is the functional level where scientific literacy is seen from the ability to use the vocabulary of science and technology but only in a small context. The third stage involves concept and procedure where literate individuals show understanding and relationships between concepts and can use process with meaning. The highest level of scientific literacy is a multidimensional one and, at this point, the evaluation of an individual's scientific literacy can be seen not only in understanding - the individual is able to develop a science and technology perspective that includes the nature of science and the role of science and technology in their personal lives and society. Moreover, according to PISA (2006), assessment of the level of scientific literacy cannot be done as a single discrete entity but it is regarded as a typological classification. This means that an individual cannot be categorized as either literate or illiterate; rather, it is a continuation of the literacy levels of low, medium and high.

As discussed, scientific literacy an important aspect to enable the community to think and critically evaluate issues and make wise decisions, developing a proper attitude towards technology dealing with a variety of issues which are ethical, social, political and economic (France, 2003). At the same time, it is important that biotechnology-based education be taught to school children in an effort to educate them to be scientifically literate in biotechnology as well as future prospective scientists in the biotechnology field. Education is the centerpiece of the country in the provision of technical and professional experts. In fact, education is also able to shape attitudes, values and people who are willing to embrace changes, innovation, and the use of science and technology in the field of work and everyday life. In the era of globalization in the 21st century the experience of school students is not so different from that experienced by adults - they are exposed to many things related to the issues and applications surrounding biotechnology but may not discover proper pedagogical explanations. In such cases, these phenomena will cause adults and students to be misled, developing negative perceptions, resulting in a rejection of biotechnology (Rota & Izquerdo, 2003). However, students represent the future generation, which will be responsible for setting up a technological advancement that will be used in the future. Thus, it is essential that here in Malaysia we take steps to implement good teaching and curriculum to ensure that the population fully understands the potential benefits of biotechnology industrial sector for their own economic benefit. Also with an awareness of how such industries have the potential of making possible a sustainable future for our societies facing the challenge of living in a world of overpopulation, potential food shortages, clean water shortage, environmental change and an increasing possibility of political and economic dislocation.

In order to investigate the relevance of the Malaysian Biology curriculum in developing students' sound attitude and perception towards biotechnology based on the knowledge disseminated, the major purpose of this study is to assess the existence of scientific literacy towards biotechnology among school students. By adapting some of the components of scientific literacy used in the previous literature this study will apply the elements of knowledge, perception and attitude to assess the existence of scientific literacy among school students. The existence of students' scientific literacy is assumed when there is a positive correlation between students' knowledge and attitude towards biotechnology, as well as positive correlation between students' perception and attitude towards biotechnology. This expression is predicated on

previous research by Ibrahim and Babayemi (2010), knowledge is a prerequisite for any attitude. This research expressed the functional approach to attitude which upholds a positive relationship between knowledge and attitude. A higher level of knowledge seems to be associated with a more favorable attitude towards biotechnology (Morren et. al 2007). On the other hand, attitude is also developed in relative to perception - attitude is the result of perception. Two people with different perception look at the same thing and will think quite differently and end up with different attitudes. A positive attitude can only be developed with positive perception because sound perception in any subject allows an individual to asses an issue critically and rationally without being bias with their own emotion. A significant positive correlation has been proven between perception of respondents and attitude towards preservation of information resources. (Oyeniyi. 2009). Besides, users' perception of the characteristic of technology can often explain and predict their attitude towards and actual use of technology.

In addition, this research was executed based on the findings of Dawson and Venville (2009), who stated that there were many studies in assessing community's knowledge, perception and attitudes towards biotechnology in developed countries (Klop et. al 2010; Dawson & Venville, 2009; Klop & Severiens, 2007; Sturgis et. al 2005; France, 2003; Rota & Izquerdo, 2003) but lack of research was done in developing countries. In Malaysia research upon this aspect is minimal and there are still no studies that focus specifically on biotechnology literacy assessment among students. Secondary school students are the main subjects in this research as for several reasons. In Malaysia, secondary school students are the best target to nurture essential knowledge, perception and attitude towards biotechnology as they are the future prospects for Malaysia in transforming this country to a high income and developed country by year 2020. This is aligned as the government had highlighted that biotechnology industry are the one of the five major industries to achieve this goal (RMK9, 2006). Besides, proper education related to biotechnology should be exposed to students as early as possible in order to increase their awareness regarding these issues. However extensive exposure and education should be disseminated to secondary school students specifically due to the nature of biotechnology itself which are complicated in terms of its technicality (France, 2003; Wells & Kwon, 2008), as well as it is enclosed with various sociopolitical and ethical issues that require a more developed cognitive ability to analyze it (France, 2003).

As to that, the objectives of this research are: i) identifying the level of biotechnology knowledge among students; ii) identifying the level of perception towards biotechnology among students; iii) identify attitude towards biotechnology among students; iv) examining the relationship between knowledge and attitude towards biotechnology among students; v) reviewing the relationship between perception and attitude towards biotechnology among students and vi) to determine the factors that affect students' attitude towards biotechnology. Based on the input of the study this research can interpret Malaysian students' level of biotechnology literacy contributing to the raising of awareness of various parties, which include the Ministry of Education, teachers and the media on the importance of relevant education for the success of biotechnology literacy in the country.

RESEARCH METHODOLOGY

Research design

The research design used was a cross-section survey design based on gender and non-science and science class stream in order to examine the scientific literacy on the biotechnology element of understanding, perception and attitude. Survey design is used that allows any issues and questions examined from different perspectives, especially in the level of understanding, perception and attitude on an issue (Chua, 2006). In addition, survey design is essential in research that involves large sample size so that the findings can be generalized to the population accurately and effectively.

Population and sample

The population in this study was made up of form 4 students from secondary schools in one of the states in Malaysia. Overall students in urban and rural areas were taken into account in this study. Based on the overall population a total of 292 students were selected as research sample. For the sampling technique, the sampling study was conducted in two phases consisting of i) cluster sampling and ii) stratified random sampling. In phase 1 cluster sampling was used for the overall student population of Form 4 secondary school in Selangor. Cluster sampling is a sampling technique used in the study cover a wide area and the number of subjects with various features, and researchers do not have a list of names of all subjects in the population (Chua. 2006). As a result, from a total of 9 districts which are the district of Petaling, Hulu Langat, Klang, Gombak, Kuala Langat, Sepang, Kuala Selangor, Hulu Selangor and Sabak Bernam, all Form 4 students from the district of Hulu Langat had been selected to represent the population of the state. Hulu Langat district was selected due to the balanced demographic structure. This criterion is important to describe the

entire population of Selangor that comprises of urban and rural population.

On the next sampling phase stratified random sampling was applied to the selected sample. In this sampling technique the schools in the district that were selected from a cluster sampling procedure were separated into two categories based on the status of rural and urban schools. Of these categories the schools involved were chosen at random. Next, stratified random sampling was carried out once again by dividing the sample according to the science and the arts stream. Finally, a simple random sampling was carried out on these categories. The detail for stratified random sampling process is as Figure 1.

The Data Collection Instrument

This study fully utilized the questionnaire as an important tool for data collection. The questionnaire consists of four parts, namely Part A - students' demographic information, made up of gender, academic stream, race and school location; Part B - items of the biotechnology knowledge construct; Part C- items made up of perceptions of biotechnology construct and Part D - items of attitudes toward the biotechnology construct. The questionnaire used in this study is an adaptation of the questionnaire developed through several previous studies.

Part B - Biotechnology knowledge. This part of the questionnaire was an adaptation from the Biotechnology Knowledge Questionnaire developed by Klop and Severiens (2007). It consists of three constructs in which the scope of knowledge is relevant to the secondary school science curriculum in terms of biology and genetics, microbiology and the foundation of modern biotechnology. The items involved were based on the principle of biotechnology and the scope measured has been covered in the Form 4 Malaysian Secondary School Integrated Curriculum; Biology and General Science subjects. The basic knowledge that students received from classroom learning may be the foundation for the students to apply, analyze, synthesize and evaluate the items in this section of the questionnaire. This part is divided into three constructs which consist of the biology and genetics construct, the microbiology construct and the foundation of modern biotechnology construct. Each items' build is relevant for higher secondary school students because each item has been covered in a general way in their school syllabus.

The Cronbach Alpha value was used to obtain the reliability index of each construct in this part. The alpha reliability of the scales ranged from 0.70 to 0.75, indicating a strong internal consistency within each scale (Pallant, 2007).
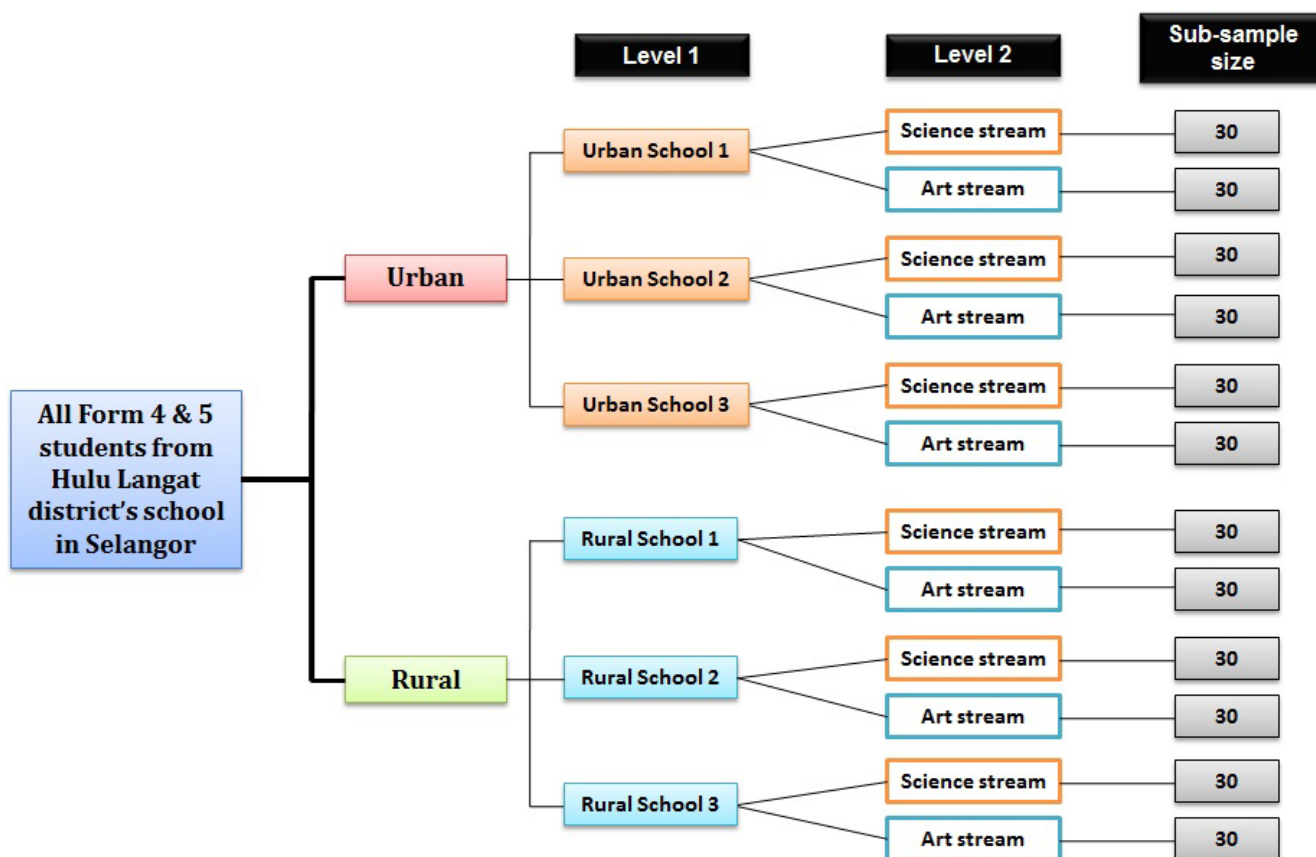

Figure 1. Random Stratified Sampling Process

Part C - Perception towards biotechnology. This part of questionnaire was an adaptation from the questionnaire developed by Latifah et al. (2012). The selection of this questionnaire instead of another perception questionnaire was made due to the suitability of the Malaysian community with it's exposure to biotechnology industry and applications. Moreover, the constructs measured covered most major aspects in determination towards the acceptance of biotechnology industry and application. All the items utilized are based on biotechnology application in agriculture and medicine. Agriculture and medicine are among the eight biotechnology elements in the Biotechnology Taxonomy Structure proposed by Wells (1994). Both of these elements form the backbone of the questionnaire because their nature is less technical in comparison with the other six elements. Besides, the products from this biotechnology field are significant to the community, thus, it can be evaluated relevantly by the students. The statistical data on the internal consistency ranged from 0.68 to 0.79.

Part D - Attitude towards biotechnology. This part of the questionnaire was adapted from the Biotechnology Attitude Questionnaire that had been used in several researches such as Prokop (2010), Erdogan et al. (2009) and Subahan et al. (2012). This questionnaire was selected in the study because it has concrete and solid constructs to measure the students' attitude towards biotechnology. In addition, it also applies elements of agriculture and medicine as the biotechnology backbone in the questionnaire. The internal consistency shows on the Cronbach Alpha

index with a value between 0.66 and 0.75.

A measurement scale was used in the questionnaire for Part B, C and D; this was the Likert scale, 1-5, with 5 options - strongly disagree, disagree, slightly agree, agree, and strongly agree. This odd-numbered Likert scale was able to reduce measurement error compared to the use of an even-numbered Likert scale. Details of the complete contents of the questionnaire are shown in Table 1.

Statistical analysis used in this study was mean, frequency and percentage based for descriptive analysis, Pearson Product-moment Correlation to investigate the relationship between knowledge and perception towards attitude, and Stepwise Multiple Regression in order to determine the factors affecting students' attitude towards biotechnology. In descriptive analysis mean score interpretation was used to determine the level of students' knowledge, perception and attitude towards biotechnology. The mean score interpretation of 1.00 – 2.33 is interpreted as low, 2.34 – 3.66 interpret as moderate and a mean score of 3.67 – 5.00 interpret as high.

RESULTS

Respondent profile

54.8 percent of all the respondents composed are female. Half of the respondents are science stream student, whilst 49.7% of the respondents are in an urban location school.

Table 1. Features of the Data Collection Instrument.

Part	Construct	Number of items	Items	Cronbach Alpha index	Source
Part B	*Biotechnology knowledge*				Adapted from Klop and Severiens (2007)
	Biology and genetics	8 items	1 to 8	0.75	
	Microbiology	3 items	9 to11	0.70	
	Foundation of modern biotechnology	15 items	12 to 26	0.74	
Part C	*Perception towards biotechnology*				Adapted from Latifah et al., (2012)
	Perception towards ethics	11 items	1 to 11	0.79	
	Perception towards risk	6 items	12 to 17	0.68	
	Perception on benefit	6 items	18 to 23	0.73	
	Perception towards religious and morale	4 items	24 to 27	0.69	
Part D	*Attitude towards biotechnology*				
	Acceptance in the use of biotechnology product	3 items	1 to 3	0.72	
	Acceptance of biotechnology application in agriculture	4 items	4 to 7	0.70	Adapted from Prokop (2010), Erdogan et al. (2009), and Subahan et. al (2012)
	Awareness of biotechnology application	4 items	8 to 11	0.66	
	Purchase of biotechnology products	6 items	12 to 17	0.75	
	Biotechnology acceptance based on ethics	3 items	18 to 20	0.69	
	Acceptance and rejection of biotechnology based on environmental impacts	3 items	21 to 23	0.74	
	Acceptance of biotechnology applications in medical field	3 items	24 to 26	0.72	

Biotechnology knowledge, perception and attitude

The results of the descriptive analysis on these aspects are shown in Table 2; from the results it can be seen that students' overall knowledge, perception and attitude on biotechnology is at medium level with mean of 3.65, 3.24 and 3.35 consecutively.

Relationship between students' biotechnology knowledge and students' attitude towards biotechnology

To determine the relationship between the students' biotechnology knowledge and their attitude towards biotechnology the Pearson correlation analysis has been used to determine the presence of biotechnology literacy among students. The results are shown in Table 3. Table 3 shows that the Pearson correlation coefficient for the relationship between the students' biotechnology knowledge and their attitude towards biotechnology is $r = 0.535$ at a significant level of 0.00 ($p < 0.05$). This indicates a significant relationship between students' biotechnology knowledge and students' attitudes towards biotechnology. The relationship between these variables is a positive correlation with the strength of a moderate relationship ($r = 0.535$)

Relationship between students' perception towards biotechnology and students' attitude towards biotechnology

To determine the relationship between the students' perception towards biotechnology and students' attitude towards biotechnology the Pearson correlation analysis was used to determine the presence of biotechnology literacy among students. The results are shown in Table 3. The results shown in Table 3 it appears the Pearson correlation coefficient for the relationship between students' perception towards biotechnology and attitude towards biotechnology is $r = 0.673$ at a significant level of 0.00 ($p < 0.05$). This indicates a significant relationship between students' perception towards biotechnology and attitude towards biotechnology. The relationship between these two variables is positive with the strength of moderate relationship ($r = 0.673$).

Factors affecting students' attitude towards biotechnology.

Stepwise multiple regressions was used to assess the ability of every constructs in students' biotechnology knowledge and students' perception towards biotechnology to predict the levels of students' attitude towards biotechnology. Preliminary analyses were conducted to ensure no violation of the assumption of normality, linearity, multicollinearity and homoscedasticity (Cohen & Cohen. 1983; Tabachnick & Fidell. 2001). The results are as summarized in Table 4 and Table 5 respectively.

From Table 4 and 5, it can be deducted that from the total of seven constructs being analyzed, only five constructs which are knowledge on biology genetic, knowledge on modern biotechnology, perception on biotechnology ethics, perception on biotechnology risk, and perception on biotechnology benefits are the significant factors explaining about 53.2 % [$F(5,286)= 65.097$, $p<0.001$] of students' attitude towards biotechnology. It can thus be concluded that perception

Table 2. Mean score and percentage of students' biotechnology knowledge, perception, and attitude towards biotechnology

Aspect	Frequencies and corresponding percentages			Mean Score	Level
	Mean score 1.00-2.33 (Low)	Mean score 2.34-3.66 (Medium)	Mean score 3.67-5.00 (High)		
Knowledge	0 (0.0%)	157 (53.8%)	135 (46.2%)	3.65	Medium
Perception	2 (0.7%)	238 (81.5%)	52 (17.8%)	3.24	Medium
Attitude	1 (0.3%)	227 (77.8%)	64 (21.9%)	3.35	Medium

Table 3. Pearson correlation analysis for the relationship between students' biotechnology knowledge, their perception towards biotechnology and their attitude towards biotechnology

		Attitude	Attitude
Knowledge	Pearson Correlation	.535	
	Sig. (2-tailed)	.000**	
	N	292	
Perception	Pearson Correlation		.673
	Sig. (2-tailed)		.000**
	N		292

** Correlation significant at 0.05

Table 4. Stepwise Multiple Regression Analysis Model Summary.

Model		R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change
dimension	1	.586[a]	.344	.342	.35944	.344	152.042	1	290	.000
	2	.681[b]	.464	.461	.32539	.120	64.873	1	289	.000
	3	.715[c]	.511	.506	.31129	.047	27.766	1	288	.000
	4	.724[d]	.524	.517	.30792	.012	7.349	1	287	.007
	5	.730[e]	.532	.524	.30561	.009	5.351	1	286	.021

a. Predictors: (Constant), perceptionethics;
b. Predictors: (Constant), perceptionethics, perceptionrisk;
c. Predictors: (Constant), perceptionethics, perceptionrisk, modernbiotech;
d. Predictors: (Constant), perceptionethics, perceptionrisk, modernbiotech, perceptionbenefit
e. Predictors: (Constant), perceptionethics, perceptionrisk, modernbiotech, perceptionbenefit, biogen;
f. Dependent Variable: attitude

Table 5. Stepwise Multiple Regression Analysis Coefficient Summary.

Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	VIF
(Constant)	1.084	.143		7.584	.000		
perceptionethics	.275	.043	.369	6.363	.000	.485	2.061
perceptionrisk	.178	.028	.278	6.472	.000	.886	1.129
modernbiotech	.210	.045	.263	4.669	.000	.516	1.936
perceptionbenefit	.108	.033	.179	3.219	.001	.530	1.887
biogen	-.091	.039	-.134	-2.313	.021	.491	2.038

a. Dependent Variable: attitude

towards ethics on biotechnology are the biggest contributor to the prediction of the students' attitude towards biotechnology with total contribution of 36.9% (t = 6.363, sig= 0.000).

DISCUSSION

The research findings indicate that the level of students' knowledge in biotechnology as a whole is at a moderate level. In general the source of knowledge and information gained by the students is attributed to the content of Science and Biology subjects that are learned in school. Although biotechnology aspects are covered in the syllabus content its' applications in everyday life is extremely restricted which causes difficulties in the effort to strengthen the biotechnology understanding and appreciation among students. Moreover, research results show that understanding is detected mostly in abstract aspects of biotechnology such as in the statements - "genetically modified foods do interfere with the content of human genes" and "genetic engineering on animals do hurt animals". Similar findings are also revealed by Subahan et. al (2012).

Moderate level of knowledge may also be causes by limited access towards biotechnology-related information. Mass media often are displays news and articles that is sensationalist - the general community is frequently exposed to news that is incomprehensive and

deviates from reality (Gastrow, 2010). In addition, the majority of biotechnology-related information and knowledge is usually published in serious scientific literature which contain jargon that is incomprehensible to the general public (Subahan et al. 2012; Wingebach et al 2003).

Abdul Munir et. al (2005) in his study states that the community should be educated and given relevant information about biotechnology to enable them to have meaningful participation in public debates and make informed decisions based on the knowledge and information available to them. Therefore, emphasis should be placed on efforts to educate, disseminate information and raise awareness to various groups such as farmers' organizations, the agribusiness sector, government and non-government institutions, consumers, the media, policy makers, academics, religious organizations and students (Abdul Latif et. al 2011). For the school students, a more formal education should be provided through a well planned curriculum. A good biotechnology education outcome gives the students current and accurate knowledge with opportunities to form their own views based on their understandings of the risks, benefits and disadvantages of modern biotechnology (Chen & Raffan, 1999).

However, the results of this research show conflicting findings when compared with studies conducted in the United Kingdom, Australia and

Taiwan. These studies showed that majority of students aged 15 to 19 years have a low level of biotechnology knowledge (Chen & Raffan, 1999; Dawson & Schibeci, 2003). In addition, the research by Klop et. al. (2010) found that the majority of high school students in the Netherlands have a low level of modern biotechnology knowledge. These scenarios in turn lead to an inadequate decision-making process on biotechnology applications in their everyday lives which are not based on evaluation by using knowledge and information.

In considering the level of students' perception towards biotechnology, analysis shows it is at a moderate level. This finding corresponds with the study conducted by Sagar et al (2000), France (2003), Klop et al (2010) and Latifah et al (2012). A moderate perception towards biotechnology among students may be due to a lack of access towards relevant information in order to disassemble the controversial issues that surround biotechnology. Biotechnology, as is the natural world, is a rapidly moving and cryptic field frequently surround by controversies and unanswered questions. According to Latifah et al (2012) the field of biotechnology can be considered as new in Malaysia and it is still unclear to the general public. In addition, developments in the field of modern biotechnology that have been happening at great speed for the past 15 years have caused biotechnology to be shrouded with questions and doubts. The mass media is often only interested in displaying news and articles that are frequently sensationalist causing the general community to be exposed to news that is incomprehensive (Gastrow, 2010).

It follows that increased knowledge in biotechnology contributes to an increase in the level of perception and a lack of knowledge leads to a negative perception. According to research by Dawson and Venville (2009) students used reasoning that conveys emotions and intuition in evaluating biotechnology issues, rather than rational reasoning. This situation occurs due to lack of exposure and a lack of relevant education relating to biotechnology. It is often difficult for the students to provide arguments critically and make rational reasoning and thus it reflects a low level of scientific literacy. Teachers also showed lack of firm biotechnology knowledge and attitude thus making the delivery of information and discussions weak with the syllabus content implemented ineffectively. As reffered to Kidman (2009), teachers' knowledge and attitudes towards biotechnology posses strong influence on teaching and learning because it contribute to the teachers' attitude on classroom practice, curriculum and learning environment.

Moderate levels of perception towards biotechnology might be attributed by the orientation of biotechnology which expanded rapidly whilst at the same time are encircled by issues and controversies

about values, ethics and social culture (Klop et. al 2010; France, 2003). Additionally, according to Sagar et. al (2000), intense debate and contradicting views among biotechnology stakeholders frequently occur. Among the key factors that trigger these controversies are an abandonment of users' needs and also a refusal to recognize community and user concerns. From the experience of developed counties, especially Europe, the community's attitude plays a significant role in determining the policy, rules and also the success in product commercialization of biotechnology initiatives. As for that, it is important for an individual to become aware of his/her own values and to explain them in a conscious way. So, today science education curricula need to focus on the elements conducive to society-wide science literacy rather than imparting 'pure scientific knowledge' to students (Keskin-Samanci et. al, 2014)

The moderate level of students' attitude towards biotechnology is at moderate level and this finding is correlate by Subahan et. al (2012). A good level of attitude is obtained when an application shows distinctive benefits and advantages for the community's utility as well as the environment. As mentioned by Sturgis et. al (2005) and Latifah and Jamaluddin (2009), a high level of attitude is reflected in the aspects of agriculture and medicine. This is due to the fact that these areas of biotechnology do contribute to the wellness of the community in the form of producing economic growth, a sustainable food supply as well as the well being of the public health improvement.

Students' lack of exposure to products and applications of biotechnology in their everyday lives might have contributed to the moderate attitude towards biotechnology (Aerni, 2002). In addition, a lack of access to relevant information has resulted in the community, especially school students, having a negative attitude towards biotechnology applications (Subahan et. al 2012). In conjunction, Klop et. al (2010) highlighted that the students' attitude towards biotechnology is dependent on the knowledge and information that they possessed. Strong knowledge on the fundamental concepts of biology and genetics are able to build a strong scientific base which in turn will produce biotechnology literate students. The correlation between knowledge and understanding in producing high levels of attitude was evidenced by Gastrow (2010). He states that a lack of knowledge and understanding of biotechnology will contribute to low levels of attitude towards biotechnology.

Discussions concerning the relationship between students' biotechnology knowledge and attitudes as well as the relationship between students' perception and attitude towards biotechnology will be discussed together, as both of these analyses portray the existence of biotechnology literacy among the students. The

analyses found that students' attitude correlated positively with both biotechnology knowledge and perception towards biotechnology with moderate a level of strength. These findings are parallel with those of Simon (2009), and Prokop (2010). All of these studies found that attitudes towards biotechnology have positive correlation with students' biotechnology knowledge as well as students' perceptions towards biotechnology. The higher the level of knowledge and perception towards biotechnology the more positive attitude towards biotechnology will become. Fishbein and Ajzen (1975), who laid the foundations for the study of attitude, argued that attitudes are a function of the individuals' beliefs and evaluative responses associated with perception. Therefore, perception affects attitude and attitude then affects intentions. According to Subahan et al (2012), knowledge can help prevent misunderstandings and negative views on matters; with relevant knowledge on a particular field people will not be outcasts to innovation and the technological society (Gastrow, 2010). This is in line with the recommendations of Allum et al (2008), which states that a solid knowledge is a major contributor to the formation of a positive attitude. Strong biotechnology-related knowledge is essential for the students to evaluate biotechnology issues with rational reasoning. This is an important process in the formation of positive attitudes towards biotechnology as well as biotechnology literacy and it is important to increase efforts to ensure that the source of knowledge and information can be disseminated. Students must also be sensitive and attentive to various sources of information and involved in scholarly discussions regarding biotechnology issues. However, according to Banner (2007), the significant positive relationship does not necessarily occur because there are various elements that contribute to the formation of attitudes, among them are the cultural, social and political aspects that overlap and surround the field of biotechnology.

In discussing the factors affecting students' attitude towards biotechnology, it is found that from seven aspects being studied, five aspects significantly contributed to the students' attitude. Those aspects are knowledge on biology and genetics, and knowledge on the principle of modern biotechnology. As from the aspect of perception, the perception on ethics, perception on risk brought by biotechnology, and the perception on benefits brought by biotechnology do significantly affects the students attitude. This study also proves that knowledge on microbiology and perception towards religious and morale enclosed in biotechnology do not significantly affects students' attitude towards biotechnology. As for this, the content of biotechnology education in school specifically, should focus on theses aspects in order to nurture good attitude towards biotechnology among students.

CONCLUSION

This research investigates the existence of biotechnology literacy among Form 4 students in Malaysia focusing on knowledge, perception and attitude elements. The correlation between knowledge and perception towards biotechnology attitude portrays the existence of biotechnology literacy. The result of this study revealed that the students have a good level of biotechnology literacy. From the positive significant correlation it follows that the students are able to relate the knowledge they possess and their perception of biotechnology to produce a sound attitude towards biotechnology. Generally, scientifically literate individuals will exhibit superior cognitive, affective and behavioral ability and these skills are necessary for an individual to survive in this fast growing and technology dependent world like Malaysia.

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