Biology Teachers' Beliefs about Biotechnology and Biotechnology Education in the Eastern Province of Sri Lanka

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Abstract

This study examines teachers' understanding of the normative connections between key concepts of biotechnology and underlying biological principles that are critical for an in-depth understanding of teaching biotechnology education in school. Many teachers avoid addressing biotechnology topics available in the Advanced Level biology curriculum. Aiming to explore the factors which influence teachers' practice, using a structural questionnaire, we examine randomly selected teachers' understanding of these relationships at school level in the Eastern Province in Sri Lanka. A total of 63 biology teachers participated in this study and completed written questionnaire on their beliefs about biotechnology and biotechnology education. Findings from this study were: there is a strong positive response on teachers believes that biotechnology is interesting and important for life improvement (M=4.46,SD=0.96, t(62)=12.02, P=0.00) and this attitude influences their practice towards biotechnology education. Almost all the teachers had a good knowledge on biotechnology but not the relationship between application and basic knowledge which was observed to be with significant value. The teachers were willing to buy GM food if they were healthiest than other foods. However, they did not accept the application of biotechnology for medical purposes for some reasons. Many teachers consider that biotechnology education is important. The interest towards the subject and subject information persuades this attitude. Although outcome is preliminary in nature, the results provide cause for concern over the status of biotechnology education in Sri Lanka that needs uplift from the ground level.

Keywords: biotechnology, beliefs, biotechnology education, biology teachers

Introduction

Producing scientifically and technologically literate citizens has been a concern of educators and many policy makers around the world for more than three decades. UNESCO (1994) suggests that scientific and technological literacy are necessary to deal with the requirements of modern life. Accordingly, an emphasis on intensifying scientific literacy is obvious in many curricula all over the world. Over the past decade, science education reform recommendations have been fairly apparent in the secondary education in Sri Lanka. Influential policy recommendations hope to prepare a scientifically literate national work force that is equipped to compete in an increasingly science and technology based global economy (Lumpe*et al*., 2000).In the recent curriculum revision in Sri Lanka; secondary science subjects in particular underwent a lot of changes. A variety of new aspects have been incorporated. For instance, the Advanced Level Biology subject has been incorporated with many molecular biological and biotechnological aspects.

Rapid development of biotechnology has contributed to important biomedical, agricultural and industrial triumphs (Fonseca, 2012). However, in spite of its potentials, biotechnology constantly challenges the public by raising many controversial issues (Hanegan and Bigler, 2009). With the litigious views provided by the media regarding issues and concerns associated with human cloning and the production of genetically modified organisms (GMOs), schools and teachers are asked to play an important role in the promotion of biotechnology education (Bryce and Gray, 2004; Hanegan and Bigler, 2009). Accordingly, in recent years, biotechnology-related topics have been increasingly incorporated in secondary science curricula in numerous countries (Hanegan and Bigler, 2009) and Sri Lanka is not an exemption. The role of the teacher, and their beliefs about teaching and the subject matters they teach, must not be ignored if the recommendations of revised curricula should result in permanent change in the classroom (Lumpe*et al*., 2000). Teachers embrace a set of beliefs, practices, practical theories and craft knowledge which influences their approach to the implementation of the curriculum (Keys, 2007).

Beliefs have been defined in a variety of ways. Oliver and Koballa (1992) as cited by Lumpe*et al.* (2000) stated that beliefs are often equated with knowledge, attitudes, and idiosyncratic convictions, or reflect a person's acceptance or rejection of a proposition. Nonetheless, people get confused to differentiate beliefs from other related concepts such as attitudes, values,

judgments, concepts, and dispositions. Pajares (1992) elucidated that clusters of beliefs about a particular situation creates attitudes, and attitudes become action agendas that influence decisions and behavior. In other words, people act upon what they believe.Bandura (1997) stated that beliefs are the best indicators of the decisions people make throughout their lives.

Ample research evidences are available to support the view that teacher beliefs have direct impact on the teacher's practices in classroom. Beliefs influence the manner in which teacher decides his/her teaching objectives, lesson plan, approach toward students and the evaluation of learning in the classroom (Munby, 1982; Brickhouse, 1990; Pajares, 1992; Prawat, 1992; Richardson, 1996; Levitt, 2002). Teacher beliefs about students, learning, teaching and nature of science influence teaching practices (Wallace and Kang, 2004). Researchers have shown that epistemological beliefs play a key role in the way teachers interpret scientific knowledge and in turn teach it in classroom (Pajares, 1992).Purposely-designed questionnaire, interviews, or careful and patient observation are necessary to explore the beliefs of teachers which would in turn be helpful for the improvement of teaching and learning. As teachers' practice is influenced by content and pedagogical knowledge, as well as teachers' beliefs about the subject matter and their own teaching practices (Falk et al., 2008), it is indispensable to explore teachers' beliefs about biotechnology and biotechnology education. Identifying these elements is essential to determine whether teachers' engagement in biotechnology education is compromised by external factors school's functioning, availability of equipment and facilities and others.

This study, set up in the Eastern Province of Sri Lanka, examines G. C. E Advanced Level(A/L) biology teachers' beliefs about biotechnology by assessing the relationship between their beliefs about biotechnology and biotechnology teaching. This investigation was conceived to characterize teachers' receptivity to biotechnology education, aiming to identify the main constraints that can determine their engagement in teaching biotechnology-related topics with limited resources in the province.

Materials and Methods

This study follows a quantitative assessment approach based on an inquiry survey through questionnaire implementation.

Sample of the Study

Sixty three A/L biology teachers from schools in the eastern province (Ampara, Batticaloa and Trincomalee districts) participated in the survey. The participants were in-service secondary biology teachers who participated in a workshop on molecular biology and biotechnology organized by the National Science and Technology Commission in association with the Provincial Department of Education, Eastern Province, Sri Lanka. Informed verbal consents were obtained from the participants after explaining the purpose of the study. A/L biology teachers were considered eligible to participate in this survey because they are professionally qualified to teach biotechnology at secondary schools. The respondents' (45females and18 males) age ranged from 25 to 58 years [Mean 41.98, Standard Deviation (SD) 6.99]. The sample included teachers with diverse initial training backgrounds in biology and different qualifications, BSc (n= 63, 100%), MSc (n = 8, 12.70%) and postgraduate diploma (n = 13, 20.60%).

Research Instrument

A multi-dimensional questionnaire consisting of 17 questions (Q1 – Q17, Appendix) was designed by adapting items from instruments published in studies conducted in different countries (Fonseca *et al.*, 2012; Bryce and Gray, 2004). The content validity of the instrument was scrutinized by three A/L biology teachers with more than ten years of experience and its construct validity was tested through psychometric analysis. The internal consistency of the instrument was assessed by directing the instrument to ten A/L biology teachers who attended a similar workshop in the North Central Province. By finding the Cronbach's alpha,the test questions of the instrument were validated.

The first seven questions (Q1 – Q7, Appendix) of the questionnaire were to gather socio-demographic data of the participants. Teachers' beliefs about biotechnology were assessed by appraising the importance they attribute to it, their attitudes towards it, and their interest in it (Q8, Q10and Q14) using five-point Likert-type scales. In addition, a dichotomous question (Q13) was also included assess the attitude. Teachers' attitudes are highly complex and multi-dimensional, determined by the interaction of cognitive, affective and behavioral factors (Fonseca *et al*., 2012). The cognitive component of teachers' attitudes was judged by measuring their endorsement of biotechnology to the quality of life by the question Q8 (Appendix). The question Q10 (Appendix) was asked to evaluate the teachers' interest towards biotechnology.

Teachers' intention to buy Genetically Modified (GM) products or to get genetic tests for medical diagnostics were using question Q14 (Appendix) of the questionnaire to evaluate the behavioral component of teachers' attitude. Question Q10 (Appendix) asked a dichotomous question to check if teachers think that GM foods are safe. This question evaluates the affective component of teachers' attitude. The accuracy of teachers' knowledge and the quality of materials they provide to students are highly influenced by the selection of information sources by teachers (Duke and Ward, 2009). Therefore, questions Q11 and Q17 (Appendix) were designed to evaluate teachers decision to use information sources according to their availability. Calder head (1996) points out the relationship between beliefs and experience and states that teachers' past experiences influence the way they think about their work. Consequently, Q11 (Appendix) was asked to assess how-well informed the teachers were about the subject. Question Q17 (Appendix) asked the teachers to identify the sources they most

frequently used from a list of 13 options. The question Q9 (Appendix) asked teachers to evaluate how important they thought the biotechnology education was.

The questions Q15 and Q16 (Appendix) were included to assess teachers' beliefs about biotechnology teaching and/or research. In question Q15, teachers' interest in implementing experimental activities in the scope of biotechnology was explored using a dichotomous question. Another dichotomous question Q16 (Appendix) was asked to investigate the teachers' interest to participate in training courses in the scope of biotechnology education.

Data Collection and Analyses

The field work was conducted from October 14th to 15th 2013. A printed version of the questionnaire was developed and administered in the participants' first language in hand. The original version of the questionnaire was developed in English and then translated into Sinhala and Tamil. All three versions (English, Sinhala and Tamil) were identical to reduce differences in teachers' responses. Enough time was given to the participants at the end of the workshop to complete the questionnaire. The data collected were codified, recorded, cleansed and subjected to descriptive statistical analyses to evaluate its suitability for further examination. Imputation of missing values for certain items was executed by linear interpolation as described by Twisk and de Vente (2002). Principal component analysis with Varimax rotation was called exploratory factor analysis (EFA) and reliability analysis were performed evaluate the dimensionality and the psychometric property of the data. EFA is used to analyze data variations to identify latent factors that account for the variability of a larger set of measured variables (Henson and Roberts, 2006).

Kaiser-Meyer-Olkin (KMO) measure and the Bartlett's test of sphericity were performed to assess the factorability of the data set to determine the adequacy of the sample for factor analysis (Worthington and Whittaker, 2006). Communalities and loading scores were considered to judge the quality of the identified factor structures (MacCallum*et al*., 1999; Costello and Osborne, 2005). The KMO score threshold was set at 0.50 for a satisfactory factor analysis to continue (Sharma, 1996) and the significance of the correlation among the variables was determined for a confidence interval of 95% via Bartlett's test as described by Ho (2006) and cited in Fonseca *et al*. (2012, p371).Factor retention was determined based on the Kaiser criterion (eigenvalues >1) and the scree test as described by Hayton*et al*. (2004) (cited in Fonseca *et al*., 2012, p371). Items which displayed communalities and loadings above 0.40 were considered for analysis (Costello and Osborne, 2005).

Frequencies and mean scores were calculated for each dichotomous and ordinal item of the questionnaire, respectively. Student's *t*-tests were performed to examine mean responses. One-sample *t*-tests were used to compare the teachers' mean responses with the midpoint of the test variables. A test value of three (3.0) in a five-point scale was set to define respondents' positioning as neutral (3.0), positive (>3.0) and negative (<3.0). Mean responses that were not significantly different from 3.0 at 95% confidence interval were considered neutral assessment (Fonseca *et al*., 2012). Mean responses, which were significantly higher or lower than 3.0, were considered as positive or negative assessment, respectively (Fonseca *et al*., 2012).

The correlations between ordinal variables were evaluated using Spearman's rank correlation coefficient. The strength of the relationships was expressed based on the values described by De Vaus (2002) and cited in Fonseca *et al*. (2012, p372). The scores were low, moderate or large when the correlations were <0.30, 0.30-0.50 or >0.50, respectively.

All data analyses were carried out using the statistical package for the social science (SPSS) version 17.0.

Results and Discussion

Beliefs of Teachers Regarding Biotechnology
Teachers play a key role in the promotion of scientific literacy (Fonseca *et al*., 2012). Teachers' orientation toward specific subjects impacts on their practice (Van Driel*et al*., 2007). As such, understanding teachers' beliefs is important to predict their practices and instructional decisions.

Teachers believe that biotechnology is important and interesting
There is a general belief that the application of biotechnology is important for the improvement of the quality of life despite the controversial thoughts over the implications of this technology (Gaskell *et al*., 2006). The teachers surveyed in this study revealed that biotechnology is important ($M = 4.46$, $SD = 0.96$, $t(62) = 12.02$, $p = 0.00$) to the quality of life. This is in agreement with Fonseca *et al*. (2012). Moreover, the teachers disclosed that biotechnology is interesting ($M = 4.73$, $SD = 0.54$, $t(62) = 25.20$, $p = 0.00$). These results demonstrate that the biology teachers participated in this study embrace similar beliefs to those of general public. A closer look into the salient features of teachers' cognitive and affective responses divulges that they are positive about the importance of biotechnology for the improvement of the quality of life.

Teachers' approval of biotechnology applications

Teachers' behavioral intention clearly shows how the purpose of the application of biotechnology impacts on its acceptability (Fonseca *et al*., 2012). In the present study, the KMO score being 0.54 (Table 1) behavioral component scale endorses the adequacy of samples for factor analysis. The Bartlett's test shows that there is a statistically significant correlation between the variables (Table 1). A two-factor solution accounting for 72.27% of the variance recorded was identified for this scale: *purchasing inspiration* and *medical purpose* (Table 1). It was evident that these teachers were willing to buy transgenic foods if they were healthier than other foods (Table 1) although half of the sampled population mentioned that GM foods are unsafe. This is in agreement with the finding by Fonseca *et al*. (2012) with a group of Portuguese biology teachers. However, teachers in the present study do not approve the application of biotechnology medical purpose for reasons which could not be explored in this study.

This may be due to the fact that the teachers participated in this survey might have considered human cloning for therapeutic and reproductive purposes and embryonic gene manipulation as one and only application for medical purposes. This is in contrast to what Fonseca *et al*. (2012) observed in their study population.

Table 1: Teachers' approval of biotechnology applications: Factor structure of the behavioral component of attitudes scale based on exploratory factor analysis presented in rotated component matrix[a]

Item	h^2	Identifiable factors		*M* (SD)	t(62)	*p*
		Purchasing inspiration	Medical purpose			
Would you buy transgenic foods if they are easily available in the markets? (14a)	0.61	0.78		2.67 (1.57)	− 1.69	0.09
Do you buy medicines obtained by genetic manipulations? (14b)	0.67	0.74	0.35	2.81 (1.60)	− 0.94	0.35
Do you get genetic test(s) for medical diagnostic? (14c)	0.88		0.94	1.94 (1.55)	− 5.43	0.00
Would you buy transgenic foods if they were healthier than other foods? (14d)	0.74	0.76	− 0.40	3.14 (1.74)	0.65	0.51

Coefficients below 0.30 were suppressed. KMO = 0.54. Bartlett's Test of Sphericity: χ^2 (6) = 29.97, *p* = 0.00.
[a] indicates that rotation converged in 3 iterations.

Many teachers (93.70%) stated that they were aware of what genetically modified foods are. However, for the question to identify the respondents' view regarding the safety of genetically modified foods, equal response was recorded (49% for safe and 51% for unsafe).

Teachers' Beliefs about Biotechnology Education

It is important to acknowledge teachers' beliefs when planning to improve or change their practice (Van Driel*et al*., 2007). Teachers' beliefs about teaching, learning, curriculum objectives and the subject matter taught seem to highly influence teaching outcomes (Gess-Newsome, 1999). Therefore, it is imperative to understand the teachers' beliefs about biotechnology education and the factor that influence them. In the present study, most of the teachers considered biotechnology education to be very important (*M* = 4.83, *SD* = 0.49, *t*(62) = 29.38, *p* = 0.00). According to the teachers' beliefs, the importance of biotechnology education positively correlates with the importance of biotechnology to the quality of life and the interest towards biotechnology (Table 2). This means that the teachers who are more optimistic about biotechnology are more prone to teach this subject. Nonetheless, this result must not be overestimated as these variables are moderately correlated with a coefficient of r_s = 0.365 (Table 2). Moreover, the importance of biotechnology positively correlates with the level of information that the teachers possess about biotechnology (Table 2). This clearly delineates that when teachers become well-informed about biotechnology, their attitude of considering biotechnology education to be important increases.

Table 2: Spearman's rank correlation between teachers' beliefs about biotechnology, biotechnology education and their interest towards biotechnology

	Q8	Q9	Q10	Q11
Importance of biotechnology to the quality of life (Q8)	1.000	0.365[**]	0.219	0.004
Importance of biotechnology education (Q9)	0.365[**]	1.000	0.596[**]	0.293[*]
Interest in biotechnology (Q10)	0.219	0.596[**]	1.000	0.193
Degree of information about biotechnology (Q11)	0.004	0.293[*]	0.193	1.000

[*]indicates significant differences for α = 0.05, [**]indicates significant differences for α = 0.01

Teachers' Selection of Information Sources about Biotechnology

Most of the studies that have focused on how science teachers choose information sources have shown that they use a limited number of readily available sources chiefly due to time limitation and the perception that they lack the skills to properly evaluate and use them (Sun and Liu, 2009). Nonetheless, the present study reveals that most of the teachers (39 teachers, 61.90%) use internet as a source of information (Fig. 1). This is in agreement with Fonseca *et al.* (2012). However, choice of information sources is highly influenced by the information literacy of the teachers and the time required accessing the sources (Williams and Coles, 2007). The teachers have mentioned that they get very limited information about biotechnology through conferences (Fig. 1). This may be due to limited chance that teachers get to attend conferences locally as well as in international level.
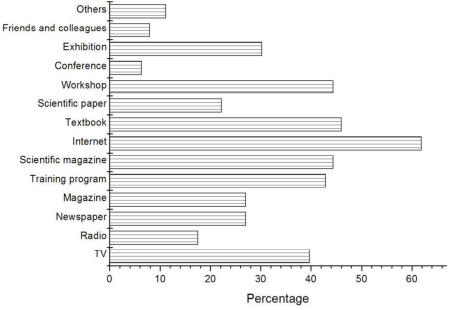

Figure 1: Sources of information teachers use to gather information about biotechnology

Teachers' Literacy Level about Biotechnology

The present study disclosed that the teachers participated in this survey were well-informed about biotechnology ($M = 3.97$, $SD = 0.95$, $t(62) = 8.09$, $p = 0.00$). However, many teachers (n = 62, 98.40%) stated that they are interested in participating in training programs in the scope of formal biotechnology education. This implies that although the teachers had greater service period (M = 13.82, SD = 7.60), they still have gaps to fill in their literacy level about biotechnology. Moreover, 60 teachers (95.20%) reported that they are interested in implementing experimental activities in the scope of biotechnology in the classes they teach. This is an important aspect to consider. Many people believe that schools do not have enough facilities to carry our experiments and research activities thereby jeopardizing the teaching and learning process. Since teachers are interested in implementing experimental activities at schools, ensuring the availability of facilities would enhance quality of experiments in the scope of biotechnology and thereby the learning of the subject.

Conclusion

This study carried out among Advanced Level biology teachers in the eastern province examined the teachers' beliefs about biotechnology and biotechnology education, the relationship between these two and the factors that affect teachers' beliefs. The teachers believed that biotechnology is interesting and important for the improvement of the quality of life and this attitude of teachers greatly persuades their practice towards biotechnology teaching or education. More interestingly the teachers were willing to buy GM foods if they were healthier than other foods. However, they did not accept the application of biotechnology for medical purpose for some reasons. There was a controversy over the safety of GM foods although many teachers were aware of what GM foods are. Moreover, majority of teachers believe that biotechnology education is important and this attitude of teachers was influenced by their interest towards the subject and the level of information literacy they have about the subject. Finally, provided that required facilities are ensured, this particular group of teachers is prepared to implement experiments and attend training programs in the scope of biotechnology and biotechnology education, respectively.

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Appendix

Questionnaire to assess the A/L biology teachers' beliefs about biotechnology

Q1. Age :

Q2. Gender:

Q3. Years of service:

Q4. Academic degree(s):

Q5. Name of the course(s) attended:

Q6. Name of the higher education institution(s) attended:

Q7. Subjects taught:

Q8. How important do you think biotechnology is to the quality of life (**1-Not at all important** to **5-Very important**)?

Q9. How important do you think biotechnology education is (**1-Not at all important** to **5-Very important**)?

Q10. Rate your interest towards biotechnology (**1-I am not** interested at all to **5-I am very interested**).

Q11. How well informed are you about biotechnology (**1-Not at all informed** to **5-Very well informed**)?

Q12. Do you know what Genetically Modified Foods are? **Yes/No**

Q13. Do you think that genetically modified foods (transgenic foods) are safe? **Yes/No**

      If No, Please state the reason.

Q14. How often. (**1-Never** to **5-Always**)

      (a) would you buy transgenic foods if they are easily available in supermarkets?

      (b) do you buy medicines obtained by genetic manipulation?

      (c) do you get genetic test(s) for medical diagnostic?

      (e) would you buy transgenic foods if they are healthier than other foods?

Q15. Are you interested in implementing experimental activities in the scope of biotechnology in the classes you teach? (**Yes/No**)

Q16. Are you interested in participating in training courses in the scope of formal biotechnology education? (**Yes/No**)

Q17. From which of the following sources do you most commonly obtain information about biotechnology?

    TV ☐   Radio☐   Newspapers☐ Magazines☐   Training programs☐   Scientific magazines☐   Internet☐   Textbooks☐   Scientific papers☐   Workshop☐ Conferences☐   Exhibitions☐   Friends and colleagues☐   Others☐