Benefits of Hands-On Biotechnology Training Workshops for Secondary School Educators and College Students

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This paper is based on a project that evaluated the benefits of biotechnology training workshops for its integration into school curriculum that is dependent on teachers' knowledge, their teaching confidence, as well as their opinion towards biotechnology. Teachers, as well as a parallel group comprising of college students, were given pre- and post-training tests to assess changes in their knowledge and opinion about biotechnology. Participant teachers' confidence in teaching biotechnology was also assessed. These evaluations revealed a significant increase in the post-test scores compared to the pre-test for teachers (df = 22, t= 12.706, p<0.0001) and college students (df= 12, t= 5.584, p<0.0001). In addition, the teachers (df= 39, t= 8.078, p<0.0001) as well as the college students (df= 7, t= 4.174, p=0.0042) registered a significant increase in their positive attitude towards biotechnology after the training workshops. Biotechnology teaching confidence of the participant educators also showed a significant increase (df= 35, t= 6.393, p<.0001) after the workshops. However, urban teachers had a significantly greater (df= 34, t= -3.191, p=0.0030) gain of 0.376 in their post-training teaching confidence compared to the 0.145 gain by their rural counterparts. Additionally, a statistically significant (r= 0.868, r-squared= 0.7534, p= .0219) relationship was found between teaching confidence and positive opinion of the teachers regarding biotechnology. Since teachers' pedagogical approach and adoption of biotechnology curriculum is dependent on the above issues, results presented in this study are important for designing future biotechnology training workshops.

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Abbreviations:
df= degree of freedom, t= t-test, p= probability value

Introduction

Biotechnology is the continuation of a long tradition of modifications based on the principles of genetics and biology that improve plants, animals and the environment to make them more useful to humans, thus it has the potential to change the very nature of humanity [1, 2]. However, due to a clear lack of understanding about the basics of molecular biology by the general population, there is public opposition to the adoption of biotechnology [3, 4]. The importance of public opinion for greater involvement by public and private groups has been stressed for the sustainability of the agricultural biotechnology industry [5]. A national study found that most high school students could not define biotechnology, thus teaching concepts related to biotechnology at the school level is being obligated as a mission by The National Council for Agricultural Education [6]. Recently, the European Initiative for Biotechnology Education was set up and the European Union funded a study on different cultural contexts in which biotechnology teaching and learning is embedded [7]. Therefore, it is important to prepare teachers in biotechnology so that they can play their roles both in the debate and the dissemination of information [3]. Teachers need opportunities to develop their own informed views on what biotechnology is, in order to help their students develop informed views and enhance the implementation of the biotechnology curriculum [2, 6]. It has been reported that though agricultural education teachers possessed a positive attitude towards biotechnology; they lacked the resources and knowledge to incorporate the subject matter into their curriculum [8]. Teachers are most likely to adopt biotechnology curriculum if they are exposed to biotechnology training, boosting their knowledge, enhancing teaching confidence and their willingness to adopt new curriculum involving plants, animals, and the environment [6, 9]. It is hypothesized that the attitudes of teachers in the sample towards biotechnology, their knowledge of it, and their teaching confidence are positively related to the training they received.

Materials and Methods

To the extent the hypothesis fails to be rejected, the results could be useful in providing insights regarding biotechnology training for teachers. Forty-two high and middle school teachers were recruited, using several means, to participate in intermediate to advanced level biotechnology workshops held during the summer months in 2005-06. Among these, six teachers had previously attended introductory level biotechnology training [10]. Demographically, there was equal representation from rural and urban areas. Twelve percent were middle school teachers and the rest were high school teachers. Female teachers accounted for 71 percent of the workshop participants while male teachers' ratio was 29 percent. In addition, 16 Tennessee State University (TSU) students who had taken college level biology courses also participated in these workshops.

Topics covered in these training workshops were chosen to clarify molecular biology's central dogma (DNA-RNA-Protein), while providing laboratory training via hands-on activities was also emphasized. Techniques for DNA extraction and quantification, gel electrophoresis, polymerase chain reaction, as well as marker analysis via bioinformatics tools were included in the training schedules (Table 1). In this quasi-experimental approach, three self-selected treatment groups were created. The self-selected treatment groups differed according to participants' academic background and their purpose for the training. The main group included all the teachers who attended the workshop, while its subgroup consisted of only those teachers who had previously attended introductory level biotechnology training. Another group was composed of TSU students who had taken college level biology courses.

Gains in technical knowledge and opinion about biotechnology as well as teaching confidence of the educators were accessed by pre-workshop and post-workshop tests (Table 2). In each test

Table 1: Topics covered in classroom and/or laboratory for biotechnology training workshop

Lectures: Basic Molecular Biology – Genes to Proteins, Molecular, Markers and Their Applications in Agriculture, Post-Translation Modifications, Economics of Biotechnology in Agriculture.
Discussions: Why to teach Biotechnology, Risks and benefits of genetically modified organisms, Applications of Biotechnology in agriculture, Bioethics Scenarios.
Hands on Laboratories: Solutions and dilutions, micropipetting and sterile techniques. Use of Bio-Rad (Hercules, CA) kits, i.e., Genes in a Bottle, DNA Finger-Printing & PV92 PCR Amplification.
Other Activities: ORF (open reading frame) Finding, Paper PCR (polymerase chain reaction), Scientific facilities tours, Genotype Frequencies. CEPRAP's (Partnership for Plant Genomics Education, University of California at Davis, CA) Virtual DNA Fingerprinting Simulation.

Table 2: Sample survey questions designed to assess participants' knowledge, teaching confidence, and opinion towards biotechnology before and after the training workshops

1. Why do some DNA bands appear more intense (darker) compared to others after gel electrophoresis? ; Describe the steps involved in bacterial transformation. What are the key ingredients? ; A DNA molecule has two complimentary strands. The number of DNA molecules doubles after each cycle of PCR. Express this with a mathematical formula. ; What are some popular misconceptions about the use of DNA in criminal investigation, many resulting from shows such as CBS's "C.S.I."? ; Other than criminal investigations, what are some other important uses of DNA Fingerprinting?
2. How comfortable are you with teaching the biotechnology component of the course(s)? ; To what extent would you be able to incorporate specific hands-on activities in your school laboratory? ; Are there any specific biotech laboratory activities that you would like to conduct but do not have adequate equipment to do so? If so please indicate. ; Why would you teach biotechnology in your classroom, how does biotechnology fit into the curriculum of your classroom? ; What would you expect to gain from participating in a workshop designed to introduce biotechnology into your existing curriculum?
3. An allergen is any substance that can cause an allergic reaction in a person. Does biotechnology pose any problems in terms of introducing an allergen to the food? ; Biodiversity is a term that is often used when discussing whole ecosystems referring to the variability of animals, plants and microorganisms within a specific ecosystem. Does introduction of the genetically altered product pose any environmental risks in terms of biodiversity? ; Since biotechnology can introduce animal genes in plants, might these application present problems to consumers due to religious or moral beliefs? ; Is the opposition to biotechnology based on the actual risk implied or only on the alleged immorality of producing genetically modified (GM) organisms? ; Should different standards of food safety be applied when the tradeoff involved is that starving people could potentially be saved by donating GM grain rejected by European importers?

several questions were designed to test the technical knowledge of the workshop participants and their understanding of basic molecular biology and biochemical analyses. In both pre- and post-tests, some questions were designed to inquire whether the participants had an anti-biotech opinion or considered biotechnology less risky than its benefits. Following the procedure of Leislie and Schibeci (2003), the neutral attitude towards biotechnology was considered pro-biotech opinion.

Additionally, in order to assess teachers' perceived level of confidence in teaching biotechnology content, they were asked to respond on a Likert scale of 1 to 5 before and after the training; where 5 was very confident, and 1 was not confident at all. Results of pre- and post-tests were analyzed using StatView (SAS Institute, Inc., Cary, NC) statistical software. The statistical analyses included descriptive and inferential analyses with the alpha level established at 0.05 a priori. To further examine the differences among the groups, multiple pair-wise comparisons were used.

Results

The post-test and the pre-test scores of secondary educators were compared in order to assess the gains in their biotechnology knowledge. The post-tests showed a mean increase of 0.360 over the pre-tests. To consider whether this was a statistically significant increase, the possibility of fairly normal distributions was determined first. The post-test distribution was considered normal with a skewness factor of -0.255. However, the pre-test was not normal with a skewness factor of 1.713. Hence, the data were analyzed using a non-parametric test, the Wilcoxon Signed Rank Test. This analysis revealed that there was a significant difference between the pre-test and the post-test ($p<0.0001$). In addition (as a backup for the Wilcoxon), a dependent (paired) t-test was utilized to test whether there was a statistically significant increase in the biotechnology knowledge. According to the results of the dependent t-test, the increase was statistically significant ($df= 22$, $t= 12.706$, $p<0.0001$). In a practical sense, teachers who attended the biotechnology workshop received a significant increase in their biotechnology knowledge (Table 3).

To assess the gains in biotechnology knowledge of college students who participated in the workshops, the post-test and the pre-test scores were compared and a mean increase of 0.345 was found. To consider whether this was a statistically significant increase, the possibility of fairly normal distributions was determined first. Both the pre-test and the post-test distributions were considered normal with skewness factors of 0.053 and 0.137, respectively. In addition, the variances were deemed fairly equal through the use of confidence intervals for the variance. With these assumptions resolved, a dependent (paired) t-test was utilized to test whether there was a statistically significant increase in biotechnology knowledge. Thus, college students who attended the biotechnology workshop showed a statistically significant ($df= 12$, $t= 5.584$, $p<0.0001$) increase in their biotechnology knowledge (Table 3).

Attitudes of the educators regarding biotechnology or genetically modified organisms (GMO), whether positive or not, was also assessed before and after the training workshops. The post-test scores showed a mean increase of 0.263 over the pre-test scores. To determine whether this was a statistically significant increase, the possibility of fairly normal distributions was determined first. Both the pre-test and the post-test distributions were considered normal with skewness factors of 0.318 and -1.130, respectively. In addition, the variances were deemed fairly equal through the use of confidence intervals for the variance. With these assumptions resolved, a dependent (paired) t-test was utilized to test whether there was a statistically significant increase in the

Table 3: Comparisons of pre-test and post-test data on differences in biotechnology knowledge, teaching confidence and biotechnology opinion

Comparison of post and pre-test scores for the two groups	Pre-test scores	Post-test scores	Average increase	Paired t-test results
Biotechnology Knowledge-Secondary Educators	0.15±0.02	0.54±0.03	0.36	df=22,t=12.71,p<0.0001
Teaching Confidence-Secondary Educators	0.60±0.05	0.86 ±0.03	0.26	df=35, t=6.39, p<0.0001
Opinion about Biotechnology-Secondary Educators	0.53±0.03	0.79 ±0.02	0.26	df=39, t=8.08, p<0.0001
Biotechnology Knowledge- College Students	0.44±0.06	0.74 ±0.03	0.35	df=12, t=5.58, p=0.0001
Opinion about Biotechnology- College Students	0.34±0.06	0.64 ±0.03	0.22	df= 7, t=4.17, p=0.0042

positive biotechnology opinion. According to the results of the dependent t-test, the increase was statistically significant (df= 39, t= 8.078, p<0.0001). In a practical sense, teachers who attended the biotechnology workshop developed a significant increase in their positive attitude towards biotechnology (Table 3).

The opinions of the college students regarding biotechnology or GMO, whether favorable or not was also assessed before and after the training workshops. The post-test scores showed a mean increase of 0.218 over the pre-test scores. To consider whether this was a statistically significant increase, the possibility of fairly normal distributions was determined first. Both the pre-test and the post-test distributions were considered normal with skewness factors of -0.151 and -0.171 respectively. Also the variances were deemed fairly equal through the use of confidence intervals for the variance. With these assumptions resolved, a dependent (paired) t-test was utilized and according to the results, the increase was statistically significant (df= 7, t= 4.174, p=0.0042). Thus, college students who attended the biotechnology workshop became significantly more favorable in their opinion about biotechnology (Table 3).

The increase in teaching confidence of the educators concerning teaching biotechnology was assessed by comparing pre- and post-test results. The post-test scores showed a mean increase of 0.260 over the pre-test scores. To consider whether this was a statistically significant increase, the possibility of fairly normal distributions was determined first. Both the pre-test and the post-test distributions were considered normal with skewness factors of -0.137 and -0.753 respectively. In addition, the variances were deemed fairly equal through the use of confidence intervals for the variance. With these assumptions resolved, a dependent (paired) t-test was utilized to test whether there was a statistically significant increase in the teaching confidence. According to the results of the dependent t-test, the increase was statistically significant (df= 35, t= 6.393, p<0.0001). In a practical sense, teachers who attended the biotechnology workshop received a significant increase in their teaching confidence relating to biotechnology (Table 3).

To assess if differences in teaching confidence gains had been influenced by school location and whether there was a statistically significant difference in teaching confidence gains between rural and urban school teachers, the possibility of fairly normal distributions was determined first. Both the rural and the urban distributions were considered normal with skewness factors of -0.114 and 0.035, respectively. The variances were not deemed fairly equal through the use of an f-test that compared the variances (p=0.0052). Thus, a Mann-Whitney U-test (non-parametric) was utilized to test whether there was a statistically significant difference in the teaching confidence gains between rural and urban school teachers. A statistically significant difference was found between rural and urban teachers (p=0.0029). Later, as a backup for the Mann-Whitney, an independent t-test was conducted and the difference was statistically significant also (df= 34, t= -3.191, p=0.0030). These results present that urban teachers who attended the biotechnology workshop had a significantly greater gain (0.376±0.065) in their teaching confidence than that of rural teachers (0.145±0.032).

For the six teachers who had previously attended introductory level biotechnology trainings [10], correlation coefficient analyses were performed to determine if two dependent variables (teaching confidence gains and biotechnology opinion gains) were significantly correlated with each other. This relationship was found to be statistically significant (r= 0.868, r-squared= 0.7534, p=0.0219). With only a few scores, this may not have any significant meaning; however, if interpreted correctly, it shows that as favorable biotechnology opinions increase for teachers, so does their teaching confidence. In other words, approximately 75 percent of the variability in teaching confidence can be explained by the variability in biotechnology opinion gains (Figure 1).

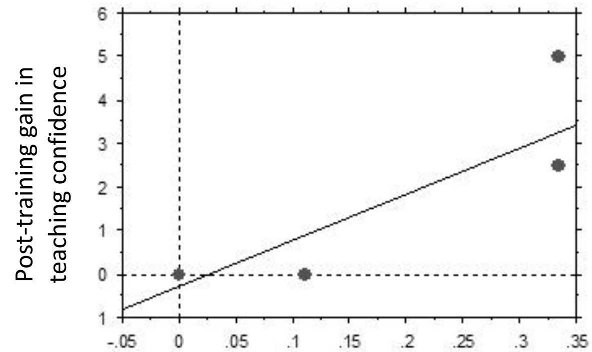

Figure 1: Six participant educators who had previously attended introductory level training were given pre- and post-training tests for the intermediate to advanced biotechnology workshop. Participant teachers' confidence in teaching biotechnology showed significant increase and they also developed significant increase in their positive attitude towards biotechnology after these training workshops. Correlation coefficient analyses were performed for the relationship between two dependent variables (teaching confidence gains and biotechnology opinion gains), which was found statistically significant (r = 0.868, r-squared = 0.7534, p=0.0219). The above bivariate scattergram with a regression line shows that approximately 75 percent of the variability in teaching confidence can be explained by the variability in biotechnology opinion gains.

Discussion

Biotechnology is a broad field encompassing various disciplines in natural and social sciences [11], thus it is an ideal subject for school curricula [2]. Biotechnology has direct significant social implications; therefore, the teaching community has a vital role to play both in the debate and the dissemination of relevant information [3, 8]. Since teachers' technical knowledge is critical in their pedagogical decisions that would also help their students develop informed views about biotechnology [2], their preparation is very important to enhance the implementation of the biotechnology curriculum [12]. To assist in this regard, the present study evaluated the implications of training especially on teaching confidence for teachers who attended biotechnology workshops.

The evaluations revealed that there was a significant increase (df= 22, t= 12.706, p<0.0001) in the post-test scores compared to the pre-test scores indicating that teachers who attended the biotechnology workshop received a significant increase in their biotechnology knowledge. Similarly, the college students who attended the workshop showed significant (df= 12, t= 5.584, p<0.0001) increase in their biotechnology knowledge after receiving the training (Table 3). These findings, that both the teachers and college students benefited by attending the workshops, are in agreement with previous studies where trainings even without hands-on exercise were found beneficial [6].

Rudd and Hillison found that educators' teaching confidence by virtue of self-perceived knowledge of the teachers was an important factor for their subsequent adoption and teaching of the biotechnology curriculum [13]. In this study, teaching confidence of the participant educators was evaluated before and after the trainings. According to the results teachers gained a significant increase (df= 35, t= 6.393, p<0.0001) in their teaching confidence relating to biotechnology after attending the workshop (Table 3). Such workshops have been reported to increase the teaching confidence of educators [6]. Interestingly, a statistically significant difference (df= 34, t= -3.191, p=0.0030) was found when the teaching confidence of rural and urban teachers who attended the biotechnology workshop were compared. Urban teachers had a significantly greater gain of 0.376±0.065 in their post-training teaching confidence compared to a 0.145±0.032 gain by the rural teachers. This could be explained by the findings that perceptions regarding food differ among rural and urban communities [14]. Rural community residents are more resistant to GMO [15]; therefore, educators who teach in rural schools felt less confident to teach biotechnology.

This study also assessed the change in the opinions of the workshop participants regarding biotechnology before and after the training workshops. As expected, the teachers developed a significant increase (df= 39, t= 8.078, p<0.0001) in their positive attitude towards biotechnology subsequent to workshop attendance. When the same test was utilized for a different group, comprised of college students, it was found that they also became significantly more favorable (df= 7, t=4.174, p=0.0042) in their opinion about biotechnology after attending the training workshop (Table 3). Similar findings have been reported by others [15, 16] supporting the notion that more biotechnology education would facilitate the GMO acceptance. This is important since teachers may not always support GMO, especially if "extremes" of biotechnology" are introduced [8]. Positive or negative opinions of the teachers regarding GMO may have an impact on the ways they teach biotechnology [1]. A statistically significant relationship was found between teaching confidence and biotechnology opinions of the participating teachers (r = 0.868, r-squared= 0.7534, p=0.0219). Thus, approximately 75% of the variability in teaching confidence was associated with the variability in biotechnology opinion gains (Figure 1).

The relationships between teachers' knowledge, their teaching confidence, as well as their opinion towards biotechnology found in this study are important, since teachers' pedagogical approach and adoption of biotechnology curriculum is dependent on these issues [9, 17]. Workshops that allow teachers to practice basic skills in applied laboratories are the most effective use of training time [6]. An important finding of this study is that biotechnology training workshops have a positive effect on the likelihood that teachers will find teaching biotechnology in schools useful. This study demonstrated that similar workshops are needed for teachers, especially those who are teaching in rural areas. Thus, future trainings that would include hands-on biotechnology laboratories would lead to integration and adoption of biotechnology curriculum as well as acceptance of GMOs. Such trainings should be extended to cover other stakeholders, including producers and consumers. This would require a concerted effort involving both private and public sector institutions. Key among the latter are land grant universities, with established extension systems, that can educate various stakeholders about biotechnology using results from this research.

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