Development of STEM tissue culture module in promoting plant biotechnology

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Abstract. Tissue culture is a part of modern biotechnology, which offers a lot of potential in tackling food security, genetic conservation and plant breeding. Thus, it is important to introduce plant biotechnology to the young generation in order to foster their positive attitude, which ultimately in the future, will result in human capital and public awareness in the field itself. This study focused on the development of STEM tissue culture module as a teaching aid to introduce plant biotechnology and exposing the variety of STEM career at school level among primary school students of ages 10-12 years old. This module consists of four activities focusing on the seed identification, water transportation in plants, grass doll and carrot tissue culture. Based on the conducted survey, 80% of the participants exhibited interest in the tissue culture module with 42% reacted positively on the statement that this module triggered their curiosity on plant biotechnology. Hence, this module is a promising teaching aid to promote STEM especially in plant biotechnology.

Keywords: STEM education, Plant biotechnology, Tissue culture, STEM tissue culture module

1. Introduction
As one of the countries located in the biodiversity hotspot and ranked 12 in the National Biodiversity Index, it is important for Malaysia to conserve these national treasures while utilising these resources sustainably. Biotechnological tools are the key to achieve these agenda and tissue culture is part of plant biotechnology, which offers a lot of potential in tackling food security, genetic conservation and plant breeding. Thus, it is important to introduce plant biotechnology to the young generation in order to foster their positive attitude, which ultimately in the future, will result in human capital and public awareness in the field itself. Apart from that, it is vital for students to be equipped with STEM skills so that they are able to apply and connect multidisciplinary knowledge and become competent in driving the 4th industrial revolution (4IR) in the future.

This strategy can be achieved via STEM education. Nevertheless, the real challenges for STEM education in Malaysia includes lack of motivation, inflexibility of syllabus, time constraints, lack of training, inadequate facilities, low number of students’ involvement and school community response [1]. To overcome the challenges, the development of STEM module by the university will be able to assist the teachers in school to conduct the STEM education effectively. In general, these modules demonstrated a positive impact on students’ level of interest towards STEM education and nurtured their interest on the specific field. In Malaysia, there are a few numbers of specialized module
developed by universities such as forensic science [2], space [3] and robotic [4] but there is still lacking of module related to plant science or biotechnology. A recent increase of research in plant biotechnology especially in ASEAN is a sign of the importance of this field to the region [5]. However, the most challenging obstacle of plant biotechnology is to gain public acceptance, as the technology can be controversial and questionable. It is not the in-depth knowledge but the accessibility to knowledge to allow public to make informed decision along with outreach and education program, which will result in positive attitude towards plant biotechnology. Early exposure to young generation especially students in school is essential to support the development of plant biotechnology in the country. Previous study revealed that students are less resistance towards plant biotechnology as compared to animal biotechnology [6] and this topic is of greatest interest in biotechnology among both teachers and students [7]. Besides, the knowledge and understanding in biotechnology is still at medium level among students especially in Malaysia [8]. In addition, studies from other countries indicate that limited understanding on biotechnology due to lack of engagement in biotechnology teaching as well as materials and practical limitation [9][10]. The study of science based on plants is compelling in fostering STEM skills, as it is large enough to be manipulated and hardy enough to be handled especially among young students. Plant’s science experiment is inexpensive and safe compared to the other experimental living things (i.e., animals and microorganisms). Therefore, the purpose of this preliminary study was to identify young generation’s interest towards STEM and plant biotechnology through tissue culture module as teaching aids for plant biotechnology as well as developing STEM skills at schools’ level through fun learning approach while exposing the variety of STEM career among young generations.

2. Methodology

This preliminary study used a combination of quantitative and qualitative approach for data collection.

2.1. Samples

100 students from the primary school of SRK La Salle, Kuala Lumpur were chosen as participants in this study. The students aged ranges from 10-12 years old with no preference over their gender. University students act as a facilitator to assist the participants throughout this tissue culture module. Students were suited with lab coats and plays role as scientist.

2.2. The module

Lecturers who have the expertise in plant biotechnology have developed the module. There are four main activities in the module; seed identification, water transportation in plants; grass doll and carrot tissue culture. In seed identification activity, seven to eight types of vegetable and fruit seeds were given to each participant. The participants were required to observe the diversity of various seeds with their naked eye as well as through the microscope and determine the differences. In this activity participants were introduced to the concept of biodiversity.

Next, is the water transportation activity where colourful food grade dyes are used to demonstrate how plants transport water extensively through the network of phloem. Students conducted their own experiment, observed and recorded the real-time changes displayed by the cabbage leaves soaked in coloured water. The module emphasize on continues learning post STEM on-site activity hence each participant is taught to make their own grass doll as their third activity. This grass doll was made with materials they can find in their daily surroundings. The grass doll will sprout a head full of grass or shoots and participant is encouraged to do their observations and record the growth in a logbook. This activity enables the participant to simulate the conducive environment required for seeds to germinate including the water and moisture level, substrate for root adhesion and sunlight.

The final activity introduces the main application of tissue culture which brings together their knowledge in prior activities in this module. Participants were given carrot cells to grow in specific culture medias under portable mini lamina flow built to replicate the ones used in laboratories. This allows participants to experience the feel of working in lab environment. Facilitators who guide every
student to understand the concept fully through hands-on and learning aids such as posters closely supervised each activity.

2.3. Data collection and analysis
After pursuing the experiments, random sampling technique has been applied for data collection. 40 random participants were given a set of questions in order to measure their understandings and interest in the module and plant biotechnology. The questionnaire used a 5-point Likert scale with 1 represent strongly disagree and 5 represent strongly agree. The data collected were tabulated in Excel and analyzed, and results were displayed in the table using a percentage. Only 31 set of answers were considered reliable with 9 remaining set of answers were excluded with the answer deemed unreliable for various reasons. Apart from the conducted survey, observation on the participants responses in each experiment as well as interview sessions with the teachers were also used as part of data collection.

3. Result and Discussion

3.1. Activities in the module
This tissue culture module was developed with four activities as elaborated in the methodology section. The order of the activities was designed from fundamental knowledge of plants as living thing all the way to the technological application in plant biotechnology, which is the tissue culture itself.

Based on the observation while the participants were undertaking the seed identification activity, they were keen to observe the seeds under the microscope. Students were introduced to the concept of biodiversity while relating their experience with edible seeds and inedible ones. Previous study mentioned that hands-on instruction and experiential learning are the most used teaching methods in biodiversity education but evaluation as highest level of thinking skills were the least used [11]. Hence, the module used in the present study involved the facilitator to guide the participants while encourage self-evaluation based on their experience while introducing new knowledge in biodiversity. One of the challenges faced in biodiversity education is communication [12]. It is important for the module to be crafted based on the specific target group, in this case, the primary school students. Same study suggested that a well-designed strategy will able to contribute towards achieving basic scientific literacy that allows a better understanding in biodiversity. This is further supported with the feedback from teachers via interview, which found this activity easy to replicate yet very effective to introduce the concept of biodiversity indirectly.

For the second activity, the module focuses on the fundamental process of plant as living thing, water transportation or scientifically known as transpiration. Previous study on students range between 8-17 years old found that 25% of them thought that leaves absorb water [13]. Thus, it is important to introduce this hands-on activity to allow a better understanding on the transpiration concept that is essential for plants. Different study revealed that transpiration concept is a good activity to introduce multidisciplinary concept by understanding the principle of physics in biology [14]. This module allow integration of both physic and biology syllabus which is hard to achieve in the classroom as agreed by the teachers based on the conducted interview.

The following activity is the fun and interactive grass doll that extended the activity post module. It is important for the module to be independent and instigate the element of art in order to stimulate the creativity of students, a vital STEM skill in the 21st century [15]. Grass doll activity allows participants to express themselves by designing their doll with the provided art materials. It is also important to have the continuous element in the module in order for the students to be able to retain their interest and curiosity for a long-lasting effect. By allowing the participants to take home their grass doll and observe the growth, this train the participants to be independent and spark their curiosity, a vital element in STEM education.

The final activity is a technological based activity in which participants experience the process of tissue culture by using a carrot. A sample of propagated callus originated from carrot was displayed to
the participants, something that is hard to be done by schoolteachers. A study conducted among teachers shown that technology is the hardest aspect to integrate in the classroom, as there are not readily available [16]. Thus, this module allows student the opportunity to get close with the technology in plant biotechnology. Such activity, while wearing the lab coat and using the dummy version of laminar flow hood, will allow experiential learning while exposing the participants with career opportunity in plant biotechnology. Based on the observation, participants really enjoy this eye-opening experience.

3.2. Feedback from the module

After pursuing the module, participants were randomly chosen to answer a survey to assess their interest on the module and plant biotechnology as a whole. The result of this preliminary study was tabulated in Table 1 below.

Table 1. Participants’ interest on the module and plant biotechnology. Data shown for the random responses after conducting the STEM tissue culture module. The responses were ranked on a scale from 1 (strongly disagree) to 5 (strongly agree).

| Percentage of participants (n=31) | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|----------------------------------|-------------------|----------|---------|-------|----------------|
| Interest in the module           | 0                 | 0        | 19.35   | 19.35 | 61.29          |
| Interest in plant biotechnology  | 0                 | 12.90    | 45.16   | 19.35 | 22.58          |

Overall, the response from participants is positive. Based on Table 1, the total of 80.64%, with 61.29% of them shown their strong interest on the module while the remaining 19.35% participants agree that the tissue culture module is interesting. Meanwhile, another 19.35% participants were neutral with the module while none participants gave a negative feedback on the module. This result is consistent with a recent published article, which observed that practical teaching improved understanding of basic plant tissue culture topic for pre-university students compared to their understanding when solely exposed with theory-based teaching [17]. This indicates that hands on activities are able to attract students in understanding tissue culture. Based on the observation in the present study, participants were engaging and able to comprehend the fundamental knowledge instigated in the module.

This finding of STEM module could generate interest in biotechnology-related field was also observed in other studies. Another Malaysian-based study revealed that biotechnology-based STEM module could foster interest of students in learning biotechnology. This particular module involved role-playing and the module was able to inculcate STEM skills including inventive skill [18]. The present study also integrated the element of role-playing with the participants were suited with lab coats and acted as scientists. A different study conducted in USA implied that agricultural education serves as an effective context to teach and reinforce STEM skills [19]. Both of these reported studies supported that STEM module are able to enhance STEM skills. Based on the observation throughout the activities, participants are able to provide a logical answer when asked with a higher order thinking question by the module’s facilitator. Apart from that, some problems were simulated in the activities and the participants were able to demonstrate their problem-solving skills when guided with appropriate hints.
The same Table 1 also portrayed the result for the participants feedback on their interest in plant biotechnology upon completing the module. Strongly agree and agree response both received 22.58% and 19.35% result respectively contributing to the total of 41.93% positive feedback while the rest remained neutral towards that the impact of the module in triggering their interest in plant biotechnology (45.16%). These positive responds are in line with previous study, which reported that interactive and enjoyable learning tools helped student to understand plant biotechnology better [20]. Though this published study used digital application as learning tools, it highlights the importance of the learning tools to be practical and fun to attract the interest of students in plant biotechnology.

On the other hand, 12.90% participants disagree that the module foster their interest in plant biotechnology. This may cause by lack of exposure to plant biotechnology or science plant in their education syllabus. A study found that student’s interest on plants was underdeveloped due to lack of exposure in the syllabus [21]. It is important to introduce biotechnology at school level as one study indicated that knowledge from science classes is the main factor to influence their perception in biotechnology with mass media, family and friends further down the rank [22]. This highlights the importance of integrating biotechnology in the education to inculcate interest and positive perception in biotechnology among students. It has been simulated before that low level of knowledge in biotechnology will reflect into negative attitude towards biotechnology [23]. Thus, it is important to introduce biotechnology-based STEM module to the young generation in order to sculpt more positive attitude towards biotechnology in the future. On top of that, based on Table 1, the mean score is 2.51 which illustrated the poor to moderate interest of participants in plant biotechnology. This result correlated with previous study conducted locally which observed secondary school students demonstrated moderate knowledge and attitude towards biotechnology [24].

4. Conclusion
The module that has been developed in this study encompasses the STEM education elements, which require the STEM skills including problem solving and creativity. The conducted study has successfully showed a positive impact on participants’ level of interest towards STEM education through the implementation of this module while also triggered their curiosity on plant biotechnology. This module will be a promising teaching aid to promote STEM especially in plant biotechnology as well as introducing the experience of STEM career specifically in plant biotechnology. In order to strengthen this module and further evaluate the impact, a future thorough study is required to assess the students in a long-term duration after completing the module. A larger sample from various background could highlight the effectiveness of this module in promoting plant biotechnology.

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