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Designing Nano-biotechnology Summer Camp with Experiential Learning Theory*

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In recent years, nanotechnology research has become a popular topic of interest, and the development of nanotechnology talent is also considered highly important worldwide. The Taiwan government has developed related policies and initiatives that support advanced and innovative nanotechnology research and budgets on human resource development in this field. It is our belief that the earlier students develop their awareness and interests in nanotechnology, the higher the possibility that they will become accomplished engineers in this field. Connected to this scenario, a nano-biotechnology summer camp was initiated in 2009 to take advantage of David Kolb's experiential learning theory. The curriculum integrates conceptual knowledge into practical activities for a complete learning experience. Fifty-two senior high school students attended this camp, and each student completed a questionnaire survey aiming to explore students' responses to this learning experience. Results of the present study revealed that the students were satisfied with the teaching and learning in the camp. They were also largely in favor of both 'hands-on experiments and laboratory experiences' and believed that more learning and better experiences occurred through these two course activities. This paper further discusses some important issues observed and suggests guidelines for future research and practice in nano-technology training.

Keywords: nano-biotechnology; summer camp; curriculum design; senior high school students; learner's attitudes

1. Introduction

Advancement of nanotechnology critically enhances social as well as economic and environmental development in all aspects and further promotes innovations in areas as broad as electronics, materials, medicine, food, clothing, communication, and education. It has brought advancement in academic research along with industrial developments. One of the most important areas is national security; hence, nanotechnology has gained great attention. As [1] noted, nanotechnology is an emerging field, one with potential impacts on various fields of science and technology. It is thus considered an important transformational aspect in present social scenarios. By definition, nanotechnology is actually a multidisciplinary and cross-disciplinary field, including chemistry, physics, biology, materials science, and engineering [2–4], and knowledge of nanotechnology can be widely applied to research and industrial arenas. In this way, it is a special field. Given the pivotal role of nanotechnology as a synthetic and fundamental grounding for other disciplines, the learning activities should include practical exercises other than simply imparting knowledge. These activities should enable students to develop whole systems involving multidisciplinary knowledge.

Human resource education and training is an important factor for the sustainability of nanotechnology development in both the academic world and industry. However, there are challenges. As pointed out by [5], current educational systems find it difficult to update their curricula due to the rapid pace of innovations in cross-discipline fields, and teenaged students lack interest in and are

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unaware of the connections between science and real-life applications [6]. To foster the talents required, there has been a greater emphasis on the re-design and development of nanotechnology education and training [4]. Interdisciplinary cooperation, reflecting unity in nature, needs to be promoted among school education of varied levels, industrial training by enterprises and technical or vocational educational systems, and other areas of common interest. The importance of the nanotechnology education of all should become and remain a primary consideration for government, commerce and technology development authorities, and educational systems in society [7].

To achieve the goal of nanotechnology education for the entire society in Taiwan, some outreach programs were initiated. 'The government of Taiwan has sponsored the K-12 nanotechnology educational program since 2002, and the main purpose of the program is to provide teachers with information regarding nanotechnology and develop teaching materials to encourage students to learn about advanced technology' [8, p. 141]. In a recent study, [9] concluded that adequate materials, preparation, and guidance for teachers, along with well-designed and engaging curriculum activities related to nano-science subjects, are necessary to facilitate the student's awareness of fundamental knowledge on nanotechnology. Based on [10], it is also emphasized that government should consider incentives or strengthen teaching activities in order to attract students to gain scientific knowledge about nanotechnology. A similar outreach program offered to youngsters is also viewed as beneficial to promoting science and engineering concepts to a wide range of students, increasing the pool of students who will be both prepared for and interested in pursuing a career in science or engineering fields [6]. In 2009, the Nano-Electro-Mechanical-System (NEMS) research center at National Taiwan University held a nano-biotechnology summer camp for senior high school students, in which they learned about nanotechnology. The camp was developed upon Kolb's ideas of experiential learning, which has been considered a suitable framework for promoting engineering learning [11–13]. The focus of this camp was on increasing students' awareness, knowledge, and academic interests in the area of nano-biotechnology. In this paper, the use of the nano-biotechnology summer camp as a learning platform to disseminate nanotechnology education is examined. Specifically, the primary study goal was to explore students' motivation for attending this camp, preference of learning activities, self-evaluation of learning experience, and general evaluation of teaching and learning offered in the camp. A correlation analysis was also carried out based on students' evaluation results. Finally, discussions and recommendations based on research findings from the student's perspective are addressed to assist instructors and curriculum developers in further improving any future implementation.

2. Kolb's experiential learning theory

Using a theoretical framework can help educators to create more effective educational programs or curricula so that their students can acquire deep learning and combine theory and practice better. Kolb's experiential learning theory can be applied to curriculum design, development of teaching materials, assessment of learning, and so on [14–16]. In contrast to traditional instructional methods, the implications of Kolb's theory allow educators to balance the teaching modes of apprehension, comprehension, intention, and extension in the learning process. Its application to the field of engineering science for improving educational practices has been proved beneficial or effective [11–13]. Hence, this paper describes a new camp approach for nanotechnology education of high school students, which is underpinned by Kolb's experiential learning theory.

Kolb's theory takes into account both John Dewey's classic theory of experience and Kurt Lewin's theory of social psychology [15]. The theory emphasizes 'experience' as the most significant factor in the individual learning and development process. The truth is that experiential learning aligns with constructivism, which posits that learner's construct meaning and learning from their experiences [17]. The main presumption of Kolb's theory depicts the learning or problem-solving process as a cycle consisting of 4 modes: concrete experience (feeling), reflective observation (watching), abstract conceptualization (thinking), and active experimentation (doing) [15, 17]. This study embraced Kolb's learning cycle as the pedagogical basis of designing a series of science learning activities, such as lab experiences and hands-on experiments, for students to learn nano-biotechnology, as shown in Fig. 1.

Table 1 shows the application of Kolb's theory in practice. While addressing the concrete experience stage, teachers can utilize different instructional strategies, including recalling background knowledge or life experiences, using speeches or lectures of practical demonstrations, and taking advantage of role-playing, etc. as possible teaching approaches. During the reflective observation stage, the lab experiences are arranged for students; they can discuss their experiences and can correlate them to previous experiences. The third learning mode is the

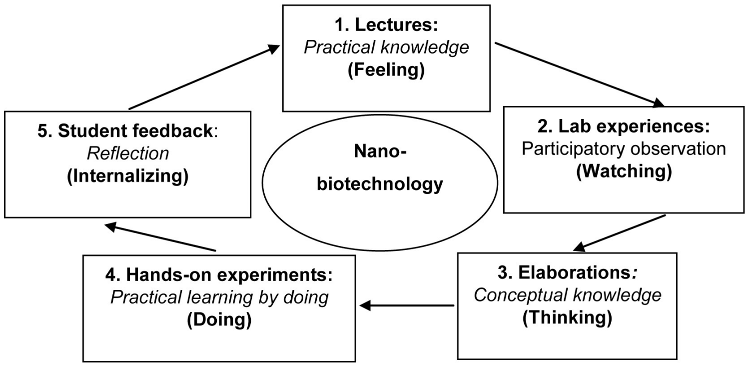

Fig. 1. Curriculum design of the summer camp.

abstract conceptualization stage, wherein teachers help students gain deeper knowledge than what is learnt in the first two stages, and then explain cases of application in various fields to assist students to achieve abstract conceptualization in nano-biotechnology. The fourth learning mode requires students to do experiments by themselves. Finally, a new stage of student feedback is incorporated in the curriculum design of this summer camp. All students are asked to share some opinions or personal interpretation of their learning experiences with each other in their groups and provide feedback as well as reflect on learning activities provided.

3. Application of summer camp for nanotechnology education

The NTU NEMS center has aimed to promote nanotechnology education nationally since 2003. Several related projects have been actively implemented, including projects for fostering excellent talents in nanotechnology and setting up the Northern Regional Center for nanotechnology K-12 education. The NEMS center's nanotechnology project mainly consists of four categories: fabrication of nano-electro-mechanical-systems, nano-fluidics, nano-biomedical technology, and nano-engineering. In 2005, the National Science Council (NSC) of Taiwan sponsored the establishment of the Interdisciplinary Science and Technology Educational Platform. The platform is mainly involved in cross-disciplinary curriculum development and provides guidance for advanced engineering education in nanotechnology. As part of NSC's project, the NEMS center initiated this nano-biotechnology summer camp by taking advantage of a resource-sharing model to facilitate nanotechnology learning and development among students. This camp is also intended to help increase general public interest in exploring the sciences and enhance the scientific knowledge in response to a national policy of promoting nanotechnology education in Taiwan.

3.1 Curriculum design of nano-biotechnology summer camp

To achieve its educational goals of diffusing theoretical and practical knowledge related to nanotechnology, the NEMS center focuses on integrating theoretical knowledge into practical laboratory experiences to develop a curriculum for this summer camp (Fig. 2). Its core concept concerns nano-biotechnology and the curriculum plan devel-

Table 1. Application of Kolb's theory into instructional practice

Stage	Theory Kolb's experiential learning model	Implication	Practice Summer camp of nano-biotechnology
1	Concrete experience	Feeling	Recall background knowledge and life experiences: Lectures of practical knowledge/Role playing
2	Reflective observation	Watching	Lab experience/Participatory observation
3	Abstract conceptualization	Thinking	Explain relative fields and facilitate abstract conceptualization: Elaborations of conceptual or principle knowledge
4	Active experimentation	Doing	Hands-on experiments/Practical learning by doing
5	--(Only 4 stages)	Internalizing	Student's feedbacks and reflection

oped upon Kolb's learning cycle, including five learning activities, is further detailed as follows:

(1) Lectures: an introduction to the practical knowledge and applied cases of nano-biotechnology, correlating students' personal experiences with the background knowledge of some application of nano-biotechnology.
(2) Lab experiences: an introduction to the research labs to motivate interest, involving students in learning various lab experiences by participatory observations.
(3) Elaborations: construction of conceptual knowledge of nano-biotechnology and emphases on the related issues preparing students for the following hands-on experiments and facilitating conceptualization of abstract or theoretical bases or principles by lectures.
(4) Hands-on experiments: Involvement of students in practical learning stage via varied activities at the Center's labs, and as [18] describe, nanotechnology curriculum that incorporates real world examples can ignite student's interest regarding science, intrigue them by emerging ideas, and help them easily understand complex concepts in nano-biotechnology.
(5) Student feedback: students are urged to reflect and share their opinions with each other in order to promote transformative learning and reflective internalization.

Overall, the concepts applied to the design of this summer camp's curriculum cover the full range of practical knowledge to participatory experience, leading to theoretical concepts with practical experimentation and finally sharing of ideas. The abovementioned learning method implies an innovative curriculum model adopted for nano-biotechnology education in this camp.

3.2 Learning activities of nano-biotechnology summer camp

The primary objective of this camp is to increase the interest in and awareness of nanotechnology of senior high school students, and subsequently to identify and nurture outstanding talents. To successfully fulfill the objectives of this summer camp, the NEMS center employs various strategies and steps to achieve clearly defined goals. During the first stage, lecturers, scholars, and high school teachers (or so-called 'seed teachers') specializing in nanotechnology collaborate to give students a preliminary understanding of nanotechnology. Afterward, participatory experiments are used to enhance their learning by observation.

Figure 2(a) shows that students visit the clean room of the NEMS center wearing clean room clothes. The lab observations help them to easily link theoretical concepts to related principles of nano-science. The lab visits also help to interest them in research. After lab visits, students attend the first lecture course, 'Construction of Fluorescent Bacteria', before their experimental activities. The purpose of the lecture course is to introduce students to the genetic transformation of bacteria. Fig. 2(b) depicts that students observe the genetic transformation of Escherichia coli BL21 by using a green fluorescent protein obtained from jellyfish as a plasmid. The instructor also demonstrates the differences between the experimental group with fluor-

Fig. 2. Photos of students' lab experiences and hands-on experiments.

escent bacteria and the control group without it. Then students have the second lecture course, 'Cancer and Nano-medicine.' It gives students insights regarding platonic solids so as to help them understand the structure of adenovirus, a regular icosahedron, formed by 20 regular triangles. In Fig. 2(c), the photo demonstrates that they can understand how to assemble the structure of adenovirus with 20 surfaces, 30 edges, and 12 points by connecting the teaching materials in their hands. Students attend a third lecture course, 'The Gene and its Applications.' The lecture introduces the double helical structure of DNA. Fig. 2(d) shows the students solving a jigsaw puzzle of a double helical DNA structure in group competition within limited time as part of the workshop. The teachers also conduct an assessment of the group competition.

4. Methods for evaluating student's camp learning experiences

4.1 Research subjects

The participants of this nano-biotechnology summer camp were selected from various senior high schools in Taiwan. Each school could only register three students. Out of 52 senior high school students participating in this camp, 50 of them (96.15%) completed and returned the questionnaire in the end. Among the respondents, 28 of them were males (56%) and 22 were females (44%).

4.2 Survey instrument

The specifically designed questionnaire included items to evaluate student's perceptions towards nano-biotechnology learning experiences in this camp. The questionnaire consisted of three parts and had an overall Cronbach's alpha coefficient of .947, which is considered highly acceptable. To ensure the validity of the measurement of the learner's perceptions, the questionnaire construction process began with a systematic review of related literature in combination with an evaluation of the study objectives of the student's learning experience of nanotechnology. When completed, the questionnaire was further validated by experts in the fields of nanotechnology and professionals in instructional design to obtain expert validity.

Part I of the survey instrument inquired about student's background information: gender, name, achievements of school work, grade, subject of specialization, and motivation of attending the summer camp. Part II of the survey instrument consisted of three groups of questions mainly exploring their overall camp learning experience, including preference of learning activities, students' self-evaluation of learning effectiveness, and general evaluation of instructional effectiveness. Each item was evaluated using a 6-point Likert-type scale further specified as follows: '6'-strongly agree; '5'-agree; '4'-some agree; '3'-some disagree; '2'-disagree; '1'-strongly disagree. Part III of the survey instrument was one open-ended question intended to extract students' opinions or feedback: 'Do you have any other suggestions for this camp regarding the teachers' instruction, curriculum design, learning contents, and schedule, etc.?'

4.3 Analysis of data

Statistical analysis was conducted using the Statistical Package for Social Science for Windows 15.0 (SPSS 15.0). Data analysis methods were as follows: (1) descriptive statistics were used to describe background information of the respondents; (2) correlation analysis was performed to determine the relationships among students' preferences of learning activities, self-evaluation of learning effectiveness, and general evaluation of teaching and learning. In addition, qualitative data collected from the responses of one open-ended question in the questionnaire were also analyzed. The content analysis of qualitative data was carried out by organizing the data, establishing codes, classifying into main categories, analyzing and interpreting the appropriate meanings for concepts identified, and finally concluding the summarized results.

5. Findings

5.1 Student backgrounds of specialty and learning motivation

To understand the students' backgrounds and learning motivation, they were asked about their special interests in particular subjects and the purpose of and motivation for attending the camp. They were allowed to choose multiple answers. Table 2 summarizes respondents' subjects of specialization. Approximately 50% of the students viewed 'physics and mathematics' as their specialty. Students taking part in this summer camp of nano-biotechnology tended to be interested in the subjects of natural or general sciences rather than the social sciences.

Analysis of participants' motivation revealed that 38 (76%) students' motivation for attending the summer camp was to enhance their learning experiences. That was followed by 37 (74%) students being interested in understanding the related knowledge, 31 (62%) aiming to have experiences in similar science events, 28 (56%) respondents attempting to understand knowledge and skills outside their own professional fields, 28 (56%) inclined to satisfy their craving for knowledge, 19 (38%) expecting to improve their research abilities, 7 (14%) wishing to

Table 2. Students' subjects of specialty

Subjects		Total (N=50)		
		Frequency		Percentage
Social Science field	Chinese	65	13	26.0 %
	English		16	32.0 %
	History		10	20.0 %
	Geography		8	16.0 %
	Citizens and society		6	12.0 %
	Arts and humanities		12	24.0 %
Science field	Mathematics	100	23	46.0 %
	Physics		24	48.0 %
	Chemistry		17	34.0 %
	Geosciences		11	22.0 %
	Life science and technology		17	34.0 %
	Physical education		8	16.0 %
Others		2	2	4.0 %

take courses with NTU teachers, and only 6 (12%) just wanting to have fun. Clearly, most of the students were motivated to participate in this summer camp by expectations of learning.

5.2 Preference of learning activities and self-perceived learning effectiveness

Table 3 summarizes the analyses of students' preferences of four different learning activities (lectures or elaborations, hands-on experiments, lab experiences, student feedback) and self-evaluation of learning effectiveness in terms of their involvement in the camp. The results indicated that conducting 'hands-on experiments' was the learning activity most favored by students (mean = 5.13). The learning activity related to 'lab experiences' (mean = 5.09) was ranked as the second highest, followed by 'lectures/elaborations' (mean = 5.07) and 'student feedback' (mean = 4.80) accordingly. The activity of 'student feedback' had the lowest mean of learning preference. Results of students' self-evaluation of learning effectiveness showed that hands-on experimentation (mean = 5.17) was also viewed as the most effective way of learning. The activity of 'lectures/elaborations' (mean = 4.81) was thought to have the least learning effectiveness. Consequently, we know students preferred the most engaging learning activities, such as 'hands-on experiments' and 'lab experiences', and they also perceived higher learning effectiveness when engaged in these two types of activities. In addition, students did not appear to like the learning activity of 'student feedback' and viewed learning through 'lectures/elaborations' less effective.

5.3 General evaluation of summer camp's teaching and learning

Table 4 shows the results of students' general evaluation of teaching and learning in this camp. All questions under evaluation had mean scores

Table 3. Students' learning preferences and self-evaluation of learning effectiveness

Courses/Learning Activities	Total (N=50)					
	Preference of learning activities			Self-evaluation of learning effectiveness		
	Mean		SD	Mean		SD
1-1. Lecture A: Biomimic nano-sensors toward biomedical applications	5.07	4.57	1.118	4.81	4.33	1.055
1-2. Lecture B: Cancer and nano-medical engineering		5.50	0.580		5.04	0.721
1-3. Lecture C: The gene and its applications		5.00	0.926		4.87	0.875
1-4. Lecture D: Construction of fluorescent bacteria		5.22	0.848		5.00	0.933
2-1. Hands-on experiment: Transgenic experiments	5.13	5.34	0.872	5.17	5.15	0.932
2-2. Hands-on experiment B: Hands-on spell adenovirus		5.12	0.746		5.19	0.970
2-3. Hands-on experiment C: Helical structure of DNA		4.92	1.038		5.17	0.940
3-1. Lab experiences A: Visit clean room of NTU NEMS Research Center	5.09	5.35	0.805	4.90	5.00	0.843
3-2. Lab experiences B: Visit atomic force microscopy Lab		4.82	0.972		4.80	0.910
4-1. Student feedback A	4.80	4.81	0.867	4.82	4.83	0.902
4-2. Student feedback B		4.79	0.874		4.80	0.859

Table 4. General evaluation of teaching and learning

Questions	Total (N=50)	
	Mean	SD
1. The curriculum is well designed to help students learn.	5.26	0.828
2. The instructor explains the contents clearly to help students understand.	5.28	0.861
3. The equipments are well arranged to help students do experiments.	5.28	0.861
4. To course schedule is suitably arranged to help students learn.	4.74	1.042
5. This curriculum is inspiring and motivates me to learn.	5.30	0.813
6. Generally speaking, this camp offers an effective curriculum of learning nano-biotechnology.	5.41	0.717
Total Mean	5.21	

higher than 4.0, and the total mean score was 5.21. Most students agreed that this camp provides an effective curriculum for learning nano-biotechnology (mean=5.41). Second, from the student's point of view, the curriculum was inspiring and motivational (mean = 5.30). The curriculum was also perceived as well designed to help students to learn (mean = 5.26). However, the course schedule was comparatively less satisfactory (mean = 4.74). Overall, the results of general evaluation of teaching and learning confirmed student satisfaction with the learning experiences in this camp.

5.4 Correlation among learning preference, effectiveness, and course design of summer camp

The correlation matrix among the three constructs of student's preference of learning activities, self-evaluation of learning effectiveness, and general evaluation of teaching and learning is presented in Table 5. The results indicate significant positive relationships among these three constructs. In addition, the highest correlation was found between student's preference of learning activities and self-evaluation of learning effectiveness (r = 0.687), implying that students perceived that they could learn better and more effectively when engaging in learning activities they prefer; likewise, they prefer those activities that they consider more beneficial to their learning.

5.5 Qualitative feedback on nano-biotechnology summer camp

Based on the results of content analysis of student feedback collected from the survey's open-ended question, we concluded four points in relation to participants' expectations and recommendations regarding the curriculum activities of the summer camp.

(1) *Curriculum design.* Most of the student feedback was concerned about curriculum design, including activity design, course contents, and group activities. These recommendations should be beneficial to the instructors and curriculum developers of NEMS center when making adjustments or proceeding with further development of the nano-biotechnology summer camp in the future.
   a. *Activity design.* Seven students pointed out that the activity design of this camp was informative, helpful, and smoothly integrated speeches, lab experiences, hands-on experiments, internal discussions, and so on. Only one student complained that there

Table 5. Correlation analysis among three constructs of student's camp learning

	Preference of learning activity	Self-evaluation of learning effectiveness	General evaluation of teaching and learning
Preference of learning activity	1	-	-
Self-evaluation of learning effectiveness	0.687**	1	-
General evaluation of teaching and learning	0.667**	0.615**	1

** Correlation is significant at the 0.01 level (2-tailed).

were too many sessions of lectures or speeches.

b. *Course contents.* Three students emphasized that they liked the course contents, particularly those offered in the 'hands-on experiments,' but the time for them to obtain the results while conducting the 'transgenic experiments' was limited. The knowledge level of all course contents was acceptable to the students. Some contents in the course of 'biomimic nano-sensors toward biomedical applications', however, were identified as difficult Hence, students hoped the instructional methods could be modified or adjusted accordingly in order to make the 'difficult' subjects more understandable.

c. *Group activities.* One student suggested it was necessary to reduce the group size in order to improve peer-to-peer interactions in groups. However, in the case of group competition, to ensure fairness, each group should have the same amount of members.

(2) *Teachers' instruction.* Two students suggested that lecturers could slow down the teaching speed/pace so that students would have more time to understand the contents taught. One student commented that the instructors of NEMS center gave a nice introduction to lab experiences, especially in the clean room. In addition, students suggested that when lecturers used technical terms in English, they should repeat their meanings in Chinese to help students better understand the technical terms. According to the feedback, the content was comparatively easier to understand during senior high school teachers' lectures; two students suggested the content could be slightly modified to fit in their background knowledge.

(3) *Time arrangements.* Seven students suggested an extended day for the camp; one student hoped that a nap time could be included in the schedule after lunch in order to improve students' learning effectiveness.

(4) *Others.* Ten students highly praised the summer camp of Nano-biotechnology and hoped the Center could hold it again in the future. One student in particular commented, 'taking part in the camp helped me understand the knowledge and skills outside my own professional field, and expanded my learning experiences in high technology equipment; this is an efficient learning activity (the camp).' In addition, three students pointed out that the team counselors were also nice and friendly.

6. Conclusions

The nano-biotechnology summer camp aims to integrate theoretical knowledge with practical laboratory experiences utilizing David Kolb's experiential learning theory for curriculum design. The primary goal of using the camp approach as a learning platform is to promote high school students' interest in and knowledge of nanotechnology, nano-biotechnology in this case. Although students' diverse learning styles were not included in the analysis in the present study, the combination of multi-discipline subject contents and varied learning activities, such as lectures/elaborations, lab experiences, hands-on experiments, and student feedback in this summer camp are confirmed to have been sufficient to meet the needs of most of the participating students. Overall, the students were satisfied with their learning experiences of this summer camp, according to the findings concluded from the general evaluation of teaching and learning. In particular, the hands-on experiments and lab experiences were favored the most and considered more effective to their learning. A significant positive relationship between student's preference of learning activity and self-evaluation of learning effectiveness is also revealed. Taking into account these findings, it is important for future implementers to making a firm connection between abstract concepts and hands-on exercises or participatory practices in order to contribute meaningful learning, rather than providing merely a playful and fun experience. When materials taught or lectured are firmly grounded in student's prior knowledge or experiences, students can easily relate and link the new materials or concepts to existing cognitive structures; thus, information acquired has a high possibility of being transferred into long-term memory [19]. Students will also find such learning more interesting and valuable due to the relevance and comprehensibility. Carefully developed experiential learning plans consisting of a reasonable balance among Kolb's four stages are needed to provide the grounding for optimal education outcomes.

As demonstrated by the study findings, more than half of the students were motivated to attend the summer camp by expectations of having learning experiences and pursuing knowledge and skills in a subject other than their own specialty, gaining nano-biotechnology related knowledge, obtaining experiences in similar science events, and satisfying their craving for knowledge. Besides, participants of this summer camp were inclined to be strong in the subjects of natural or general science. Apparently, the senior high school students of the present study had high learning-related motivation, similar to previous research, where engineering students were found more likely to be energetic learners [20–21]; thus, it is possible to elicit their potential in nanotechnology engineering or this similar direction. This camp approach of learning nano-biotechnology is also perceived as beneficial and well-designed, as indicated by participant evaluations. It is confirmed that it is useful to apply these constructive pedagogical principles like Kolb's experiential learning theory to science and engineering education in order to facilitate learning of great worth and increase students' interests in science, as reported in previous research findings [22–26]. Consequently, it is recommended that a similar camp program be scaled up to make it more widely available to a wider audience, as a feasible strategy to cultivate in high school students a strong interest in learning nanotechnology.

Furthermore, it is worth noting that the learning activity of 'hands-on experiments' was the most favored and considered the most effective and useful by the students, as shown in the survey results of both the structured questionnaire and qualitative feedback. Similarly, a study by [20] indicated that 'active learners' study and work well in class groups and are more inclined towards practical learning. Further probing into the reason why participants prefer 'hands-on experiments' reveals that it is related to the idea of 'seeing is believing' because they can see the final results of experiments in person. This finding corroborates the ideas by [21] emphasizing 'students should be taught through their perceptual strengths from the beginning of instruction; they can also identify their preferences accurately; and younger students learn better through visual than auditory, and best through tactile-kinesthetic, experiences' (p. 381).

Although implementation of the current nanotechnology-related summer camp program has resulted in positive student responses, some suggestions derived from the student feedback on instruction are further concluded, such as to add more peer-to-peer interactions, moderately adjust the materials to better fit the students' knowledge level, and make changes in teaching approaches for difficult content. For example, when lecturers use technical terms in English, students would expect a further explanation of those terms in Chinese to promote better understanding. On the other hand, the pitfalls associated with the evaluation of student's camp learning experience documented in this paper include a lack of objective academic performance comparisons of student's learning outcomes. This can be improved by incorporating an experimental research design or student knowledge test to identify the genuine learning effectiveness in future evaluations. Moreover, a narrative interview can also be administrated to students for individual reflection on the learning output of the camp. Both would allow better support of the positive results of the current study and catch the most prominent experiences developed from this learning in line with Kolb's thoughts. As shown in the findings, the summer camp approach based on the experiential learning model actually facilitates the learning processes of students in nanotechnology in spite of the study limits. We sincerely hope that these encouraging results inspire the various stakeholders to continue to devote collaborative efforts toward sustaining the success of these and future educational outreach programs in nanotechnology.

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