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Developing Experiential Learning with a Cohort-blended Laboratory Training in Nano-bio Engineering Education*

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The rationale and design of this cohort laboratory training, which blends both real NBTLC and virtual NBTLC, are considered for their effect on student learning. After implementation of the program into a graduate engineering laboratory course, an evaluation study was conducted to investigate the effectiveness of this blended laboratory training program. According to results, most students showed positive attitudes toward this practice. In addition, students perceived positive impacts of this effort on their laboratory learning experience. Furthermore, this paper discusses the important issues observed in the study, such as interdisciplinary learning and teaching. It is expected that this study will contribute to the practice of innovative adoption of technology in engineering laboratory education and research on cyber learning.

Keywords: cohort blended laboratory model; digital learning contents; experiential learning; evaluation; laboratory training

INTRODUCTION

NANOTECHNOLOGY HAS BEEN RECOGNIZED as a future technology with significant potential in the cutting-edge technology industry in the twenty-first century. With its rapid development over the past decade, the lack of trained personnel as well as preparation for a nanotechnology workforce have emerged as great challenges to industry worldwide. As interdisciplinary human resource cultivation has become a critical issue along with the development of the global knowledge economy, many universities have started new engineering education programs or courses on nano-scale science, technology and engineering. Researchers [1] have further pointed out the importance of promoting multidisciplinary research and educational programs, as well as the inclusion of interdisciplinary overview courses in nano-science and technology for undergraduate first year students and graduate first year students in engineering.

In responding to these needs, the National Science Council (NSC) of Taiwan launched the National Science and Technology Program for Nano-science and Nanotechnology in 2002 to promote research and development in the field. NSC also initiated some human resource development programs in collaborative efforts with the Ministry of Education, Ministry of Economic Affairs, Industry Technology Research Institute, and Academia Sinica in support for K-12, higher education, and industrial training in nano-science and technology [2]. These programs are aimed at cultivating leaders who are able to explore the potential of nanotechnology, and at pushing this technology toward industrialization and commercialization. As one of the human resource development programs, the Interdisciplinary Science and Technology Education Platform (ISTEP) Project was initiated in 2005 as a platform to align academic programs of higher education institutions and relevant research centers to develop courses for university and college students across the country. It identified Nanotechnology, Optomechtronics and Imaging Display Technology, and Biomedical Engineering Technology as three key technologies and intended to coordinate professors from different universities to build an alliance to co-teach via video-conferencing technology and co-develop multimedia and digital course materials as individual learning modules [3].

Under the Interdisciplinary Science and Technology Education Platform (ISTEP) project, the sub-project of Nanotechnology developed its own strategies for faculty alliances, curriculum design, hands-on laboratory training, and the demonstration center management [4]. It first recognized the important features that nanotechnology professionals should have [1], including the ability to deal with large systems at the nano-scale and to manipulate the matter at nano-scale under control. Thus in talent training, this sub-project set out the objectives to prepare students for learning to integrate methods of investigation from various disciplines at different length scales, and to develop tools and processes to measure, calibrate, design,

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and manufacture nanostructures. To achieve that goal, laboratory skills and performance were defined as key foci in training future nanotechnology engineers.

To ensure the abovementioned skill training and performance improvement, the Nanotechnology sub-project decided to reconsider the curriculum and pedagogy design. It consulted the Instructional Congruence Model [5] and a similar approach [6] that emphasizes the alignment of the critical components of curriculum, instruction, and assessment, which must match the teaching goals and learning outcomes. In addition, applications of cohort-based models were surveyed [7–10], including a cohort design of team-teaching, group learning, and community of practice. The constructivist paradigm with a mix of instructional principles with integration promise [11] rooted in student-centered learning [12] was also considered in the pedagogical design. It further attempted to adopt the advantages that information and communication technology might bring to instruction and learning, which aimed at engaging students in a virtual world with online learning activities [13] and with the course design to develop students' experiential learning [14].

Based on the experiential learning approach [14], students can bring in their previous concrete experiences, observe and reflect on their observations, conceptualize theories and applications, and conduct experiments to test their understanding. To incorporate experiential learning into laboratory training for engineering education, the Nanotechnology sub-project selected a first year graduate course on the "Applied Mechanics Laboratory" as the experimental context to redesign the curriculum, including course and instructional approaches, to train students for broader learning of laboratory skills including nano-science and technology components. To improve the training of lab skills learning and performance, researchers adopted a cohort course design with the experiential learning approach as the principle for designing laboratory learning activities. The goals of this case study were to design a cohort blended laboratory training program in Nano-bio Engineering Education and to evaluate the effectiveness of this program in terms of student response to it.

A COHORT-BLENDED LABORATORY TRAINING DESIGN

Designing a cohort course in applied mechanics laboratory

The cohort design of the "Applied Mechanics Laboratory" course intended to align relevant laboratories; integrate faculty, staff, and laboratory resources; provide interdisciplinary learning experiences; and offer students a holistic approach with which to better understand nano-science and technology as a new discipline. It is a required course for all graduate and doctoral students who enter the graduate program of the Institute of Applied Mechanics at National Taiwan University. The course contains the four key subject areas of dynamics, mechanics of materials, fluid mechanics, and nano-biomechanics, with emphasis on components of nano-science and bio-technology. Within each area, there are several laboratory learning units that include required items and others for students to select. With a self-directed learning approach, the objectives of this course are to have students self-study the principles and theories of each subject, read the operation manuals of the laboratory equipment and facilities, and learn the methods of design procedures and measurement of experiments. Therefore, instead of using traditional lecturing and demonstration methods, the four faculty members who co-teach the course and the supporting personnel, including teaching assistants, researchers, and laboratory attendants, all together work in cohort teams and serve as facilitators to help guide or give advice to students throughout the course period. Meanwhile, they need to evaluate student learning performance in each laboratory learning unit during the process and at the end of the semester.

Establishing the nano-bio technology laboratory corridor

As Roco [1] proposed, the nano-science and technology curriculum should integrate research and education to make every laboratory a place of learning. To help enhance the interdisciplinary learning with cohort laboratory training, a "Nano-bio Technology Laboratory Corridor (NBTLC)" was established. It integrated efforts and resources of four laboratories: the Nanotechnology Teaching Laboratory, Micro/Nano Device Fabrication Teaching Laboratory, Nano-Electro-Mechanical-Systems (NEMS) Research Center, and Nano-Bio Laboratory. These four laboratories are responsible for providing six lab learning units, which correspond to training subjects in nano-biomechanics within the "Applied Mechanics Laboratory" course. Within each laboratory, there are principle investigators, researchers, professional staff, and graduate teaching assistants that are in charge of designing the laboratory learning units, planning the schedule and resources, and facilitating students' learning during the semester. This Nano-bio Technology Laboratory Corridor is the first group of laboratories that combines nano-manufacturing and biomedical science manufacturing processes in higher education in Taiwan. The idea of NBTLC signifies a metaphor of open laboratories, which supports both independent laboratory work and integrated interdisciplinary learning laboratories.

Developing the virtual nano-bio technology laboratory corridor

As researchers in web-based learning and virtual reality have suggested [15–19], virtual spaces

Fig. 1. Portal of the virtual nano-bio technology laboratory corridor.

Fig. 2. Example of virtual laboratory view under VNBTLC.

provide opportunities for students to transform their learning, improve the quality of immersion and perspectives, and may be expanded to incorporate experiential learning events of every aspects of daily life, which exemplifies the constructivist paradigm of knowledge construction through active interaction with the world. Therefore, to further advance the idea and practice of NBTLC, a "Virtual Nano-bio Technology Laboratory Corridor (VNBTLC)" was constructed as a supplemental learning space to the NBTLC. It represents a virtual portal to NBTLC with integrated multimedia design and includes digitized learning materials such as lab handbooks, conceptual lectures, instrument illustrations, step-by-step procedural demonstrations, as well as some virtual and remote controlled experiments in the four laboratories.

This initiative involved fifty faculty members from different departments, colleges, and universities in an inter-institutional collaboration effort. Those participants contributed their knowledge and experience by giving lectures, designing and developing courseware, and sharing resources. The digital content was designed by a professional instructional and multimedia development team with a systematic instructional design model [20]. As of this writing, the VNBTLC has accumulated about 114 learning units as courseware, with three different formats of media: streaming videos of lecture archives, electronic books of conceptual illustrations, and multimedia titles of laboratory demonstrations, which have been designed and transformed into digital learning contents. All the materials are mounted on the website of the Virtual Nano-bio Technology Laboratory Corridor and are open to students anytime and anywhere for flexible learning. Figures 1 to 4 illustrate the portal, sample websites, and content pages of the VNBTLC.

Developing students' experiential learning in the laboratory

Based on the experiential learning approach, as noted earlier, appropriate laboratory activities can be developed and concrete learning experiences in which students interact with the rich learning environment and learn to use methods and procedures of science to observe phenomena, investigate and solve problems, as well as pursue inquiry and

Fig. 3. Example view of learning unit: "atomic force microscope technology" on VNBTLC.

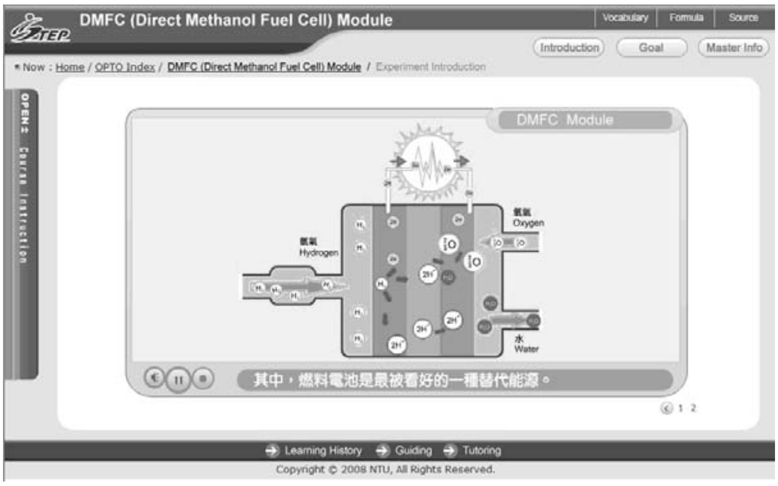

Fig. 4. Example view of learning unit: "direct methanol fuel cell module" on VNBTLC.

interests [21–22]. When applying experiential learning to laboratory training in nano-science and technology can be contrived; it is expected that students can acquire knowledge and skills with more concrete experiences that would help them transform their learning of the methods for future applications.

Further blending the real world Nano-bio Technology Laboratory Corridor and the Virtual Nano-bio Technology Laboratory Corridor in order to support the Applied Mechanics Laboratory course, instructors of the cohort team allowed students to self-direct their learning; they could start from any subject area without any restrictions. Students had to plan and manage their work in this course, surfing on the VNBTLC website and exploring proper courseware for learning the concepts, skills, operation procedures, measurement, and demonstrations that match with learning units within each subject area. They could preview some online content to prepare for their lab work in advance, and they could also browse those units after they completed the experiments to prepare for the lab reports. Through this experiential learning, it was hoped that students could self-regulate their lab learning, develop their own knowledge and skills within all subject areas, and further integrate their own learning experiences and interdisciplinary perspectives.

Toward a cohort-blended laboratory model

Throughout the redesign and development of the "Applied Mechanics Laboratory" course, which integrated various efforts and resources, a new cohort-blended laboratory model with four levels of cohort-design was developed. As Figure 5 illustrates, from center to outward, there are cohorts of team-teaching faculty members and supporting staff, learning topics under investigation, real world laboratories, and virtual laboratories with plenty of digital learning resources. This cohort model represents a blend of real world and virtual world interactions that were aimed at facilitating experiential learning for engineering students' laboratory learning.

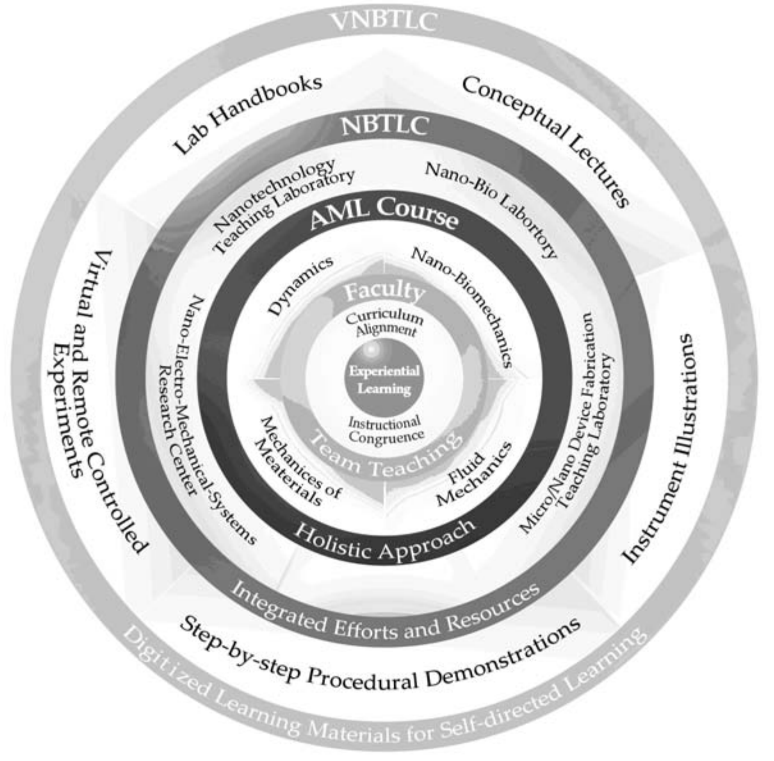

Fig. 5. Cohort-blended laboratory model.

EVALUATION OF THE CASE

Purposes of the study

This study employed the case study approach [23] with program implementation and a quantitative survey design to explore the particular design of the cohort-blended laboratory training design in depth. The Nano-bio Technology Laboratory Corridor was implemented with the cohort design in the fall semester of 2007 in support of the "Applied Mechanics Laboratory" course as a pilot. In the spring semester of 2008, the Virtual Nano-bio Technology Laboratory Corridor was formally opened to students to provide cohort blended laboratory training. Meanwhile, an evaluation study was conducted in order to determine the appropriateness and effectiveness of this effort. This evaluation study aimed to understand student responses to the blended virtual and real world laboratory training in the "Applied Mechanics Laboratory" course. Specific purposes were: (1) to understand students' perceptions of and attitudes toward this Cohort-Blended Laboratory, including the cohort course design, instructor's teaching, real world and virtual corridor; (2) to collect students' perceptions of design of the digital learning material on the VNBTLC website; (3) to investigate the impacts of VNBTLC on their learning that students perceived; (4) to explore how students' background data would influence their perception of this Cohort-Blended Laboratory on different dimensions; and (5) to explore the effects of students perception of this Cohort-Blended Laboratory on their perceived learning impacts and their learning performance.

Study design and instrument

Under the structure of the course, students followed the guidelines in their laboratory learning by going through each laboratory of the real world Nano-bio Technology Laboratory Corridor. At the beginning of the semester, the Virtual Nano-bio Technology Laboratory Corridor was introduced to students so that they could access to the website freely throughout the semester. After completing each laboratory task, students had to submit a lab report as well as attend an oral examination by the faculty in charge of that laboratory. And at the end of the semester, all faculty members would discuss and summarize students' overall performance in this course.

To answer the research questions of this study, a comprehensive questionnaire was designed by the researchers to collect students' background information, frequency of courseware learning units visited by self report, and their evaluations of the course cohort design and instructors (12 items), digital learning materials design (three categories):

1) contents and instructional design,
2) navigation and orientation,
3) media design and quality, (19 items), as well as
4) their perception of impacts of VNBTLC on their learning (15 items).

All evaluation items were on a 6-point Likert scale for students to decide on the degree of agreement or fitness. This questionnaire was distributed at the end of the semester, when all the students had completed their laboratory coursework. The final marks students received in this course were also collected for further analysis.

RESULTS

Participants

A total of 65 students participated and returned the questionnaires. There were 52 male (80%) and 13 female (20%) students, most of whom were graduate students (57 students, 87.7%). The students reported a variety of specialties; the majority included mechanical engineering, applied mechanics, and some physics, mathematics, and others. About half of the students (35 students, 53.8%) perceived the course as highly important in their academic learning, while the other half (30 students, 46.2%) thought it was less important. How they thought the course might help their personal learning fell into four areas: learning of lab skills (49 students, 75.34%), theoretical perspectives (47 students, 72.3%), research methodology (32 students, 49.2%), and experimental design (21 students, 32.3%). Most students received marks within the range of 80-89 (40 students, 61.5%), some received scores between 70 and 79 (22 students, 33.8%), two, grades higher than 90 points, and one under 70. Table 1 summarizes the details.

Students' evaluation of the cohort laboratory course design

As seen in Table 2, student evaluations of the cohort laboratory course design and instructors' teaching were, on average, from middle to high, 3.95 on the total scale. The alignment of the four laboratories as a learning space with integrated resources received the highest score. Students thought it had helped their integrated learning of methods/skills (mean = 4.26), as well as principles and theories (mean = 4.12) of the Applied Mechanics Laboratory course. Students also gave high evaluations to the course arrangement, such as time arrangement (mean = 4.03), teamwork (mean = 4.12), teaching methods (mean = 4.14), grading system (mean = 4.14), and instructors' attitudes toward students (mean = 4.14). However, they were not too satisfied with instructors' teaching of the content (mean = 3.45), motivation strategies used (mean = 3.57), or their enthusiasm (mean = 3.86); nor were they highly satisfied with the performances of teaching assistants (mean = 3.69) and laboratory facilities (mean = 3.83). The reasons for the low evaluations might be that there were no formal or structural classroom lectures in this laboratory course, so students may not have clearly perceived the instructors' efforts in teaching or motivation strategies.

Table 1. Background data of the participants (N=65)

Variable	Frequency	Percentage
Gender		
Male	52	80%
Female	13	20%
Current status		
Graduate students	57	87.7%
Doctoral students	8	12.3%
Specialty		
Mechanical Engineering	46	70.8%
Applied Mechanics	33	50.8%
Physics	15	23.1%
Mathematics	11	16.9%
Materials Science and Engineering	2	3.1%
Electronics Engineering	2	3.1%
Liberal Arts	2	3.1%
Others	2	3.1%
Biology	1	1.5%
Electrical Engineering	1	1.5%
Importance perceived of the course on students' academic learning		
More important	35	53.8%
Less important	30	46.2%
Types of help of the course on personal learning		
Lab skill learning	49	75.4%
Theoretical perspectives	47	72.3%
Research methodology	32	49.2%
Design methods of conducting experiment	21	32.3%
Others	2	3.1%
Grade received in this course		
90+	2	3%
80–89	40	61.5%
70–79	22	33.8%
60–69	1	1.5%

Table 2. Results of cohort laboratory course and instructor evaluation (N=65)

Dimensions	Items	Means
Course Design	This course is well designed with grouping and team working.	4.12
	The alignment of four laboratories helps on my integrated learning of principles and theories in this course.	4.12
	The alignment of four laboratories helps on my integrated learning of methods and skills in this course.	4.26
	The arrangement of equipment and facilities are sufficient in number and quality to help my laboratory learning.	3.83
	The time arrangement is adequate and helps my laboratory learning.	4.03
	The teaching assistants help my learning in this course.	3.69
	The grading system of this course is appropriate.	4.14
Average		4.03
Instruction	Instructors of this course have clearly illustrated the contents of the experiments and helped my understanding and learning.	3.45
	Instructors of this course have tried to use various strategies that motivate my learning.	3.57
	Instructors of this course have shown enthusiasm toward teaching.	3.86
	Instructors of this course have had good attitudes toward the students.	4.14
	The grading system of this course is appropriate.	4.14
	The cohort course design and instructional methods used in this course helped my learning.	4.14
Average		3.88

Students' experience of using the digital learning materials on VNBTLC website

About half of the students responded that they had browsed the learning units on the Virtual Nano-bio Technology Laboratory Corridor website before and after their learning (33 students, 50.8%), and the other half (32 students, 49.2%) reported that they had only previewed the learning units before doing their laboratory works. Although all students actually viewed the courseware, there were differences in frequency of students' usage of learning units. The top five most viewed units were "Atomic Force Microscope Technology" (59 students, 90.8%), "Cell Culture Demonstration" (53 students, 81.5%), "Demonstrative Operation of Atomic Force Microscope" (52 students, 80.0%), "Industrial Safety & Hygiene Training" (25 students, 38.5%), and "Bio-Operation Safety Training" (20 students, 30.8%). Meanwhile, students' preferences toward those learning units somewhat matched those most viewed units. The most preferred learning units as reported by students were the "Atomic Force Microscope Technology" (29 students, 44.6%) and "Cell Culture Demonstration" (28 students, 43.1%), followed by "Demonstrative Operation of Atomic Force Microscope" (19 students, 29.2%).

Students' perceptions of design of the digital learning materials on VNBTLC website

Since all students actually viewed the courseware, they were asked to evaluate the design of those digital learning materials they browsed on VNBTLC website in terms of appropriateness of content and instructional design, navigation and orientation design, as well as media design and quality of the website. Results indicated that students generally liked those learning units they viewed and gave high marks to all three dimensions of evaluation criteria. Students reported that those learning units represented good content and instructional design (mean = 4.33), which were well structured and could clearly present the professional knowledge, as well as all contents of laboratory learning, which included principles, equipment, procedures and steps, results, summaries, and reminders of experimental methods. They also thought the VNBTLC website navigation and orientation designs were appropriate for use (mean = 4.27), and gave high ratings to the media design and quality (mean = 4.35) in terms of the appropriateness of text, images, videos, sounds, and layout of the materials and websites.

Students' perceptions of impacts of VNBTLC website on personal learning

It is always important to evaluate how the course and instructional design can affect student learning. When students were asked to report the impacts from implementing the Virtual Nano-bio Technology Laboratory Corridor on their learning, the feedback was mostly positive. Results indicated that after they viewed those learning units, students felt that they had better understandings of the principles and theories (mean = 4.60), equipments set up (mean = 4.60), procedures (mean = 4.60), awareness to reminding (mean = 4.58), and attention to operation details (mean = 4.52), and that they decreased the probability of making errors (mean = 4.55). Consequently, they

Table 3. Results of VNBTLC learning materials evaluation (N=65)

Category	Means
Contents and Instructional Design	4.33
Navigation & Orientation Design	4.27
Media Design and Quality	4.35
Average	4.33

Table 4. Impacts of VNBTLC on students' learning (N=65)

Dimensions	Items	Means
Lab skill learning	After browsing the VNBTLC learning unit, I have better understanding of the principles and theories behind the experiment.	4.60
	After browsing the VNBTLC learning unit, I have better understanding of how to set up the equipment.	4.60
	After browsing the VNBTLC learning unit, I have better understanding of procedures of the experiment.	4.60
	After browsing the VNBTLC learning unit, I am more aware of the special attentions to experiment.	4.58
	After browsing the VNBTLC learning unit, I am more attentive to details of presentation.	4.52
	Since browsing the VNBTLC learning unit, I have decreased the probability of making errors.	4.55
	After browsing the VNBTLC learning unit, I have a more complete learning of the content and key points of the laboratory work.	4.48
Overall learning in this course	I think the VNBTLC can help to improve my learning performance in this course.	4.62
	I think the VNBTLC can help to improve the depth of my learning in this course.	4.32
	I think the VNBTLC can help to improve my systematical learning in this course.	4.32
	I think the VNBTLC can help to improve the completeness of my skills learning in this course.	4.38
Advanced learning	I think the VNBTLC can help to improve my learning the effectiveness of my learning of advanced courses and laboratory methods.	4.51
Preference	I like the approach of using VNBTLC to assist in laboratory learning.	4.63
	I think this approach of using VNBTLC is better than traditional laboratory instruction led by teaching assistants.	4.63
	I would recommend my classmates to use VNBTLC materials to improve their learning.	4.68
Average		4.52

could more completely learn the content and key points of the laboratory work (mean = 4.48). Students also reported that this VNBTLC initiative actually helped them to improve their learning performance (mean = 4.62), depth of learning (mean = 4.32), systematic learning (mean = 4.32), and completeness of skill learning (mean = 4.38), and to increase their learning effectiveness of advanced courses or laboratory methods (mean = 4.51). Moreover, they liked this kind or laboratory learning approach with digital learning materials (mean = 4.63); they had higher preference toward this approach over the traditional laboratory instruction led by teaching assistants (mean = 4.38). Furthermore, they would recommend it to their peers for self-learning improvement (mean = 4.68). Table 4 summarizes the students' perceived impact evaluation of VNBTLC on personal learning.

How students' background data affect their perceptions of the cohort-blended laboratory

This study also examined the relationships between students' background data and their perceptions of the cohort-blended laboratory design as well as their performance. Table 5 summarizes the results of students' background differences in their perceptions of course design, instruction, media, perceived overall impacts of VNBTLC on personal learning, and grades received in this course. Based on the correlation analysis (see Table 6), this study further conducted

Table 5. Results of students' background differences in their perceptions of different variables (N=65)

Variable	Perception of course design	Perception of instruction	Perception of digital learning materials	Perceived overall impacts of VNBTLC on personal learning	Grades received in this course
Gender (N=65)					
Male (N=52)	4.10	3.83	4.32	4.48	82.17
Female (N=13)	4.08	3.82	4.31	4.51	83.23
Status (N=65)					
Master students (N=57)	4.09	3.80	4.31	4.45	81.79
Doctoral students (N=8)	4.16	4.08	4.32	4.73	86.62
Specialty (N=65)					
Mechanical Engineering (N=46)	4.09	3.81	4.31	4.46	82.67
Non-Mechanical Engineering (N=19)	4.09	3.88	4.32	4.54	81.95
Importance Perceived (N=65)					
Less important (N=30)	3.87	3.62	4.19	4.32	81.60
More important (N=35)	4.30	4.01	4.41	4.62	83.06
Grade received in this course (N=65, Mean=81)					
Above 81+ (N=30)	4.07	3.75	4.38	4.47	84.83
Below 81– (N=35)	4.12	3.89	4.39	4.50	80.29

Table 6. Results of correlation analysis

	1	2	3	4	5	6	7	8	9	10
1. Attitude toward course design	1									
2. Attitude toward instruction	0.495**	1								
3. Attitude toward media	0.538**	0.097	1							
4. Impacts of VNBTLC on students' lab skill learning	0.488**	0.155	0.686**	1						
5. Impacts of VNBTLC on students' overall learning in this course	0.513**	0.222	0.645**	0.803**	1					
6. Impacts of VNBTLC on students' advanced learning	0.46**	0.237	0.487**	0.619**	0.642**	1				
7. Impacts of VNBTLC on students' preference	0.488**	0.301*	0.480**	0.709**	0.642**	0.619**	1			
8. Overall impacts of VNBTLC on students' learning	0.547**	0.229	0.690**	0.959**	0.902**	0.725**	0.822**	1		
9. Perceived importance of the course	0.411**	0.463**	0.091	0.212	0.094	0.144	0.318**	0.217	1	
10. Grade received in this course	0.263*	0.064	0.091	0.151	0.000	0.026	0.181	0.429**	0.184	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 7. Results of differences of students with high/ low perceptions of the course in their perceptions of different variables

Items	More important Mean (N=35)	Less important Mean (N=30)	t-value	Sig. (2-tailed)
Attitude toward course design	4.29	3.87	–4.004	0.000***
Attitude toward instruction	4.01	4.19	–2.897	0.005**
Attitude toward media	4.38	4.41	–1.292	0.201
Impacts of VNBTLC on students' lab skill learning	4.71	4.38	–2.067	0.043*
Impacts of VNBTLC on students' overall learning in this course	4.50	4.30	–1.191	0.238
Impacts of VNBTLC on students' advanced learning	4.63	4.37	–1.497	0.139
Impacts of VNBTLC on students' preference	4.60	4.16	–2.969	0.004***
Overall impacts of VNBTLC on students' learning	4.62	4.32	–2.178	0.033*

***p<.001, **p<0.01, *p<0.05.

comparison analyses of students' background data on other variables. The results revealed that significant differences existed only in students' perceived importance of the course for their academic learning on their attitudes toward course design, and instruction, and perceived impacts of VNBTLC on lab skill learning, preference of this VNBTLC design, and overall impacts on their learning (see Table 7). These results might have the implication that students' personal aptitudes would affect their perception of online learning. This echoes findings of previous research on transformative learning experiences [16].

Effects of students' perceptions of the cohort-blended laboratory on their perceived learning impacts and learning performance

This study also attempted to explore the effects of students' perception of this initiative on their perceived learning impacts and their learning performance. Results revealed that only their attitudes toward course design, instruction and media would predict the expected overall impacts of VNBTLC on their personal learning. Table 8 illustrates the final regression analysis model with 50% explanation power. It indicated that the more positive the attitudes that the students had toward the course design, instruction, and media design, the greater their willingness to explore the digital learning materials; therefore, they would expect higher impacts of this virtual laboratory on their overall learning.

Table 8. Summary of regression analysis

Model	R	R Square	Adjusted R Square	F-value	Std. Error of Estimate
	0.724	0.524	0.500	22.350*	0.414

*p<0.01.

CONCLUSIONS

Previous research has usually shown that adjustments in the implementation of the integrated curriculum had slight and slow influences on a college curriculum. In addition, early studies of laboratories in science, technology and engineering did not demonstrate a clear relationship between experiences in the laboratory and student learning [21]. This study reports a new curriculum design using groups of laboratories as a cohort with integration of resources and cooperative efforts of engineering faculty. The establishment and implementation of "Nano-bio Technology Laboratory Corridor" has successfully demonstrated a trend of coordination of the new interdisciplinary teaching of nano-science and technology. It further incorporated e-learning methods by developing a Virtual Nano-bio Technology Laboratory Corridor with prosperous learning materials to support students' learning in the real laboratory corridor. With students' high ratings on both cognitive and affective evaluations and their feedback to this practice, the blended approach also confirmed that students perceived positive impacts on their learning in specific laboratory learning and in overall subject learning. Students perceived the virtual nano-bio technology laboratory corridor to be an effective approach to help them prepare for their hands-on learning in real laboratory work, and thus improved their understanding of the theories, methods, and skills of laboratory learning.

More importantly, this study intended to design and provide an open environment to students, and hoped to encourage them to develop experiential learning in laboratory course. By so doing, it would prevent students from the fragmented learning of individual experiments. Instead, the blended approach of a cohort group of laboratories allowed students to connect their learning in each laboratory work and to integrate those experiences for further knowledge construction as well as interdisciplinary learning. This study represents a new approach to maximize the teaching potential of the engineering laboratory by aligning the multiple cohort efforts and providing a rich environment that blends virtual and real world laboratory to encourage students to transform and develop experiential learning.

While the results of this study are encouraging, it also indicates that further efforts are needed to continue the development of both a real and a virtual nano-bio technology laboratory corridor. Much more needs to be done; more faculty members and laboratories should be included in this collaborative effort to enhance the cohort course with increments of quantity and quality of contents. Moreover, future studies are necessary to further explore potential applications of this cohort blended laboratory learning design, as well as to achieve a more comprehensive understanding of the effectiveness on interdisciplinary teaching and learning in cutting- edge science and engineering education.

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