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A Technology-Enriched Active Learning Space for a New Gateway Education Programme in Hong Kong:

A Platform for Nurturing Student Innovations

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A Gateway Education Programme is established in Hong Kong that aims to broaden students' interdisciplinary knowledge and nurture student innovations under the Discovery-enriched Curriculum. To support the initiative, a novel idea was proposed for the creation of a Gateway Education Laboratory (GE Lab) with a highly configurable layout equipped with a 3D printer, a cloud-based eLearning tool and user-friendly scientific instruments. Course leaders report that the GE Lab provides a very good physical environment that enhances student attitudes and supports various instructive styles and interactive learning tasks that traditional classrooms fail to provide. Students' creative achievements have been recognized internationally.

KEY WORDS: 3D Printing, Active Learning Space, Technology-Enhanced Learning, Hong Kong

Active learning classrooms (ALCs) are student-centered interactive learning spaces that are designed to encourage student collaboration and active engagement in learning tasks. ALCs are intended to promote interaction, and usually feature round tables where students can sit together, allowing them to participate in group discussions and conduct cooperative learning activities. The layout is carefully designed to minimize the barrier between the teacher and students and to facilitate in-class participation and engagement. ALCs, or similar projects, were first introduced in universities and higher education institutes in the United States, including the Student-Centered Active Learning Environment with Upside-down Pedagogies (SCALE-UP) (http://scaleup.ncsu.edu/) initiated by North Carolina State University and the Technology Enabled Active Learning (TEAL) classroom re-design project (http://web.mit.edu/edtech/casestudies/teal.html) by the Massachusetts Institute of Technology. The concept has since spread around the world, for instance, in the establishment of ALCs at McGill University, Canada, in 2009 (Finkelstein, Weston, Tovar, & Ferris, 2010) and at SoongSil University, Korea, in 2010 (Park & Choi, 2014). Studies have reported the positive effects of ALCs on improving student learning outcomes, promoting collaboration, enhancing engagement, changing learning attitudes and encouraging interactions between students and teachers (Alexander et al., 2008; Beichner & Saul, 2003; Dori & Belcher, 2005; Finkelstein et al., 2010; Foulds, Bergen, & Mantilla, 2003; Taylor, 2009).

These positive outcomes of ALCs are well aligned with the desired characteristics of the newly established Gateway Education (GE) Programme at City University of Hong Kong (CityU) in 2012 under the advocated Discovery-enriched Curriculum (DEC) (Association of American Colleges and Universities, 2012). Under the DEC, the University seeks to nurture students in making original discoveries by creating an active learning atmosphere on campus and by making advanced technologies available to all students (including educational technology and research grade facilities), while the new GE Programme promotes interdisciplinary knowledge through collaborative learning and self-discovery. As well-designed physical space can support and enact an institutional mission (Fugazzotto, 2009; Harris & Holley, 2008), thus resources have been allocated to establish a Gateway Education Laboratory (GE Lab), a technology-enriched interdisciplinary active learning space (ALS) with a flexible layout to support students from all disciplines to experience active learning pedagogy, to learn and make use of key advanced technologies and to work together to generate and realize their innovative ideas.

The Gateway Education Programme

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In 2012, under the recommendation of the University Grants Committee (UGC) of Hong Kong, all eight local publicly funded universities/institutions expanded their undergraduate curricula from 3 to 4 years (University Grants Committee, 2012). While the individual institutions developed their new curricula separately, all of them adopted a general education approach (Jaffee, 2012, 2013), similar to the US system, which aims to broaden students' knowledge by exposing them to multiple disciplines and to infuse them with language, communication and other generic skills. Assisted by Fulbright scholars from the Fulbright Hong Kong General Education Project (Gaff, 2014)(http://www.fulbright.org.hk/main/fhkgep/), CityU developed a unique General Education Programme with the distinctive characteristics of Chinese cultural awareness, English communication skills and exposure to interdisciplinary knowledge. Starting with the 2012/13 cohort, all CityU students take core/required courses on Chinese civilization and English, and select seven GE courses from three Distributional Areas (Area 1: Arts and Humanities; Area 2: Study of Societies, Social and Business Organizations; Area 3: Science and Technology) to broaden their knowledge across disciplines. All Distributional GE courses are designed with engaged pedagogies for students with no specific background requirements or prior training, and are required to "*adopt an interdisciplinary frame of reference to foster an appreciation of the relations among different fields of knowledge*" (http://www.cityu.edu.hk/ge/). These criteria ensure that students from different disciplines can learn and work together to generate interdisciplinary knowledge and ideas. The programme was renamed the 'Gateway Education Programme' to reflect its uniqueness, as expressed in the following statement:

"GE, in essence, augments and rounds out the specialized training students receive in their majors by enabling them to achieve a breadth of knowledge through exposure to multiple disciplines. GE is the glue that holds disciplines together." (http://www.cityu.edu.hk/ge/)

At the same time, CityU launched the DEC, an institutional-level initiative to promote student discovery, innovation and creativity (Wang, 2013), with the goal of "giving all students the opportunity to make an original discovery" (http://www.cityu.edu.hk/provost/dec/). To align with the DEC, the teaching and learning activities of GE courses are designed to nurture student innovation and discovery, which generally involves collaborative learning, hands-on activities and project work. These active learning activities require extra space, specific layouts and workshop-type equipment. Even though the regular classrooms on campus are well equipped with multimedia equipment such as projectors, computers and AV systems, they simply cannot provide the flexible space or the desired layout, not to mention the special teaching and learning facilities; such as 3D printer, presentation capture system and instrument, to support these active learning activities (Jamieson, 2003). Individual academic departments may have their own laboratories or studios; however, these facilities only serve students enrolled under the department programmes and are not open to other students. Thus, the senior management proposed the novel idea of a technology-enriched ALS open to all students via the GE Programme.

Guiding Principles of the GE Lab

Similar to all established ALCs, the GE Lab was designed for active and collaborative learning. An ALC needs to provide adequate work areas and suitable furniture for groups of students to work together, generate ideas, participate in hands-on activities and even conduct low-risk experiments. To encourage student-teacher interaction, teachers should be able to move close to students and walk freely around the classroom to engage individual students without physical obstacles. Furthermore, as the GE Lab was intended to support all GE courses, different teachers may have different needs in terms of classroom layout for them to conduct active learning activities, thus a flexible, transformable, layout was highly preferred (Monahan, 2002; Taylor, 2009). Another mandate for the GE Lab was to provide key technologies to support student innovations. Students in Hong Kong in general have a high level of information literacy and a culture of adopting new technology. A recent study found that Hong Kong students obtained their highest scores in information technology among the six measured generic skills (Education Bureau, 2014). Their learning can be motivated by integrating advanced technologies into learning tasks. The technologies adopted in the GE Lab are not common educational equipment with which students are already familiar - for example, personal response system, interactive whiteboard, and lecture capture tool; rather, the technologies were selected because they have the potential to inspire creative thinking and support innovative ideas. The key philosophy behind the GE Lab is to supplement the discipline-focused laboratories operating under academic departments such as Physics, Chemistry and Engineering, which support knowledge transfer to a specific group of students through structured lab work. The GE Lab is a platform that provides technologies and space for all students, via the GE Programme, to discover interdisciplinary knowledge and to generate, realize and verify their ideas.

Design of the GE Lab

Two adjacent rooms were assigned for the establishment of the GE Lab. A 969 ft2 (90 m2) room was converted into an ALS for hands-on activities and student group work. An 861 ft2 (80 m2) room houses the key equipment and a workstation for the technical staff to provide face-to-face technical support. Both rooms are equipped with standard multimedia equipment and are covered by the University wireless network. The GE Lab is managed by the Office of Education Development and Gateway Education, an administrative unit that supports teaching and learning in the University.

Room 1: Active Learning Space

The requirement to establish a flexible, transformable, layout was fulfilled by using 16 trapezoid-shaped foldable tables with wheels that can be arranged into different layouts to serve different teaching needs. In the standard layout, two tables are assembled to form a hexagonal table (Figure 1a), similar to the round tables found in most ALCs, for student group work. The setting can easily be transformed into a large semi-circular layout, so that the instructor can conduct a demonstration in the middle and be easily observed by students seated around the semi-circle (Figure 1b). A GE course named "Science in Chinese Kung Fu" used the setting for a demonstration of motion in the martial arts and its relation to physics by a Kung Fu master and a physics professor. The room can also be changed into a team debate setting for two or more teams, or into an exhibition area with rows of tables/benches for student project exhibitions. When a large space is required for an activity, the tables can be folded up and rolled away (Figure 1c), leaving an empty space for activities such as a robot competition, which require no physical obstacles in the area. This open space setting has been transformed into a mock crime scene complete with plastic dummies and crime scene furniture for a GE course, "Forensics & Modern Society", in which students conducted learning activities related to a crime scene investigation. The room is also equipped with running water and exhaust ventilation for students to conduct hands-on activities or low-risk experiments. The normal capacity of the room is 40 students, but it can accommodate up to 50 with additional tables and chairs. The ALS essentially provides a very flexible layout for students to conduct interdisciplinary active-learning activities.

Figure 1. GE Lab Room 1 - Active Learning Space: (a) (b) (c)

Room 2: Equipment Area

Advanced technologies were carefully selected to support interdisciplinary learning and student innovations. High-value equipment is installed in the Equipment Area. This facility enables non-science/engineering students to learn and use advanced technologies that were not previously available to them. The following three major technologies were acquired based on their potential for technology-enhanced learning, impact on society and user-friendliness.

3D Printer. 3D Printing technology, also known as rapid prototyping technology, has been identified as one of the emerging technologies that is likely to have a major influence on higher education in the coming years (Johnson, Adams Becker, Estrada, & Freeman, 2014). While 3D printers are not new to the University – some academics have been using them for almost 20 years – such equipment is usually housed in special laboratories and is only available to students in certain disciplines (Lantada et al., 2007; Strong & McCowan, 2005). With the implementation of the DEC, 3D printing is available to all students via the GE Lab. It serves as key visualization equipment to realize students' dream designs and to test their innovative ideas. A production-grade 3D Printer, model Stratasys Fortus 400mc, has been installed in the Equipment Area.

Echo360 Presentation Capture System. Almost 70% of CityU GE courses include a presentation component as an assessment task. Although English is the University's medium of instruction, the first language of most students is Chinese. Facilities are needed for students to practice their English communication and presentation skills. Research has shown that video capture technology can be used effectively to improve students' presentation skills through self-assessment (Cochrane & O'Donoghue, 2008; Lewis & Sloan, 2012; Smith & Sodano, 2011). The Echo360 system, a cloud-based eLearning tool that can capture student presentations with a very simple user interface, has been installed in the GE Lab. Students can use the system to record their presentations, review their performance, polish their presentation skills and showcase their project achievements. Students can select the recorded videos and upload them to the central learning management system (LMS) for peer-review and assessment. A 60-inch touch-screen monitor and a high definition camera were purchased for use with the Echo360 system.

Scanning Electron Microscope. The popularity of science-themed TV series has inspired many students to learn about scientific equipment and its usage. Technical terms such as nanotechnology that appear on consumer products increasingly trigger students' curiosity to acquire related knowledge. Science/Engineering students have opportunities to use scientific equipment in specialized laboratories in their own departments, but other students may not have the chance to learn about and use these facilities. To allow students the opportunity to use important research grade equipment, a very user-friendly scanning electron microscope (SEM) was acquired for students to examine the "nano" or "micro" world, such as the compound eyes of a housefly. A JEOL SEM model JCM-6000 with touch screen interface has been installed in the GE Lab to support GE courses teaching and learning activities (TLAs).

Implementation

The GE Lab officially opened in September 2013 and has attracted GE course leaders from all three Distributional Areas to make use of the ALS and its technologies to enhance and enrich their courses. Throughout the 2013-14 academic year, the GE lab supported 18 GE courses from 12 academic departments/units with a total of 2020 student enrollments (Table 1).

Table 1.
GE Lab usage 2013-14

GE Distributional Area	Number of courses	Percentage	Student enrolments	Percentage
GE Area 1: Arts and Hum.	7	39%	788	39%
GE Area 2: Study of Soc., Social and Business Orgs	3	17%	356	18%
GE Area 3: Science and Technology	8	44%	876	43%
Total	**18**	**100%**	**2020**	**100%**

More than half of the usage (56% by number of courses and 57% by student enrolments) is from non-science/engineering GE courses, which suggests that teachers from the arts, humanities, business and social science fields are comfortable in using the GE lab for student learning activities. The flexible layout of the ALS encourages GE course leaders to design diverse active learning activities such as small group discussions, role plays, team presentations, project exhibitions and other hands-on activities. All of these GE Lab-related tasks enrich the student learning experience in a way that is impossible in the traditional classroom.

Apart from the ALS, GE course leaders have welcomed the three selected technologies by adopting them in their TLAs. Echo360 is the most frequently used technology, as presentations because of the frequency of assessment tasks in GE courses, and students are eager to use the system to practice and improve their presentation skills. Some of the course leaders even use the cloud-based system as an inventory to store outstanding student presentations and convert them into future teaching materials.

The availability of 3D printing has caught the attention of the GE community at CityU. While most GE course leaders are interested in learning about 3D printing technology, not all of them have yet adopted it in their courses. In this academic year, three GE courses pioneered 3D printing as part of their learning activities and two of them made it the key tool for students to create prototype items. The course leader of "Creating Your Smart Home" provided a very creative environment and professional guidance for his students to create prototypes of intelligent home appliances using 3D printing technology. The course leader of "Visual Expression and Communication" nurtured his students to innovatively represent a daily message using 3D printing.

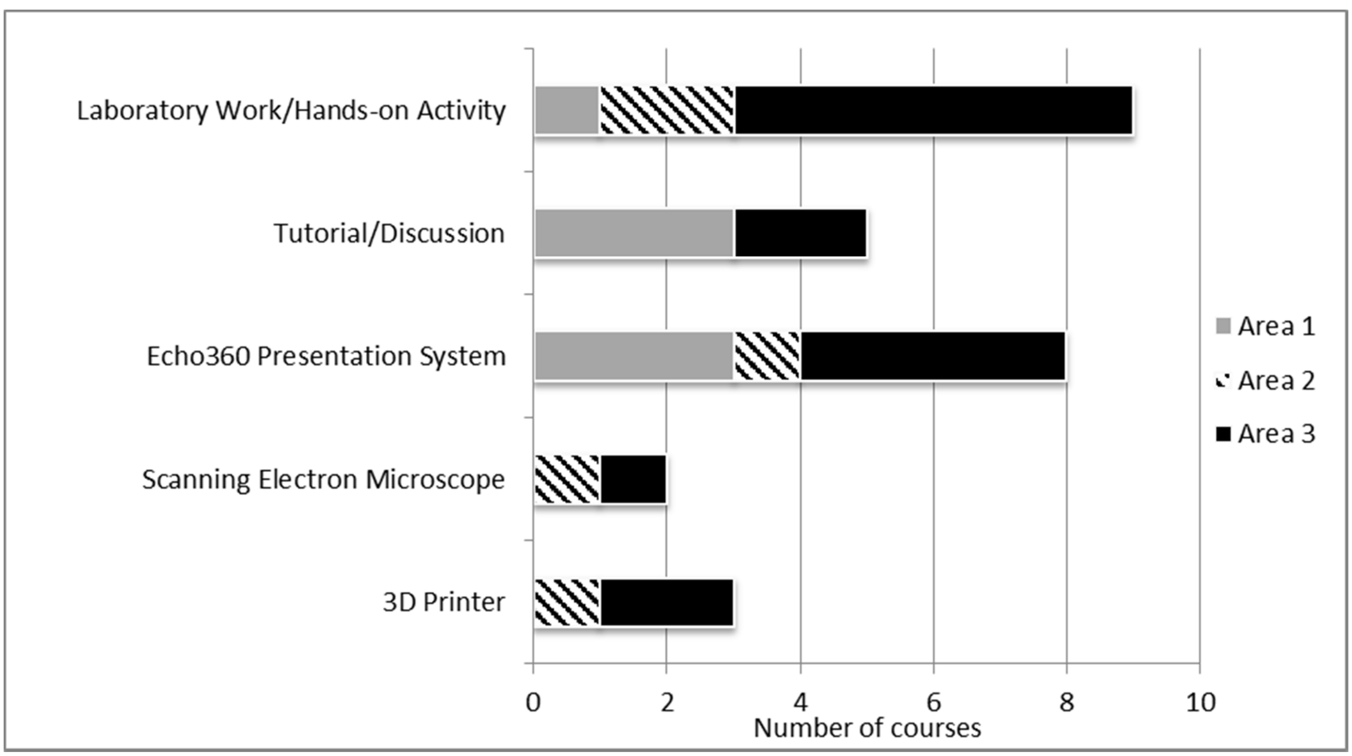
The SEM has been applied in specific GE courses. Students taking the "Food: Culture, Science and Society" GE course have used the SEM to examine different types of daily food. They were amazed by the beautiful crystal structure of table salt and surprised by the rough surface of a grain of rice. They conducted further investigations based on their observations and discovered the knowledge behind them. Students of "Forensics and Modern Society" used the SEM to examine evidence collected from a mock crime scene. A summary of GE Lab-related TLAs is shown in Figure 2.

A Successful Active Learning Space

To evaluate the effectiveness of the ALS, a 12-item user experience survey was constructed to gather feedback from the course leaders in three categories: the physical environment, learning attitudes and instructive styles. Items in the physical environment category assessed the usability of the ALS based on its physical design. The items relating to learning attitudes revealed students' reactions and perceptions, while those relating to instructive styles provided information on learning activities. The survey was sent to 21 GE lab users (including instructors who co-teach GE courses) at the end of Semesters A and B. GE lab users were invited to complete the survey based on their experiences of using the GE Lab compared with the University's regular classrooms. They rated each item on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Eleven completed surveys were received, with a response rate of 52%. The descriptive statistics of the survey results are shown in Table 2.

The results clearly show that the users considered the ALS to provide a better physical environment for conducting active learning activities, with a mean score of 4.43 in this category. In particular, the users agreed that the ALS is a better place than the traditional classroom for engaging

Figure 2. GE Lab-Related Teaching and Learning Activities



students, creating closer relationships and sharing ideas with them. In general, they also agreed that the ALS can enhance students' attitudes towards learning, especially in supporting student motivation and providing good support for different instructive styles, with category mean scores of 4.18 and 4.25. Users' qualitative feedback provided additional evidence of the effectiveness of the ALS and reinforced the survey results. The following are some of the users' comments:

- "It fosters a friendly and comfortable environment for teaching and learning."
- "The setting naturally draws students into a small group discussion."
- "The Lab layout enhances student interaction."

The survey results suggest that the ALS has been successful in providing a supportive educational environment and a flexible layout that encourages student interaction and participation. Because of the ALS setting, course leaders are more willing to design active learning activities that are not supported in a traditional classroom. The enhancement of student participation, engagement, discussion and interdisciplinary collaboration leads to idea generation and innovation development (Farrell, 2001; John-Steiner, 2000; Sawyer, 2006). Course leaders and GE Lab staff have identified a number of innovative ideas from students. Some of these ideas were very practical and the students were invited to continue to develop their ideas subsequently. Some of the students' achievements are described in the next section.

Table 2.
Descriptive Statistics of the GE Lab User Experience Survey

Category	Items	Mean	Std Dev
Physical Environment	Provides a better environment for the teacher to engage students.	4.55	0.52
	Provides a better environment for the teacher to share ideas/teaching materials with students.	4.45	0.52
	Provides a better environment for the teacher to create closer relationships with students.	4.55	0.52
	Provides the teacher with a better view of students wherever they are sitting.	4.18	0.60
	Category	4.43	0.56
Learning Attitudes	Provides a better environment for students to maintain longer concentration on instruction (based on your observation).	3.82	0.60
	Provides a better environment for students to make an effort to attend classes (based on your observation).	4.00	0.89
	Provides a positive environment for supporting student motivation.	4.45	0.69
	Provides a better environment for students to generate ideas.	4.18	0.75
	Category	4.11	0.75
Instructive Styles	Provides a better environment for group discussion.	4.27	0.79
	Provides a better environment for student presentations.	4.36	0.67
	Provides a better environment for students to conduct group work during class time.	4.27	0.65
	Provides a better environment for student peer-review (students provide comments to other students).	4.09	0.83
	Category	4.25	0.72

Technology-enhanced Learning - Supporting Student Innovation

Throughout the academic year, a number of talented student users of the GE Lab were identified during their active participation in course activities. They were not only keen on acquiring interdisciplinary knowledge through coursework and learning with new technologies, they also showed potential in generating innovative ideas. The students were encouraged to develop their ideas using resources from the GE Lab under the guidance of the Lab staff and academics from related fields. They mastered the technologies available in the GE Lab and made good use of them to develop prototypes that could prove and demonstrate their ideas. The knowledge and skills acquired during this process were outside of their major study areas and were interdisciplinary in nature. Some of the talented students were coached to participate in regional/international student contests with good results. Some of the students' achievements are described below.

An electronic engineering student had an innovative idea to develop smart energy-saving ventilation and air-conditioning system that can save more than 10% of the energy used by an office operating from 9 AM to 6 PM. His inspiration came from the discovery-based learning experience of his previous associate degree in the Division of Building Science and Technology and his current Bachelor's degree programme in the Department of Electronic Engineering, as well as from serving as a student helper in the GE Lab where he learned and mastered the skills of 3D printing technology. He then developed his idea based on his interdisciplinary knowledge and made use of the 3D printer to create a functional prototype. He enrolled in a regional student competition, "Samsung Solve for Tomorrow Competition 2014", on the use of technology to solve an environmental issue. He won first prize at the tertiary institution level. His winning project is called a "New Concept of Humanized Variable-Air-Volume Air Conditioning System" (http://hdl.handle.net/2031/7294).

A student from the Department of Biology and Chemistry demonstrated her creative idea in a public speaking contest by infusing her scientific knowledge into everyday life topics. She spoke on "Lessons from Nature" and on "Blood Clotting 101" in the FameLab Hong Kong 2013, organized by the British Council, the Hong Kong Science Museum and the Education Bureau and was First Runner-up in the competition (http://dspace.cityu.edu.hk/handle/2031/7100). She made use of the Echo360 presentation capture system to practice her presentation skills and to receive peer-reviewed feedback to perfect her performance. She also received the "Favourite Video Award" in the competition.

A School of Creative Media student created a novel 3D sculpture by capturing the movement of a dancer using sensors attached to different parts of the body to generate a 3D computer model. The model was then processed and printed out by the 3D printer in the GE Lab. The artwork was submitted to an international competition, "Extreme Redesign 3D Printing Challenge", organized by Stratasys, and was among the top 10 finalists in the Art & Architecture category in 2013. A video demonstrating the concepts can be viewed on YouTube (https://www.youtube.com/watch?v=FYeAt4gzEoU&list=UUO2UPHLDCwmjr-JZrRv7lsg, 0:39-056). The community was impressed by the idea of combining art and technology into a visualized object.

Discussion

The GE Lab's guiding principle of designing an ALS with a flexible, transformable, layout has proved to be a sound decision. The GE Lab reached almost full capacity in its first year of operation, revealing the University community's need for such a flexible space. A rich variety of active learning activities are accommodated according to different course leaders' instructive styles. The availability of the ALS has encouraged course leaders to adopt an active learning pedagogy, and the same idea has driven the creation of the GE Lab. The use of the GE Lab by courses in all three Distributional Areas is a good indicator of the user-friendliness of the space. Course leaders with different backgrounds can make effective use of the facility and the GE Lab serves its purpose of supporting the GE Programme, not just a particular discipline.

Students are very happy to make use of the technologies available in the GE Lab. To support the effective integration of technologies into GE courses, both course leaders and students have been taught the advantages and limitations of the equipment, thus ensuring that course leaders can design appropriate learning tasks and students can make full use of the facilities. On-demand training workshops are provided by GE Lab staff to serve this purpose. Additionally, well-trained student helpers, who act as mentors, are available in the GE Lab during regular hours to provide additional help to students in learning the technologies and using the equipment for their projects. Effectively integrating the technologies into GE courses to enhance student learning is a key part of the overall success of the GE Lab.

The GE Lab has proved to be successful in supporting student innovations. It provides opportunities for talented students to test and realize their ideas. The ALS serves as a base for students to collaborate, discuss and generate ideas, and they can then use the GE Lab equipment to realize and try out their dream designs with very promising results. However, the practice of identifying talented students through GE Lab activities has its limitations. Only those who showcase their ideas in class, through student presentations, can be identified and followed up. A number of students who have good ideas but are unable to present them are lost. A more systematic operational model that can harvest student ideas more effectively is needed, instead of relying on in-class observation.

From the University's point of view, the GE Lab is a special facility designed to support the newly established GE Programme. Its novelty is in combining the ALS and advanced technologies to support student learning. After just one year of implementation, the GE Lab has demonstrated its value in enriching and enhancing the GE Programme with high levels of student achievement. Course leaders and students welcome this non-traditional classroom as a supplement to regular classrooms. The University could consider opening other similar facilities, such as ALSs with or without special features, to support diverse teaching and learning activities. These special spaces will not replace regular classrooms, which will continue to serve as the workhorses in the University, but they can provide a unique function to support different types of student activities and active learning pedagogy, thus enriching the overall student learning experience.

Conclusion

The establishment of the GE Lab is a novel idea that merges the ALS with advanced technologies to enhance TLAs in the new GE courses at CityU. It is designed to support students from all disciplines to learn and work together using selected technologies with potential impact. The GE Lab provides a very flexible ALS for various student learning activities, such as small group discussions, exhibitions, project work, presentations and demonstrations. Couse leaders report that the GE Lab provides a better environment for enhancing learning attitudes and for supporting different instructive styles. The collaborative learning activities help to trigger student innovations and the availability of advanced technologies in the GE Lab enables students to develop their creative ideas with support and guidance. A number of innovative ideas from students have been harvested and nurtured during the first year of operation with very good outcomes, and some of these achievements have received public recognition.

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