Maker Education in a Sino-American Joint Institute: Taking Sichuan University - Pittsburgh Institute as an Example

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Maker Education in a Sino-American Joint Institute:

Taking Sichuan University - Pittsburgh Institute as an Example

Abstract

Sichuan University-Pittsburgh Institute (SCUPI) is a new academic entity jointly established by Sichuan University (SCU) and the University of Pittsburgh (Pitt), which is one of five large-scale partnerships between an American and a Chinese university. Currently, three undergraduate degree programs are offered: Industrial Engineering, Materials Science and Engineering, and Mechanical Engineering. From the interactions between the instructors and students, it has been identified that Chinese students tend to be very focused on theoretical learning, while their hands-on abilities and creativity are relatively limited. To stimulate imagination, innovation, creativity in Chinese engineering undergraduates, SCUPI set up a student-run-design-build-play space, named as *Makerspace*, in April 2016. This article introduces in detail as a start-up academic institute, how SCUPI, learning from excellent makerspaces world-wide, launched innovative maker education activities based on the existing resources and characteristics of Chinese students. These activities include: 1. Regular technical lectures for training makers 2. Hands-on projects based on engineering courses 3. Supporting students in STEM competitions; 4. Involved in feature events and outreach activities of SCUPI 5. Guiding students to take part in academic research 6. Establishment of an online maker sharing community. As a result, SCUPI has initially created a dynamic maker education system based on this small-scale makerspace, which provides guidance to brainstorming, CAD model simulation, prototype manufacturing and hands-on practice. The organization, facilities, challenges, and planning of *Makerspace* are also presented to guide others in the creation of similar organizations.

Introduction

Sichuan University-Pittsburgh Institute (SCUPI) is a new academic entity jointly established by Sichuan University (SCU) and the University of Pittsburgh (Pitt). This institute is a realization of the new archetype of institute-scale, collaborative entities between leading universities in the U.S. and China. SCUPI is designed to follow an international model and is aimed to provide a world-class engineering education that focuses on design, innovation, and a global vision. Currently, it offers three undergraduate programs in Mechanical Engineering, Industrial Engineering, and Materials Science and Engineering and all courses offered are taught in English. Now SCUPI is in its third year of operation, and there are around 400 Chinese students. Among the first class of students enrolled in 2015, 37% of them have transferred to top universities in the U.S., like Carnegie Mellon University, University of Pittsburgh, University of Southern California, etc.

To distinguish itself from the traditional teaching, SCUPI's program design and teaching environment put great emphasis on active learning, creative thinking, problem-solving, and teamwork. However, during the interactions between the instructors and students, it has been identified that Chinese students tend to be very focused on theoretical learning, while their hands-on abilities and creativity are relatively lacking. To solve this problem, in April 2016,

SCUPI set up a small-scale makerspace to create an informal, free and open student-run-design-build-play environment.

Background

Gaokao, China National College Entrance Exam, is a fair system for selecting college students in such a huge country with a pollution of 1.38 billion people, which enhances social stability, and configures the whole education system as well. It is like a navigation compass in Chinese pre-college education. It defines the concept of "excellence," and shows the route of how to be "excellent" [1]. Thus, thousands of students share the same effect after taking the standardized test-focused education for 12 years. Dr. Michael L. Reed, Associate Dean of SCUPI, states that Chinese students "are very used to a formal lecture style mechanism of information transfer; they have a laser-focus on getting the "answer", and they don't ask questions; they do not like teamwork, etc.". A study shows that only 9% of students, from two provinces of China, take learning initiatives when listening to teacher in class [2]. Thus, most mainland Chinese students are used to passive learning instead of active learning.

Since Gaokao system over-emphasizes on studying for tests, the college education is highly expected to improve the students' shortage of practical skills, teamwork spirit, and self-study techniques. However, the traditional college education is designed to teach the courses based on pure theory, which missed a vital part - interaction with the real world. For most engineering undergraduates of China, the graduation project is a mock industry-level engineering design, which provides an opportunity for students to apply what they have learned to a project. This project calls for skills of teamwork, self-study, research, presentation, etc. Unfortunately, the quality of graduation design project cannot be guaranteed and this education activity does not work well as planned, due to the lack of quality control, mentoring resources, and sense of responsibility [3]. Meanwhile, for management and safety reasons, universities do not provide complete open access to workshops and assembly spaces. Thus, college students' shortage mentioned above can not be improved, and they are left unprepared for the future career.

At the same time, for industry companies, they prefer to recruit graduates who are fast learners and real-world problem solvers. Specifically, they hope their future employee to be strong in hands-on skills, an excellent communicator, and highly adaptive. Unfortunately, none of the qualities above is well trained under Gaokao education system.

To solve similar problems, maker education, started from 2005, became popular among education institutes worldwide. Makers are such a group of individuals who are interested in the creation, design, and building of new objects and are willing to share their experience. A "makerspace" is a physical location that works as a meeting space for makers and houses the community's design and manufacturing materials [4]. This place provides access and training for students to realize their ideas and serves as a compliment to the theoretical curriculum already in place. A study indicates that creativity values of students increase after working and learning in a makerspace. Also, the majority of the students state that the technology learned is useful and will benefit their future career as engineers [5], [6].

China, the world's factory, is trying to transfer its economy from low-cost, labor-intensive manufacturing to innovation and design-led production. With the wave of innovation and entrepreneurship education, an increasing number of Chinese universities are also planning and building such an informal, free and open learning environment, like I-center of Tsinghua University and Makerspace of Huazhong University of Science and Technology [7].

Before setting up SCUPI *Makerspace*, the author has personally visited the benchmark of makerspaces - Think[box] in Case Western University in the United States. As the largest university-level open-access innovation center in the world, Think[box] has seven floors and a total area of 5000 square feet, including communication community, collaboration community, prototyping space, manufacturing space, project space, entrepreneurship space and incubator space. In 2016 alone, think[Box] has attracted more than 4,000 students from different disciplines such as technical schools, business schools, healthcare schools, and engineering schools to participate in its innovation activities. Think [Box] has grown into a mature ecosystem of innovation and has become a significant factor for students choosing CERU due to its values in maker education. During the visit, the author asked a question how to attract or motivate students to get involved in innovation activities. The director replied that in the US if students know there is a free, open, student-led space, they are naturally willing to come to this place to learn, play and share. However, in China, since most students are used to passive learning, management team of a specific makerspace needs to come up with some customized incentives to encourage students to spend more time on practice learning.

Overview of SCUPI *Makerspace*

Makerspace in SCUPI was set up in April 2016. This small-scale space (860ft^2) was equipped with 3D printers, 3D scanners, processing units, robot components, unmanned aerial vehicles, and more (Fig. 1). The purpose of building such a place is to encourage students to come and explore their passions using raw materials, tools, technology, repurposed items, and imagination. Students can work individually or collaboratively, using technology or brainstorm to realize their ideas in the shared space. The author is aware that the key to running a makerspace successfully in China is to create and foster a self-sustaining maker culture among students. Some unique aspects are as follows, which are reflected in the section of maker education.

- Provide training certificates for students who completed theoretical training and hands-on projects
- Open to students during daytime hours and free to use
- Use social media mobile application such as Wechat and QQ to promote image of *Makerspace*
- Involve students to participate in daily management and operation
- Serve as a resource platform, providing projects, training, competition, activities, etc.
- Closely linked to the engineering curriculum

Fig. 1: *Makerspace* of SCUPI

Management Structure

Makerspace management structure is identified as three different models: faculty run, student run, or specific support staff [8]. As a newly built organization, SCUPI *Makerspace* has adopted a mixed model, which combines student support and specialized staff.

Student Support: A student club called Technology and Science Association (TSA) are deeply involved in the daily management of *Makerspace*. For each type of machine, there is a student leader in charge. They help students to learn equipment, supervise safety, maintain facilities during the open hours. They actively assist in organizing activities and helping to promote the image of *Makerspace*. The reward to these students is: Twenty-four-hour access to *Makerspace* and a stipend of 12RMB per hour.

Specialized staff personnel: At present, there are three lab engineers from different disciplines providing full range of support. They offer instruction, training, supervision and set up safety regulations. The expansion of the equipment and space layout planning is also a part of their work. Also, they work with faculty to introduce new hands-on projects and conduct performance review of TAS members at the end of each semester.

Maker Education in SCUPI

Although SCUPI *Makerspace* was only set up in 2016, various maker education activities have been given to students. These activities include: regular technical lectures, hands-on projects based on engineering courses, STEM competition, feature events and outreach activities of SCUPI, assistance of academic research, and online maker sharing community (Fig. 2).

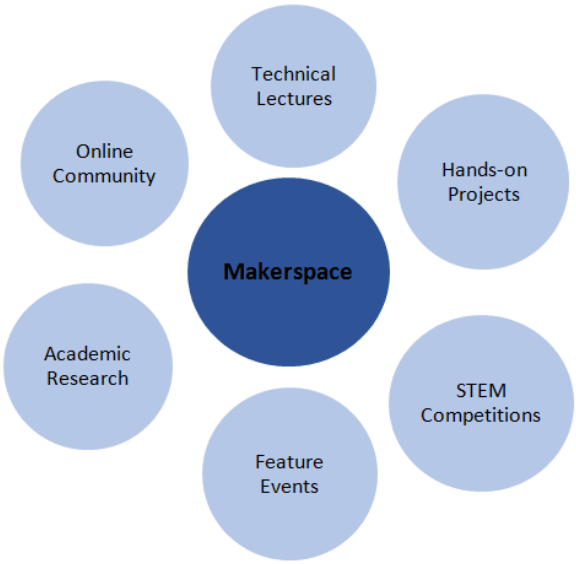


Fig. 2: Activities held in *Makerspace*

Regular Technical Lectures

So far technical lectures hosted in *Makerspace* have been given to students regularly (Fig. 3). The speakers consist of lab engineers, faculty and industry professionals, talking about machining techniques, 3D printing, electrical circuits design, robotics (Fig. 4(a)), etc. After each lecture, as a highlight, a hands-on training opportunity was provided, aimed at helping students to apply what has been learned from the lecture to the real world. Specifically, students were required to 3D print an object, manufacture a work piece using machine tools, assemble a module of an Arduino robot, etc. The lectures are popular among students for the lectures provide: the introduction of new technology, the connection between theoretical knowledge and real practice, manufacturing methodology, and safety training.

Activity Schedule in 2017 Fall Semester

Item	Lecture	Content	Speaker	Time	Sep		Oct		Nov	Dec
					11	25	9	30	20	18
1	Aviation Lecture	Introduction to GE Aviation and Aircraft Engine	CoCo (GE employee)	1.5 hours						
2	3D Printing Lecture	Introduction to 3D Printing/3D scanning and 3D printing practice	Dong (Lab engineer)	2 hours						
3	Manufacturing Lecture	Manufacturing fundamentals and applications	Senbao (Lab engineer)	2 hours						
4	Electronic Lecture	Introduction to electronics and electronic design practice	Luna (Lab engineer)	2 hours						
5	Robot Lecture	Introduction to Robot(History,conmpany,example)/DIY obstacle crossing vehical	Senbao/Dong (Lab engineers)	2.5 hours						
6	Presentation Skill	How to improve the presentation skill?	Richard (Faculty)	1.5 hours						

Fig. 3: Technical lectures schedule in 2017 Fall semester

After accomplishing the training, students are awarded a certificate (Fig. 4(b)) as proof of their learning experience. The certificate benefits *Makerspace* activities in the following aspects: to obtain the certificate, students come to the lecture and receive the training; students with the certificate have more access to *Makerspace*; students with the certificate have the priority to be considered for internship opportunities from *Makerspace*, etc.

(a) (b)

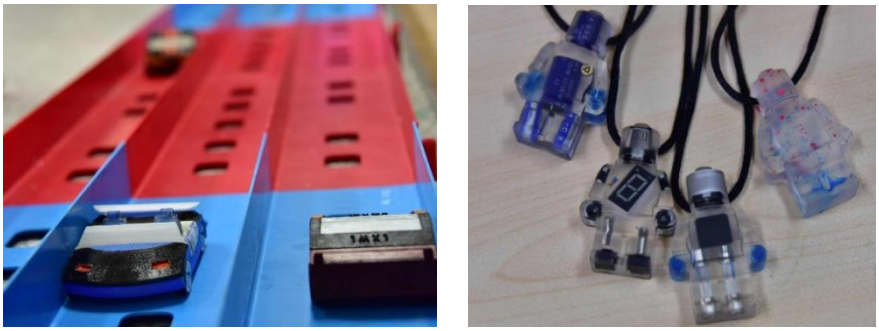
Fig. 4: Technical lectures. (a) Robot training, (b) certificate

Hands-on project based on engineering courses

To provide students a practice-based curriculum, *Makerspace* is served as a teaching lab where students do hands-on projects, thanks to the collaboration between instructors and lab engineers. Although SCUPI *Makerspace* was only set up in 2016, it was already been used in three different courses including sophomore and junior level engineering courses. These projects encourage students to use their knowledge and the resources of *Makerspace* to make their design into a wonderful product in life.

One example is SCUPI Derby, a hands-on project of Mechanical Design course, which is very popular among students [9]. In this project, students were divided into groups to design a model car after learning SolidWorks. After taking the relevant training in *Makerspace*, students used 3D printers to produce every part of the car model, like the wheel, axis, and chassis, etc. In the end, an exciting physic race was held in *Makerspace* to evaluate and validate the performance of the students' design by the distance the car traveled from an inclined track as well as the time it took to reach the final destination (Fig. 5(a)).

Another example is a group project of Manufacturing Process & Analysis. This project assigned to students involved making a table with one tube and casting of polymer pendant with epoxy etc. (Fig. 5(b)) . During this project, students come to *Makerspace* and use hand-held tools such as drilling tools, saws, grinding tools, sandpapers, etc. to remove the redundant material and polish the surface. TSA members and lab engineers are also on duty to help students and ensure safety.



(a) (b)

Fig. 5: Hands-on projects. (a) SCUPI Derby, (b) Casting of polymer

Support of students in STEM competitions

Since the institute highly values the application of engineering knowledge, it is a feature program of SCUPI *Makerspace* to organize students participating in national STEM competitions. Participating in STEM competitions not only enhances students' teamwork ability, practical ability and innovative ability, but also increases the prestige of SCUPI. One example is China Engineering Robot contest (Robowork) in 2017. One subproject of this contest was to design and make a robot, which can cross different obstacles (including stairs, pipes, narrow bridges, grasslands, etc.) along the fixed path (Fig. 6). Under lab engineers' guidance, students conducted a one-month pre-match preparation in *Makerspace*. They took advantage of *Makerspace* resources and made plenty of experiments, innovations, and improvements in the design structure, programming and motion optimization, etc. In the final contest, two SCUPI teams stood out from more than 100 teams and got one first prize and one second prize.

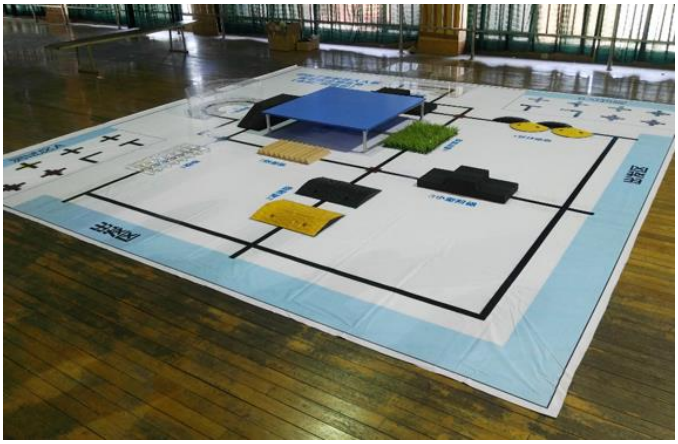


Fig. 6: Robowork competition field

Involved in feature events and outreach activities of SCUPI

Many students use knowledge and skills learned from *Makerspace* lectures including 3D printing, machining operation and electronical training to make special and creative works. For example, in a SCUPI Christmas feature event, students are encouraged to exchange gifts, such as 3D-printed cartoon models, machining processed Christmas trees (Fig. 7(a)) and flowing water light showing the letters of "SCUPI" (Fig. 7(b)), which are all designed and

made in *Makerspace*. By combining *Makerspace* and feature events, students are motivated to accomplish personalized and meaningful projects out of their own thoughts and interests. Besides, this is also a fantastic way to exhibit their creations, which will provide positive feedback and a sense of accomplishment.

(a) (b)

Fig. 7: Christmas gifts DIY by students, (a) Christmas tree (b) flowing water light

Makerspace also closely ties with outreach activities as particular feature of SCUPI. On the SCUPI open day for students and parents, the open creative space always attracts the most attention. During the visit, lab engineers and TSA students will showcase 3D-printed models, drones and robot cars made by SCUPI students to visiting parents and students. This special laboratory is highly praised by visiting parents and students. The following is the feedback from SCUPI visitors after visiting *Makerspace* on the open day (Fig. 8), from which it is obvious that *Makerspace* was inspiring and impressive to most visitors and a "huge plus" for enrollment marketing.

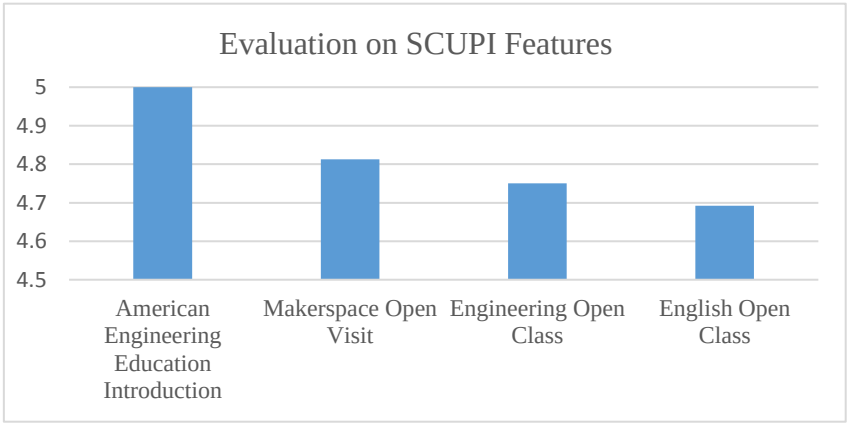


Fig. 8: Evaluation on SCUPI Features on the open day

Guiding students to take part in academic research

Makerspace provides students with opportunities to be involved in research projects. Not only students can be familiar with all kinds of equipment and devices, but also can students be familiar with how to work in a project or program and be more creative in a project or research projects. In 2017, three research projects were open to students through the platform of *Makerspace*. Finally, six students were selected as research assistants. Active involvement in *Makerspace* activities is one of the most important selection requirements. On the one

hand, exposure to research gives students the opportunity to experience cutting-edge technologies, helping them to discover their own interest, and enhance their future career competence. On the other hand, this can attract more and more students to show their talent and creativity in *Makerspace*.

Establishment of an online maker sharing community

Combination with Blackboard: An online maker sharing community is also established to share resources and exchange ideas. Learning materials about the devices are uploaded to Blackboard (Fig. 9), which is used as the e-Education platform in SCUPI. Students can find operation manuals and study materials of devices. Leading-edge achievements and research results are also regularly uploaded online to help students keep up with the latest technical development.

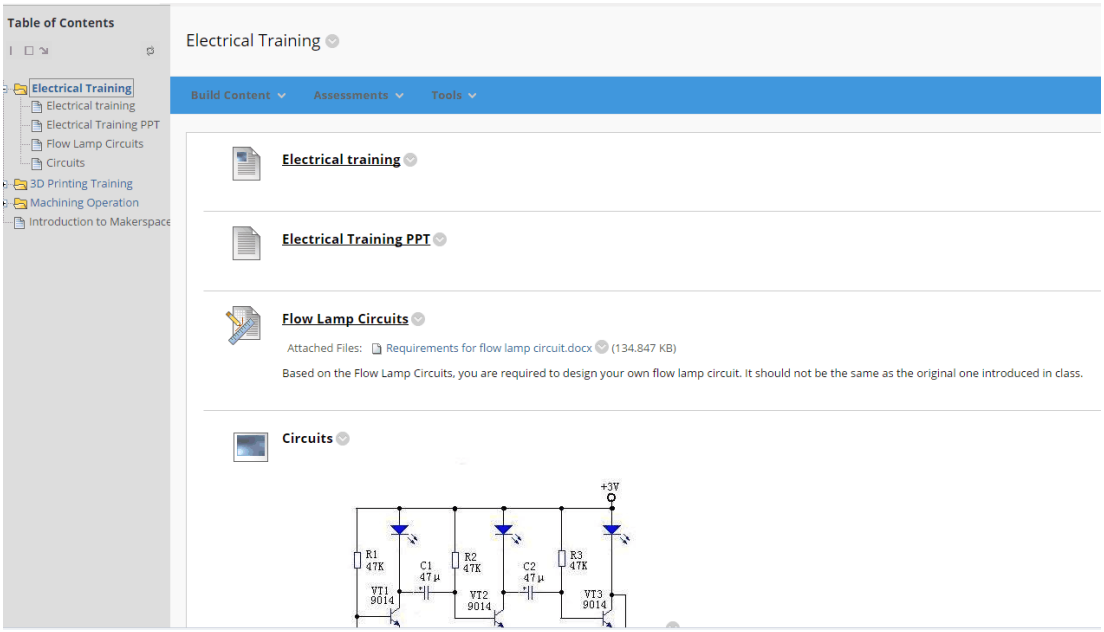


Fig. 9: Blackboard online sharing

Exchanging ideas on QQ group: There will be a QQ group (like MSN) for each *Makerspace* lecture and training. Students can share their thought via QQ group, communicate with trainers, and find suitable partners to realize creative projects in *Makerspace*.

Releasing news through Wechat, Weibo and Website: Once those projects are finished, students can share their works in the form of pictures and videos on abundant social medias like Wechat (similar to WhatsApp), Weibo (similar to Twitter) and website of SCUPI with the help of SCUPI media center. In this way, there will be a virtuous circle in attracting more students taking part in *Makerspace* and stimulating their hands-on interests and creativities.

Interactions between Chinese and American students.

Although SCUPI merely enroll Chinese students currently, the administration of SCUPI hired two American Teaching Assistants, who are both senior undergraduate students, from the University of Pittsburgh, in the fall semester of 2017. They also helped to conduct some

activities in Makerspace, which are highly valuable to SCUPI students, like training on data analysis, research on cultural difference between Chinese and American students, co-op and SAE competition experience sharing, etc. In the near future, the administration team of SCUPI will continue to bridge the gap between Chinese and American students using similar cooperation programs.

Impact on Students

Benefits of students

Taking part in *Makerspace* activities have influenced students in many aspects. Firstly, the practice-based curriculum introduced by faculty and lab engineers are deeply loved by students. These hands-on projects give students the taste of the deign realization as well as the true meaning of engineering. Secondly, students after training show more interest in practical exercises. There were frequent fierce discussions on QQ group about their creative thoughts and how to realize those thoughts by *Makerspace*. Thirdly, the initiatives of those students have been improved at a large scale. They are willing to spend more time to design and make their own projects in *Makerspace*. Fourthly, those students are more active in involving in various competition. With the experience obtained from *Makerspace*, they were more confident and thoughtful in those competitions than those who did not take part in *Makerspace*. Finally, those students have a much better idea of their strength thanks to the training from various projects and hands-on opportunities. This is beneficial for them for they obtained a clear vision of their future development.

SCUPI students and TSA members said they had learned a lot from *Makerspace*.

"*Makerspace* helped to develop scientific thinking, which is especially important to engineering students. Moreover, your competency can improve a lot. You will be more confident to take part in competition." Said Peter, who took part in the China Undergraduate Physics Tournament.

"I took part in the Robowork Competition. *Makerspace* training has helped me to a significant extent in this competition, making me be more familiar with mechanical structures. A lab engineer is assigned as our mentor for the competition. Moreover, as a member of TSA, I really feel lucky to assist with trainings, from which I've learned a lot." Said Jerry, who took part in the Robowork Competition and is also a TSA member.

Reactions of female students

Since engineering is a field occupied mostly by males, only one fourth of students in SCUPI are females. Thus, management team of Makerspace always encourage female students to join Makerspace activities and provide them with abundant opportunities. It is observed that female students tend to be good communicators in teamwork, detail oriented, and good at blending technology with art. Some female students also described their experience in Makerspace.

"I was afraid that manufacturing machines are too difficult to use. After the trainings, I had a

better understanding of how the machines work and how to operate them. Then it turns out that machines like 3D printer are pretty easy, once you know how to configure the basic parameters." Said Icey, who received trainings of 3D printers from Makerspace.

"I thought these (manufacturing) machines are created for smart people. As a female, I believed I was not good at abstract thinking. However, I was able to understand the working principles of the machines after taking the hands-on trainings of Makerspace. Later I realized the machines are like assistants of engineering work, which are very friendly." Said Verna, who took trainings of machining tools from Makerspace.

Statistics of Makerspace activities in 2017

Fig. 10 shows the number of students who have participated in technical lectures and the number of students who eventually obtained the certificates. The data indicates that over 90% of participants take the trainings seriously and would like to apply what has been learned from the lecture to the real world.

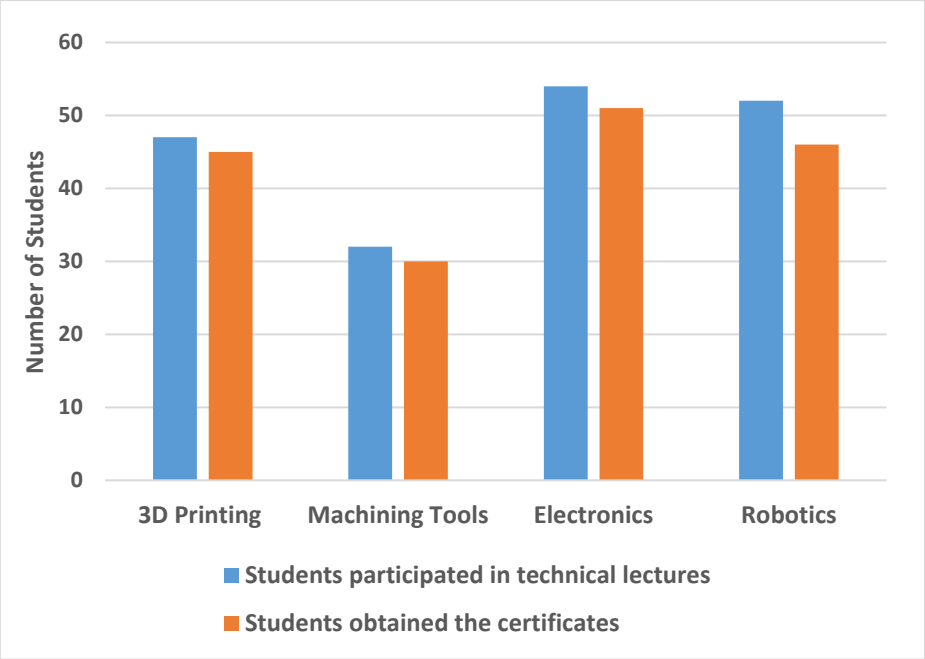


Fig. 10: Data statistics of students' participation in technical lectures

Fig. 11 shows Makerspace activities in 2017 and the expected goal in 2019. This demonstrates SCUPI Makerspace has already achieved a great number of achievements. On the other side, it is shown that there are few people doing personal projects at present. Since "number of personal projects" is a key indicator of assessing students' long-term engagement in Makerspace, stimulus efforts need to be implemented in this aspect of future work.

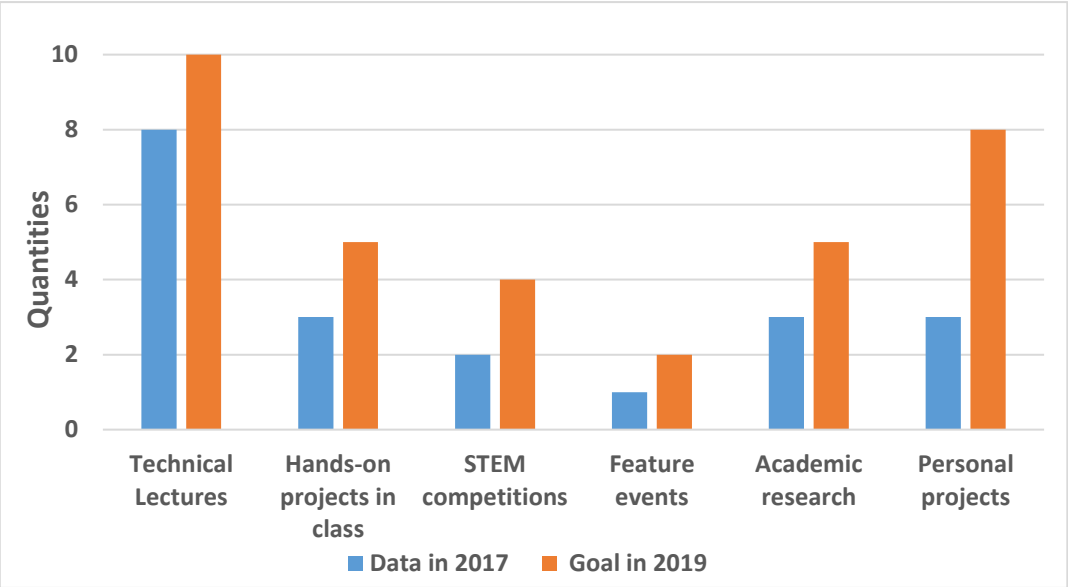


Fig. 11: Maker education activities in 2017 and the expected goal in 2019

Challenge

Since the first day of the establishment of *Makerspace*, challenges await along the way.

Conflict between freedom and safety

Students wish to have access to and use *Makerspace* whenever they want to. However, the safety of the students and *Makerspace* needs to be always assured. Hence students are only allowed into *Makerspace* when a student leader or lab engineer is present.

Students have limited time for *Makerspace*

SCUPI students at SCUPI do not have enough time allocated for *Makerspace* activities. Apart from STEM courses, SCUPI students are confronted with the challenge of improving their English proficiency. Because only top 30% students in GPA who pass the TOEFL (Test of English as a Foreign Language) with a score of 90 or above are qualified to transfer to the University of Pittsburgh or other similar university. Thus, they always prioritize STEM course and English learning over spending time at *Makerspace*.

Talent gap in students after transfer

Most well-trained students from *Makerspace* transfer to the University of Pittsburgh after their sophomore year. Therefore, a talent gap is formed in the institute, resulting in lacking experienced students in STEM competition, *Makerspace* training, etc. It is common that some students participate in a robot competition in China six months before they depart for their junior year in the United States. After their departure, they are busy adapting to new life in a new environment with a 12-hour time difference.

Future Planning

Introduce superior resources from Swanson School of Engineering

Founded in 1846, Swanson School of Engineering (SSOE) of University of Pittsburgh has

had success in energy technology and sustainable innovation. Thus, SCUPI has the privilege to make full use of established resources from Swanson School of Engineering. Considering the three majors offered by SCUPI, the most suitable student activities to cooperate with SSOE are Formula SAE and SAE Aero. These programs are engineering design competition for students. The engineering design goals for teams are to develop and construct a single-seat racecar (Fig. 12) and an aircraft model. Shortly, SCUPI students will join SAE teams of SSOE as a sub-team working on the design of a module, a part or an assigned task. SCUPI students can brainstorm with SSOE students via conference and then they can work on the design of different parts of the project. The two sides can literally work around the clock due to the 12-hour time difference. This kind of global teamwork is precisely how global companies, like General Electric, work under globalization. From these activities, SCUPI students will learn about multicultural collaboration, project management, mechanical design, and manufacturing, etc.

Fig. 12: The university of Pittsburgh formula SAE Team with their self-made race car [10]

Open to the campus community

Due to the limited space and resources, *Makerspace* is currently only open to SCUPI students with engineering background. The authors are well aware of interdisciplinary interactions are conductive to incubating valuable ideas and igniting collective creativity. Therefore, in the new building of SCUPI, to be put into use in 2020, a more spacious (3230ft^2) and multifunctional *Makerspace* will be built. As planning, the new *Makerspace* will be open to the whole university to encourage interdisciplinary communication and collaboration among students from all years and majors. At that time, SCUPI *Makerspace* will play a significant role in promoting the culture of innovation and entrepreneurship at the university-level.

Seek more cooperation with enterprise

SCUPI is currently reaching out to companies to build meaningful and constructive connections. The goal of *Makerspace* is to improve students' hands-on abilities and encourage their involvement in projects, which corresponds to requirements of companies for future employees. Now, SCUPI is working closely with enterprises to introduce some sub-projects into *Makerspace*. Meanwhile, SCUPI is encouraging students to participate in STEM

competitions sponsored by industrial partners. As a result, *Makerspace* works as bond between SCUPI and enterprises.

Conclusion

Although SCUPI *Makerspace* was only set up in 2016, under the effort from faculty, staff and students, a self-sustaining maker culture is gradually forming in this new joint institute. *Makerspace* significantly contributes to stimulating imagination, innovation, creativity in Chinese engineering undergraduates. Although there are still a lot of challenges to be explored, like the balance between safety and individual freedom, and students' limited time etc., the strong support from the university gives authors confidence in the future development of SCUPI *Makerspace*.

By introducing SCUPI *Makerspace* in detail, the authors hope to share its best practice and novel approaches to universities that are planning to build a similar student design-play-share place. More formal, structured surveys will be implemented to collect students' feedback and study the impacts of *Makerspace* on participants in the future work. It is expected that SCUPI *Makerspace* will continue to be an attractive platform for learning, which meets the need for more practice-based engineering education.

Acknowledgement

The authors gratefully acknowledge that the support for this work was provided by the Innovation and Entrepreneurship Education Foundation No.1431721. The authors would also like to express his sincere gratitude for the efforts on maker education from the faculty, staff, TSA members of SCUPI.

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