Makerspace at Singapore Polytechnic

Fang Sin Guek
Singapore Polytechnic Library
Singapore

Abstract
Singapore Polytechnic Library embarked on a transformation journey in 2011 to revitalise spaces and services in support of the Polytechnic's vision. The idea for creating a makerspace for engineering students in the library to foster activity-based learning was conceived as part of this journey. The Makerspace@SP Library (Makerspace) was launched in October 2013 and has achieved success beyond expectations. This article outlines the design and development of the Makerspace from concept to implementation, including the engagements necessary to ensure it meets the needs of students and staff.

Introduction - Remaking the Library

Singapore Polytechnic (SP) Library embarked on a remaking journey in 2011 to revitalise spaces and services under the Polytechnic's vision of being "A leading institution that prepares our students to be work-ready, life-ready and world-ready." (Singapore Polytechnic, 2011). The Library focused on two key areas. One was to create innovative learning and social spaces and the other was to provide learning opportunities for students to develop their full potential so that they can succeed in an economy based on skills, innovation and productivity.

The remaking started with the creation of a thematic space, the Da Vinci Level, focusing on Architecture and Design. The Da Vinci Level opened in January 2012. It provides creative hubs with collaborative spaces, learning pods with writeable surfaces, a gallery for showcasing student projects and an overall environment that is conducive to group discussion and project work. Relevant resource materials are placed within easy reach/access to facilitate discussion and project work. It goes beyond the usual library books and magazines to include LEGO sets for experimentation with city planning, building models and space design. Equipment such as PCs, Mac Pros, iPads, scanners and printers are strategically deployed for students to use as they require.

The thematic space was very well-received by architecture and design students, and also by students in other courses. There was a 35% increase in the usage of the Da Vinci Level in the first year of its opening. Many favourable comments were received from students during dialogue sessions and annual student satisfaction surveys.

There were many requests for the Library to expand on the Da Vinci Level concept. Concurrently, we were exploring new ways to ignite curiosity and interest in engineering, and to inspire practice-oriented students to learn and create. This created the opportunity to

pursue the development of Makerspace in the SP Library as an engineering thematic space that would support new pedagogical methods for Science, Technology, Engineering and Mathematics (STEM) education and the learning styles of engineering students. Positioning Makerspace in the SP Library versus a standalone makerspace elsewhere has the advantage of ready access to a myriad of learning resources spanning across the disciplines.

Strong Leadership Support

SP leadership gave early and strong support to the creation of Makerspace as it was closely aligned with the newly crafted Polytechnic vision of being "A caring community of inspired learners committed to serve with mastery." Unveiled in 2013, the revised vision called for a culture to nurture inspired learners and to build skills in our students so that they have mastery of skills for the future economy. (Singapore Polytechnic, 2014).

It was also consistent and aligned to the national vision. The Singapore Government had set up a high level ASPIRE (The Applied Study in Polytechnics and ITE Review Committee) to enhance education and the job prospects of technical students. Furthermore, the Government announced the importance of SkillsFuture, a national drive to provide opportunities for students to develop their fullest potential throughout life. The SkillsFuture movement was placing great emphasis for students to develop their passions, interests, deep skills, and a mindset for lifelong learning.

Conceptualising the Makerspace

At that time, Makerspace was a new concept for the Library management and also for libraries in Singapore. The team started by doing extensive literature searches, environmental scanning and visiting innovative learning spaces to understand the emerging technologies and educational developments that would impact library services for youth who are inclined towards practical and applied learning approaches.

Burke (2015) suggested that makerspaces would bring together the characteristics of knowledge sharing and tool sharing, focusing on hands-on learning and exploration, and in the process create an interested community of users collaborating and working on projects. He elaborated that a makerspace serves as a creation and collaboration space for students to experiment and learn beyond the classroom and outside the normal structure of their assignments.

We drew inspiration from the YOUmedia movement at Chicago Public Library which provided engaging learning opportunities for youths using the connected learning framework. This framework builds learning by connecting the individual's pursuit of interests, peer culture and academic content. (The University of Chicago Consortium on Chicago School Research, 2011).

Further inspiration came from makerspace developments in the United States, especially those set up in libraries such as the Fayetteville Free Library in New York, the first public library to create a makerspace and the University of Nevada, Reno's DeLaMare Science and Engineering Library. (Fisher, 2012). We were particularly impressed with developments at the DeLaMare Science and Engineering Library which was named as one of the most interesting makerspaces in America by Make Magazine (Conway, 2014) and the North Carolina State University Hunt Library (North Carolina State University Libraries, n.d.)

which had just started its makerspace with a focus on exposing students to emerging technologies. (Rogers, 2014, p. 123)

The YOUmedia initiative at Chicago Public Library and the two American academic libraries have some similar objectives. They aim to inspire creativity and collaboration amongst young people by providing them a welcoming, dynamic environment to interact with people who have similar interests. They created a place where users felt safe to try new activities. Library resources were provided to support learning, and while users were creating their projects, they would help each other or call upon mentors to guide them. In this hands-on learning environment, young people developed confidence and a sense of self-efficacy.

Burke (2014) cited two learning theories highlighting educational benefits from making and doing activities**.** Henry Jenkin's learning theory of participatory culture suggested that as students participate in the making process, they have the opportunities to play multiple roles and to gain understanding from each other's perspective. Students learn that they are not just users and consumers of the products, but are empowered to become inventors and creators as well. The hands-on making experience helps them to strengthen their understanding of creating an object and enhances their learning skills.

Seymour Papert's theory of constructionism proposed that learners strengthen their learning when they actually make a meaningful product from the mental models they have created. The process of creating the product or seeing the final product produced from concept reinforces the student's understanding of that concept. The use of problem-based learning exercises in making activities help students to build and reinforce understanding of the subject.

It was from these theories, case examples and literature searches that the objectives for Makerspace@SP took shape. It aims to be a creative space for students and staff members from all disciplines to come together to share ideas, encounter emerging technologies, access tools and resources, and make things. It will enable users to discover their interests, embrace the spirit of experimentation, innovation and creativity. It is an inclusive, non-threatening, and discipline-neutral environment where students and staff learn and apply cross-discipline insights for their personal growth and development.

User Studies and Pilot Test

With the help of enthusiastic academic staff and students, we carried out several rounds of user empathy studies using a design thinking methodology to better understand the needs, expectations and preferences of the 17 to 20 year old students from the Schools of Electrical and Electronics Engineering and Mechanical Engineering.

After the ideation and prototyping phases, we piloted an Engineering Pod at the Library's Level 2A with the following spaces:

- Messing Around – a playground for exploring possibilities;

- Ideation – a place which provided resources for tinkering, working on DIY activities, e.g. experimenting with LEGO Mindstorms to build robots;

- Staging – a place to hold talks, to display projects done by students and to meet other students to interact and share ideas.

Deliberate efforts were undertaken to make the Engineering Pod a fun and inviting place for students to visit, interact, explore new ideas and do things. Tinkering and playfulness were encouraged in this space for seeding imagination and innovation. Thomas and Brown (2011) explained that when people engage in playful tinkering, their learning retention improves as they expand their problem-solving capability to embrace change. This learning process helps students acquire skills for finding solutions by imagining new possibilities, and not getting stuck with old solutions and old practices. When a student acquires such skills to solve problems creatively, he/she has gained those precious skills for life.

Through this pilot run and the positive feedback from users and academic staff, we were confident that our design to create a unique learning experience for engineering students was ready for implementation.

Creating the Makerspace

The Makerspace was retrofitted out of the former Reference Reading Room which housed the entire Reference Collection of about 10,000 volumes as well as the offices and workroom of the Information Services staff. A large number of reference books were replaced by digital copies while a minority of books were integrated with the lending collection so as to create new spaces for making activities. The staff workroom previously occupied by 10 staff members was relocated to another floor of the building.

The Makerspace was designed as a free and open platform for collaboration and co-creation, and as a learning space to create value and meaning for our community. This is consistent with the core values of a library to provide open access to information, facilities and resources to all interested users.

The following spaces and facilities were designed:

- ***A Tinkering Space*** with open benches and simple hand tools for students to lose themselves in their tinkering;

- An ***Idea Box*** for presentation of fresh ideas from game apps to experiential displays;

- A ***Make-Kit Box*** with a variety of amateur invention sets such as electronics kits to MaKey MaKey sets for try out and loan;

- A ***3D Exploration area*** with 3D printers and 3D scanners;

- A ***RoBoPod*** for students to explore LEGO Mindstorms NXT kits and to build their dream robots;

- The ***Event Box*** with seating for 60 people for holding Maker events and workshops;

- Attractive displays of science and engineering magazines and books, as well as regular screening of videos on emerging technologies, TED talks related to the maker culture, new technologies and inventions.

Makerspace in the SP Ecosystem

While the Library was developing its Makerspace, the engineering schools were also enhancing their network of FabLabs (Fabrication Laboratory). Fablab was modelled after the Massachusetts Institute of Technology Media Lab. It was set up to provide fabrication equipment such as 3D printers, laser cutters and a 3D CNC prototype mill to facilitate hands-on training in cutting-edge technologies.

These parallel developments complemented each other in building a sustainable tinkering and making ecosystem in SP. The ecosystem consists of a three-tier framework, the Makerspace at Library, the FabLab and the Centres of Innovation (Diagram 1). With this framework, each entity has clarity of purpose and is focused in reaching out to its target users.

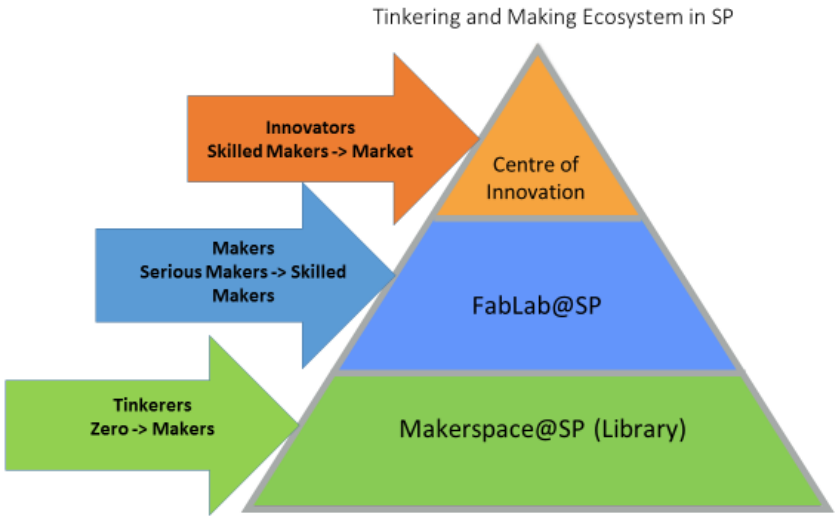


Diagram 1. Tinkering and Making Ecosystem

The Makerspace is a starting point for zero-experience, novice and interested makers (both students and staff members) to go to for tinkering. It welcomes anyone from any discipline to use the tools, resources and facilities. A Maker Coach will guide and help, if required to make simple things. It is a fun place for non-makers to get inspired by displayed works completed by beginning makers.

The seasoned and serious makers who have acquired the basic skills in making can progress to use the FabLab which provides a full range of tools and more sophisticated fabrication equipment for students to work on projects. Skilled technical staff are available to train and assist students as required.

Centres of Innovation are available to highly skilled and expert makers to use specialised facilities and equipment to work on their projects. They enable experienced makers to take

their innovation to the highest level, for example, creating prototypes, developing projects sponsored by industry partners, or testing products to meet commercial standards.

Firing Up the Makerspace

The Makerspace@SP was launched in October 2013 with an initial offering of retrofitted facilities, technical assistance by the Maker Coach and a suite of programmes and activities. Among the many activities organised, 3D printing proved to be immensely popular. Talks, workshops and facilitation on anything to do with 3D modelling, 3D scanning and 3D printing have consistently attracted large crowds.

Every month the Makerspace holds a series of **Maker Kickstart** programmes for beginners. They are usually conducted in small-groups to cater to beginners who are new to a specific skill or technology that they are keen to learn. Participants are provided with an introduction to the skill or technology in a supportive and non-intimidating environment. Examples include basic electronics, basic soldering, clay sculpting, etc.

Maker Workshops are conducted to help the SP community keep abreast of emerging technologies. Workshops are typically conducted by SP staff as well as external makers who have demonstrated technical competence and expertise. Examples include: e.g. Arduino programming, LED lighting, mobile apps development, games programming, etc.

Make Together sessions are organised to provide opportunities for students and staff from different departments and academic schools in SP to work together on a focused project. The goal is to encourage collaboration and to build up camaraderie.

Maker Meet-ups in the format of show-and-tell sessions in which makers present and demonstrate their own creations in an informal and friendly setting are held. The goal is to encourage sharing and cross-pollination of ideas. In October 2013, over 30 students and staff attended the first ever HacKIDemia event hosted at the Makerspace. Participants came together to tinker with Arduino programming, littleBits, 3D printing, paper craft electronics and even created their own Andriod app!

In April 2014, more than 200 local makers, hackers and tinkerers from across Singapore gathered at the Makerspace to showcase their latest technological inventions and ideas to forward the maker movement.

Embracing Art and Craft

The Makerspace subsequently expanded to embrace art and craft when we saw growing interest and participation from students and staff from the non-STEM disciplines such as design, business and social sciences. The areas of focus were broadened from STEM to STEAM to include Art, design and aesthetics. Newly added facilities included a photography studio and an audio recording studio. Workshops, boot camps, and pop-up sessions were offered to meet new demands.

The range of programmes grew rapidly to include digital making such as photo editing, video making and editing, music recording, programming, apps and games development, Arduino/Raspberry Pi, and animation. Among the new art and craft activities were poster making, clay sculpting, balloon sculpting and paper craft.

The expansion of programmes and activities was made possible with the increase from one Maker Coach to three Coaches and the additional support of staff from a newly formed Learning Spaces team. Based on Burke's survey on the 16 most common technologies and activities in academic library makerspaces (Burke, 2015, p. 499), we are currently offering about 75% of those listed.

News, calendar of events, inspiring stories of our makers as well as external high profile makers, and current topics of interest are posted regularly on our website, http://makerspace.sp.edu.sg/ to engage the community of makers, as well as to raise awareness to the wider community.

User Experiences and Feedback

The Makerspace attracted strong interest and active participation by students and staff from the start. They come from many different disciplines and schools ranging from business, social science, design, and information technology to science and engineering. In response, we aggressively increased offerings of programmes and activities to a total of 127 for academic year 2015/2016. This is a significant increase of 84% over the previous academic year. Participation rates increased even more by 162% to 3,029 participants over the same period.

One of our students from mechanical engineering, worked with two other maker students to assemble a game arcade machine (which they proudly called Makercade). They scoured for left over wood materials and acrylic sheets for the machine's body and installed electronics parts for the joystick controller. This student remarked, "It is about exploring imagination and pushing the limits."

Student makers working on a handmade cajon

Biotechnology students were introduced to 3D printing for the first time and were given hands-on guidance to convert digital models to 3D printed proteins. This allows them to play with physical models in their hands, enhancing their appreciation of these complex structures.

3D Protein printing hands-on session

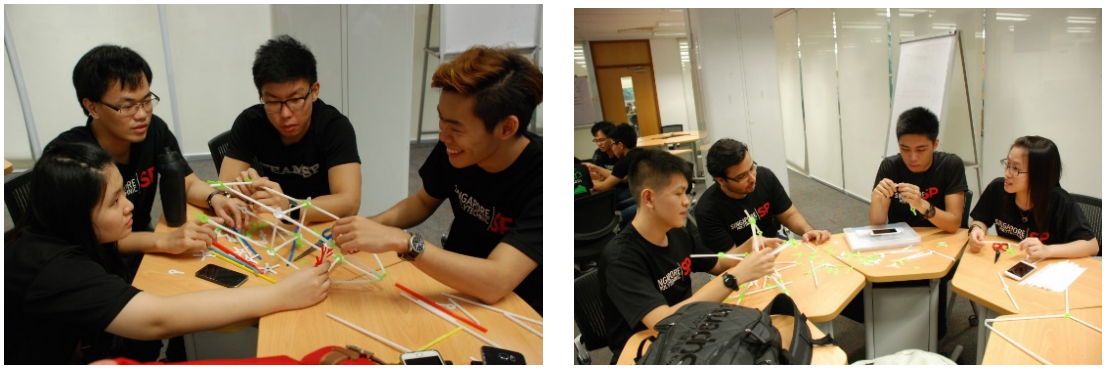
Creating electronics through art and craft

Trainee students from the Kindergarten Education – Teaching course attended a simple circuits workshop to learn and create electronics through art and craft. They made cards that lit up when the LED circuit switch was closed. This workshop was an eye-opening experience for the participants as they discovered that science and engineering could be introduced in a fun and interesting way to kindergarten pupils. The lecturer in-charge of these trainees said that her students benefitted as they discovered the technological possibilities that a teacher can use in a pre-school classroom.

A tinkering workshop was held for students from 3 different engineering courses: bioengineering, mechanical engineering and electrical engineering to enable students to better appreciate the knowledge and abilities of people from different disciplines. Participants had to put a constructor set to work, which not only allowed them to create functional mechanical devices, but also gave an opportunity to understand the limitations one might experience during designing and manufacturing. The session introduced basic control elements with the use of the Arduino, for students to understand programming of control boards to add function to their design.

Tinkering workshop on Arduino for engineering students

In an out-of-classroom activity, aeronautical engineering students who were studying aircraft structures were provided with "straw" based construction sets called Strawbees to build an aircraft fuselage. Strawbees were used creatively as another form of material to understand structural design and the theory of toughness and durability for an eventful landing.



Using Strawbees to build an aircraft fuselage

An educational design strategist at SP said that his engineering students played with interlocking cardboard pieces to build 'furniture'. It was a great, fast-paced, hands-on activity that got everyone excited. They learned about being a maker and the importance of quick prototyping.

A staff participant of the GarageBand Workshop gave this feedback: "As someone who has no music background but has an interest in it, I gained knowledge through this workshop with the guidance of the knowledgeable and helpful student instructors and lecturer. My two hours spent in this workshop was fulfilling and fruitful."

What's Next

Seeing the benefits that the Makerspace has brought to our students and the Polytechnic, a blueprint plan for Makerspace 2.0 has been developed. Makerspace 2.0 is being proposed as a thematic focused engineering floor integrating Makerspace with a new FabLab to be created in the Library to inspire makers to raise their game. This will ensure that our Makerspace concept will evolve and adapt to remain relevant in serving the learning needs of students and in supporting the Polytechnic's vision.

Our strategic focus on Makerspace is further strengthened and supported by the NMC Horizon Report 2015 which highlighted that one of the important developments in technology that will impact academic libraries within the next year is makerspaces. In developing the Makerspace, we are "solidifying the library's position as a hub where students and faculty can access, create, or engage in hands-on projects across departmental lines." (Johnson, 2015, p. 36).

Through the various stages of experimentation, adaptation and progress in setting up the Makerspace, the SP Library team encountered challenges but also saw potential and opportunity.

Our team embraced many changes such as taking on new roles, upgrading skills, and curating spaces and activities to launch the Makerspace and other associated services. This openness and receptiveness to trying new ideas in order to give our students a unique learning experience was critical to the successful implementation of the Makerspace@SP Library.

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