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The Role of Makerspaces in Enhancing the Student Learning Experience*

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Makerspaces are areas where its participants are able to design and build products of varying complexity. Many such areas exist within institutions of learning as well as in common areas that are frequented by children and adults alike. In fact, there are those that run a business based on the frequency or popularity of operating a makerspace. One of the main reasons makerspaces are so popular is due to the nature of the space itself, where it allows a person to touch and feel their own product after designing and subsequently building it. This "hands-on" approach is highly motivating for young learners and assists in further enhancing their awareness of STEM based activities. It is hypothesized that makerspaces are able to significantly enhance the learning experience of young learners who engage in these areas. These learners are able to enhance a variety of skills while designing a tangible product within a makerspace. The present investigation aims to validate this hypothesis, focusing on the roles makerspaces play in enhancing the learning experience. Through the review and results obtained, the key attributes or roles a successful makerspace should consist of would be identified. The main objective of the study would be to identify how makerspaces enhance the student learning experience. The research methodology is that of a case study, focusing on qualitative results obtained from a questionnaire. The questionnaire was answered by students who were tasked to design and build an engineering system while (in parallel) given access to a particular makerspace (to be used in assisting them to accomplish their design and build task).

Keywords: market space; STEM; PBL

1. Introduction

The ability to work with one's hands, using the relevant tools to design and build an engineering system is incredibly fulfilling. This enhances one's self-efficacy, promoting confidence and instilling skills that would be necessary to solve challenges. There exists a large amount of research which infers that human-beings thrive on being able to be self-sufficient, utilizing tools to enhance their lives by designing and building efficient and effective systems. It is interesting to note that young children, when attending pre-school or nursery at a very young age, are primarily exposed to performing activities that involve their hands in producing a piece of work. As we progress through life, education systems diverge away from hands-on or psychomotor based activities and on to more cognitive-based as well as affective-based learning and assessment. While it is incredibly important to consider all areas of the learning domains, particularly in engineering education, there are now studies that support an increase in psychomotor-based activities. This is because, both students and staff observe an overall increase in the student learning experience (through the increase in learning outcome attainment) when engineering students are able to "make" what they have designed.

With such motivation existing intrinsically with students in using their hands to develop a useful system and noting the existence of pedagogy that supports this in engineering education (e.g., project-based learning), it would make sense to provide students with an equally motivating space where they can realize their designs. These work-spaces tend to be filled with heavy (and in some cases expensive) equipment that are generally operated by qualified or competent persons. Noting also, that, because of health and safety issues, undergraduate students are not allowed to use such equipment and feel detached from the actual production of their engineering design (or system).

As such, educational institutions should be reviewing their own workspaces, and re-evaluating the equipment within, deeming whether it would be necessary for students to use large workshop based equipment and materials to produce a working prototype. The outlook is positive, as such spaces do exist, within and off-campus and are normally called makerspaces.

Makerspaces present an excellent opportunity to engage engineering students and to foster and promote a variety of skills. Research has shown that makerspaces are able to enhance the following skills.

- The ability to articulate complex engineering activities.

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- Design, manufacturing as well as safety knowledge and skills.
- Collaborative learning.

Throughout available literature, previous investigations seem to imply that many makerspaces sit outside the curriculum and are not embedded within, as a course requirement. This reduces its potential in enhancing creativity and innovation within young engineers.

Thus it begs the main research question for this paper. If makerspaces are perceived to be valuable, then, *how can it be used to motivate students in such a way that it promotes retention and more importantly, enhances the student learning experience?* Thus enhancing the understanding of key engineering knowledge. Herein lies one of the main challenges of a makerspace in terms of its tangible and actual value to engineering education. *The main objective of the study is therefore to identify how makerspaces enhance the student learning experience*. As such, the upcoming literature review section will now focus on a review that aims to explore how makerspaces influence the students learning experience.

2. Literature Review

The following review has been divided into two sections. The first describes investigations that have explored the usage of makerspaces and how these spaces have influenced the learning experience. The second part of the review provides an in depth look at the maker movement in general within the authors local context or specifically the Malaysian environment.

2.1 The Maker Universe

It is undeniable that the maker movement, which spawned the utilization of makerspaces to motivate young learners to enhance their engineering design skills, is bearing fruit. The modernization of technology and the ease of affordability of prototyping equipment as well as the user-friendliness of design software means that all which is needed to produce a usable prototype of a product is an entry level computer and a 3-D printer.

The overall maker movement, which inspired the makerspaces was first proposed at the Maker Faire hosted by an American organization in 2006 [1]. This trend observed an exponential increase in the number of people who were becoming part of the maker movement for the reasons surrounding self-efficacy. Such trends also become noticeable in educational institutions. Many realise that makerspaces present an excellent opportunity to attract new students. Such spaces are able to attract young learners in producing their own designs and hence increasing intentional learning, promoting creativity and innovation. The National Academy of Engineering in their "Engineer of 2020" document recognizes that creating, inventing and innovating are essential engineering skills that would need to be embodied by all graduating engineers [2]. Makerspaces present an excellent opportunity to engage engineering students and to foster and promote these skills. Throughout available literature, current investigations seem to imply that many makerspaces sit outside the curriculum and are not embedded within, as a course requirement. This reduces its potential to enhance creativity and innovation with young engineers.

Researchers from the University of Ottawa, Canada has described makerspaces as being able to "empower students to fabricate their own design, which helps them to achieve a deeper learning experience, and gain higher satisfaction". The authors go on to state that 80% of their students who responded to a survey said that makerspaces enabled them to be more articulate in sharing engineering concepts and jargon with non-engineers. 60% of the respondents shared that they feel more confident in their engineering knowledge and skills to solve a complex engineering problem. Finally, a whopping 90% stated that they were able to enhance their design skills while utilizing the makerspace. The researchers also note the makerspace's lack of integration into the engineering curriculum [3].

Other researchers have stated that "makerspaces also contribute to producing more student entrepreneurs" [4] and they also work to "strengthen community ties by offering a space for the community that facilitate and foster broader community life" [5].

It was noted that in the middle of the 20th century, engineering education shifted towards a heavier emphasis on theory and less so on practical based approaches [6]. It wasn't until the end of the 20th century and early 21st century where engineering educators began to realize the importance of practical and soft-skill components within the engineering curriculum continuum. For example, current accreditation criteria within the Washington, Sydney and Dublin Accords, requires engineers or its derivatives to be more holistic, not merely focusing on technical prowess but on interpersonal skills as well as critical thinking. As such, engineering curriculum globally have begun to introduce design experiences throughout, in some cases as early-on as the freshman year (or Year 1) of an engineering degree course. This indicates its importance on molding future engineers. With the availability of makerspaces across the board for all engineering students to utilize and realize their own engineering products, it is not surprising that students enjoy using the space. Researchers from Georgia Tech indicated that students spend a majority of their time in their makerspace while 80% of their students even indicated that they've used the space for their own personal projects. More than three-quarters of their students who were interviewed indicated that the utilization of the makerspace has led to them enhancing their design, manufacturing and safety skills. The researchers have also found that slightly more than half have said that it helped their Grade Point Average (GPA), employment and collaborative skills [6].

Thus if makerspaces are perceived to be valuable, how can it be used to motivate students in such a way that it enhances the understanding of key engineering knowledge? More research work would be needed in this area as there are few published works that are able to support makerspaces in having a positive and significant impact to the learning experience.

Most makerspaces, as mentioned earlier, consist of light, easy to use (and maintain) equipment that requires little to no (or only intuitive) training. Thus, reducing the risk of injury to untrained students by not exposing them to unnecessary hazards. It was noted that most makerspaces are run either by faculty or students and are operated on-campus. Researchers in Australia, who performed a review on available makerspaces in the country noted that there are several key parameters that makerspaces should possess which are; exposure to new, leading edge technology and equipment as well as being student driven and finally having the ability to foster collaborative learning [7]. The authors go on to state that makerspaces are primarily used for research, personal, coursework projects as well as for club activities and workshops. They further recommended that research would be required to understand how a makerspace would impact the lives of students.

2.2 The Malaysian Maker Movement

Over the last 2–3 years, makerspaces have been growing in popularity and presence across Malaysia [8]. These spaces are sprouting up in universities, schools as well as in shopping malls. Mobile makerspaces are also present, "setting up shop" outside areas that are frequented by the public. This enables ease of access to tools and equipment for those who are interested in the "DIY-ing" culture. The article goes on to state that within the Malaysian context, the makerspace movement inculcates and promotes entrepreneurialism and believes that this would enhance employability. The article further states that makerspaces also cater for start-ups and people who have ideas, but need just the right tools to make their prototypes. Many start-ups rent the equipment in these spaces to refine their products to reduce costs and as such, makerspaces play an important part in the start-up ecosystem. To further cement the importance of the maker movement within Malaysia, the article states that it has been embraced by the Malaysia Digital Economy Corporation (MDEC) which is working on the policy front with the Malaysian Ministry of Education to design a curriculum that incorporates the maker element. In order to ensure an ecosystem which is sustainable and assists in the execution of a successful maker movement, stakeholders such as the government, public and private companies as well as institutions of higher learning would need to embrace the movement.

Makerspaces are a sub set of creative hubs as defined in [9] as a place which innovative individuals gather for brainstorming, networking, and access to facilities and resources. Examples of creative hubs are studios, incubators, art centers and makerspaces. Although the overall maker movement is gaining traction, makerspaces are still rare and only a limited number of them currently exist in Malaysia. One of the examples is KakiDIY which was founded in 2014 and its focus is on recycling. It has two branches now and devises regular collaboration with schools and institutions by running maker competitions. One of the branches of KakiDIY is located at Malaysian Communications and Multimedia Commission (MCMC), which is named the myMaker IoT Lab [10]. It encourages the implementation of IoT technologies as well as establishment of more makerspaces in Malaysia. The maker community used the lab as a learning space where students were able to showcase and work on their projects. The government through MCMC held the first Makerthon, a design competition containing product and software development, in the region. The event was joined by ten ASEAN countries and dedicated to the usage of IoT in the respective industries [11].

Most of the work accomplished above focuses primarily around digital hubs or digital makerspaces. There are other spaces that focus on both digital and more traditional or manual based projects. One such makerspace is that of Me.reka [12]. Me.reka Makerspace provides trainings and services for 3D printing, virtual reality, and application of textiles. Another similar space is that of FabSPACE makerspace [13] offers UV and latex printing, as well as milling machines. The Penang Science Cluster has a huge involvement in educating the public about STEM and provides its own makerspace and facilities to the enthusiast [14]. Data showed that only 32% of tertiary students in Malaysia were enrolled for STEM courses. One of the suggestions to enhance students' participation was to familiarize and attract them to STEM from young age through the makerspaces. This will not only uphold STEM, but also instils the essentials skills in the learners.

Based on the review of the maker movement in Malaysia, it primarily focuses on two main thrusts. The first focuses on creating digital makerspaces – specifically being supported by the government to address the STEM gap present nationally. The second thrust is that of a more traditional makerspace, where manual labor and prototyping equipment are required to design and build a product. These spaces are primarily run by social enterprises with the main goal of encouraging the entrepreneurial mindset with young Malaysian learners.

From the review performed above it is clear that makerspaces possess an innate quality to motivate young learners and enhance their engineering design skills. This was echoed by researchers who performed a study on how university makerspaces provide opportunities in supporting equitable participation for women in Engineering [15]. The authors concluded that makerspaces do indeed provide a unique opportunity in developing a sense of community and provides better support for women in engineering. The authors also state that makerspaces have the potential of reinvigorating engineering education.

The key issues from the reviews performed seem to point to a common area that would need to be addressed, mainly, how such spaces are able to enhance the overall student learning experience and specifically whether such spaces enhance the knowledge and skills of engineering undergraduates. Another key challenge would relate to how such spaces can be embedded within engineering curriculum. Finally, another area of concern is that of how to ensure that such spaces exist for the convenience of the students and hence create a safe and healthy environment for all of its users.

3. Research Design and Methodology

The research design that will be employed to answer the research question within the present investigation is that of a case study. In particular, a case study where students, as part of a project-based learning course (module) are tasked to design and build an engineering system which addresses a specific engineering design challenge. In this particular module, students have been challenged to develop an easy-to-use solution which aids educational therapists in working with autistic children. The present investigation aims not to share the product that's produced but essentially the experience (positive or otherwise) the students and the lecturer had. They were tasked to design and build their engineering system while having structured access to an established makerspace. The overall research design, research participants and the makerspace description are summarized as follows.

Research Design – the overall research design employed is that of a case study. Specifically, the study will examine the impact of makerspaces in enhancing the engineering design and build learning experience. The case study will primarily be qualitative in nature.

Research Participants – 50 engineering undergraduate students in Year 2 of their degree programme (who were part of an engineering design and build course) were selected to be part of this study. Within this course all students were required to design and build a system that would address a specific engineering challenge. In the present case, the challenge was where they were tasked to develop a product that is able to assist educational therapists when working with autistic children. Instead of spending all of their time on campus, the current structure of the course now requires that they spend or utilize an off-campus makerspace to assist them in developing the design concepts and/or prototypes. The students visited the makerspace twice throughout their 14-week semester (once before week 8 of the semester and the other after week 8).

Research Methodology – in order to support the research design and to provide a generalization of the findings, a simple survey was developed and taken by 46% of the students (who were research participants).

Makerspace Description – the makerspace identified for this particular study is that of Me.reka Makerspace. As viewed and taken verbatim from [12] "Me.reka is an innovative and alternative education space. By removing all barriers to designing and making, the team at the makerspace teach students and professionals to excel in the industries and businesses that will shape the future of the nation. Me.reka provides access to tools, technology and experts. Using highly collaborative and immersive methods, the team sharpen the skills that students and professionals need to flourish in our rapidly changing world. The ecosystem at Me.reka brings together students, professionals, communities and makers, and connects them to real projects and income-generating opportunities, building sustainable solutions and realising potential". The makerspace described above as well as a picture showing students working in the space are provided in Fig. 1. As mentioned earlier, the research participants have visited the space twice throughout their semester to assist them in further developing their design concepts.

Fig. 1. Me.reka Makerspace [12].

4. Results and Discussion

Based on the review conducted in the present investigation, it is clear that makerspaces provide a positive environment to inculcate intentional and collaborative learning. Through the combination of infrastructure, activities and the presence of a community that are project-based in nature, the concept of making fosters collaborative and experiential learning [16] It is also clear that the makerspace, or specifically a successful makerspace that is able to embody the qualities described earlier would require attributes that contribute towards its ecosystem. In particular, the investigation was able to show that through the surveys conducted with 46% of the research participants:

1. 100% of all participants agreed that:
   (a) They enjoyed their experience (in some cases "a lot") of utilising the makerspace.
   (b) They would like to do it again – i.e. to utilise the makerspace again during other design and build courses or assignments.
   (c) They all wanted a makerspace on campus, for them to utilise and access in a free and flexible manner.
2. 78% of the participants stated that the most valuable part of the experience was gaining access to the expertise or the experts that were part of the makerspace i.e. the facilitators. Indeed as indicated in [16], individuals with engaging personalities and high degrees of empathy are needed as facilitators. The remaining 22% stated that the most valuable part of their experience was the space itself, its tools and the environment being open, accessible and very conducive for learning.

In terms of feedback from the participants, the free access to makerspaces were also important, hence why all of the participants wanted such a space on campus, similar to the free access provided in academic libraries.

It should also be noted that the design and build course was coordinated by a full-time member of staff and the feedback from this faculty member was also taken in lieu of answering the research question. The feedback is as follows (which are divided into strengths and opportunities for improvement – OFI's).

From the feedback provided above the following may be summarised.

1. The integration of multiple labs and equipment from differing disciplines together with discussion and rest areas coupled with the diversity of the expertise in one single accessible area is key in producing a meaningful experience. This is in line with the transdisciplinary approach to engineering education where there is a presence of a multitude of stakeholders, developing solutions for a specific engineering challenge.
2. The only downside of the whole experience was

Table 1. Strengths and Opportunities for Improvement – Feedback from Faculty

Strengths	OFI's
The integration of multiple labs in one space facilitates ease for the students to move from one design need to the next if they need to.	The facilities available for prototyping is more limited compared to what is available on campus.
There are also common areas that are suitable for discussions and good spaces for ideation and brainstorming of ideas. Very effective for Design Thinking.	There isn't enough specialist consultants to accommodate the needs of many students at a time.
There are also areas of rest and recreation where users can mingle and relax before beginning their next work session. The entire space is conducive for cultivating good working relationships and a supportive working culture.	I think that the students are only allowed limited usage of the prototyping facilities there. They did not get to do much prototyping while they were there.
The space employs an open workspace concept where everyone including the lab heads and specialists of different fields are sitting together. Anyone can approach anyone with no obvious barriers in position or work status.	

the fact that there wasn't enough of what the student enjoyed! Specifically the facilitators and the facilities.

Based on the results above, it would seem that one of the key strategies in ensuring that the learning experience is maximised when a makerspace is involved would be to embed the makerspace into the curriculum through project-based learning experiences.

Project-based learning is a well-known pedagogy that focuses on "learning by doing" and has a large body of research work behind it that supports its ability in enhancing the student learning experience in an engineering degree. When an engineering undergraduate designs and builds an engineering system, to address a design challenge, this promotes intentional learning and enhances collaborative skills. Many engineering degrees in institutions around the globe already incorporate project-based learning through its project-based modules or subjects – the most well-known type of module is that of a group-based capstone project. Capstone projects are modules or subjects where a group of students, working as a team, design and build an engineering system, using their engineering knowledge and skills to address an engineering challenge. Some engineering schools (or faculties) also have freshman and sophomore design and build experiences (or modules). Most of these modules are assessed primarily through a submitted report, which is quite comprehensive, attempting to cover most areas of the knowledge profiles required of a globally recognized engineering graduate. It should be noted however that almost none of these assessed submissions makes an effort to provide marks for students who utilize specifically designed makerspaces to assist them in designing and building their engineering systems.

The clichéd statement, where it is said that "what gets measured gets done", primarily drives the need of providing marks (the measurement) to students who successfully utilize tools and equipment in a particular manner to achieve the design and build goals. As described in the earlier review and from the results provided in the survey, students and staff enjoy using makerspaces to design and build their prototypes, hence why not provide them with marks when they do so? Granted, there may be operational issues and logistical issues to deal with, depending

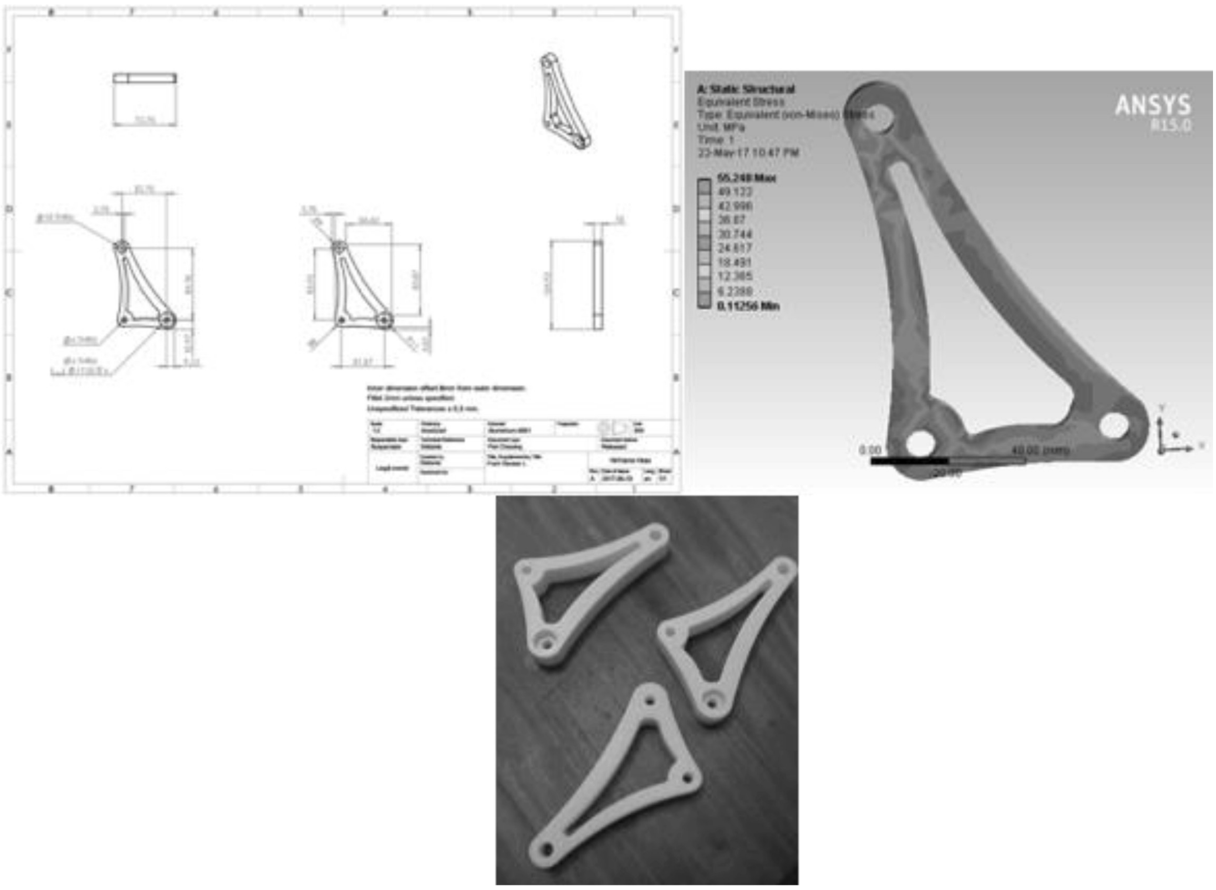

Fig. 2. Prototyped Designs.

on the size of the space and how many students would need to use it, but since many curricula already have design and build experiences embedded within, it would make sense that faculty spend the time and energy to provide assessment based around the makerspaces. Once this is accomplished, the arduous task of monitoring the students and observing whether the space is truly able to enhance learning can take place.

It is therefore hypothesized that makerspaces can be embedded as part of engineering curriculum through the design and build experiences. Assessments may be built around the students being able to utilize the space to perform tasks relating to the experiences – such as weekly team meetings, brainstorming sessions or through utilization of the computers for designing and the 3-D printers for developing prototypes. This has been done successfully is many cases, namely in [17] where students were, as part of their capstone project, required to design and build an engineering system, performed brainstorming, designing and prototyping in different labs or spaces, while such activities could have actually been done in one combined space.

Fig. 2 illustrates different aspects of students work that may be performed in a makerspace, however in this case, it was not as there was no dedicated space available and all of the work was done in separate labs or spaces. Referring to the figure, clockwise from the top, computer-aided design drawings and stress analysis of a designed structure which were accomplished in a computing lab and finally prototyping of the structure in a product design studio using 3-D printers.

Another key observation are how can one allow students to utilize equipment within and occupy the space without the need or presence of a qualified person that would be able to address health and safety issues if a near-miss or injury occurs? This is a question that plagues makerspaces and may in some case cause limitation to the creative process of students who participate in utilizing the space. It is hypothesized that if students have access to a health and safety tool that is easy enough for them to learn from while using it and in turn keeps them safe, this will increase their skills in relation to health and safety.

The most obvious way of ensuring health and safety awareness would be to sufficiently train those who want to use the spaces and provide them with consistent training and updates when necessary. For example, this can be accomplished by organizing a safety and health refresher training for students and staff who utilize the space. While this is commendable, human beings do tend to forget about what was taught and hence the need for a competent person to be present in the space to ensure nothing untoward occurs. However, in the review performed earlier one of the key factors in running a makerspace is to empower the students and allow them to operate the makerspace, effectively making it student-run. If this were to occur how would one, then ensure that students are sufficiently aware of the hazards that are present within the space and what are the risks that may cause injury while using the relevant equipment in the space?

From the review performed, it was noted that many makerspaces only contained lightweight equipment such as laser cutters or 3-D printers that don't require specialist knowledge to operate and maintain. This is a positive in mitigating the risks or hazards that may be present with larger, heavier equipment such as CNC machines, welding areas etc. However, risk of injury is still prevalent, even when precautionary and proactive safety measures are taken by the university management to ensure a safe environment. One way of empowering the students and making them accountable for their safety and wellbeing in a makerspace would be to implement student groups, prior to using the makerspace for the first time to fill in a Job Hazard Analysis or a JHA.

A JHA is a planning activity used by all workers in the industry to increase their awareness of how the work will impact safety and the environment. A plan to identify how risks will be removed or reduced once job hazards have been identified. JHAs are implemented to eliminate job related injuries, increase employee awareness of job safety, promotes safe & environmentally friendly behaviors. Employees must agree to follow the safe work plan by signing the JHA Almost every conceivable task should require a JHA to be done and almost every job has some hazards associated with it, some having more and others less hazardous. For any task where there may be potential for an accident, injury, or property damage, a JHA should be filled out. The process of filling out a JHA must involve all employees in the work crew and supervision when needed. This also includes the workers performing the task. The equipment owner reviews the initial JHA to insure it is filled out properly. All workers involved in the permitted job should be involved with assessing the scope of the job and in identifying any potential hazards that may be encountered before any work begins. A JHA can be summarised into four (4) basic steps as follows.

- Selecting the job to be analyzed.
- Breaking the job down into a sequence of steps.
- Identifying potential hazards.
- Determining preventive measures to overcome these hazards.

The JHA is simple enough to be understood by the lay person and a sample is provided below. Student groups who complete the JHA and gain approval from the relevant competent persons are then able to use the makerspace as long as they carry a soft copy of the JHA along with them to refer to when using differing equipment within the space itself.

4.1 Attributes of a Successful Makerspace

Using the information available throughout this paper, the following describes the key attributes that make a makerspace successful. While the attributes below may not be exhaustive, it represents the findings from the present investigation and therefore may be generalised to be the key attributes that should be present in any makerspace.

Throughout the current study, from the review performed as well as the survey results from the research participants, it may be inferred that an attribute that would ensure a successful makerspace is when one is filled with passionate and qualified facilitators. Such expertise is vital in providing thought provoking questions to would-be designers and entrepreneurs with solutions to design challenges. The presence of such expertise also ensures that those using the makerspace do so in a manner that is meaningful and sets them up for success. Not forgetting that the presence of such expertise would assist students in enhancing their health and safety skills as they would need to be trained to use makerspace equipment.

Another attribute that ensures the longevity of makerspaces is when its utilisation is embedded within the curriculum. The best way to do this would be to couple the utilisation of the space with a project-based module and/or assignment – since students would need the space to design and build an engineering system in such an assignment. It was also noted that students found the seamless integration of multiple labs and equipment coupled with various learning spaces (such as discussion areas, mini-amphitheatres, relaxation areas) incredibly rewarding. The concept of brainstorming a solution with your design team and then being able to walk 3-feet away and prototyping it using a 3-D printer is an attribute worth considering when designing makerspaces.

Finally the presence of integrated labs and learning spaces would require that the makerspace have appropriate flexibility and access to all students who wish to use it. The removal of bureaucratic red tape or territorial mindsets would need to be a thing of the past when embracing the makerspace culture – everyone is a maker. With such attributes executed within a specific makerspace, it will act as a conduit for students who would eventually develop the entrepreneurial mindset and hence encouraging budding start-up's as well as promoting the nature of transdisciplinary education. Transdisciplinary education in particular is a key outcome from makerspaces as they promote the development of solutions with the involvement of a wide array of experts and hence stakeholders.

4.2 Limitations and Areas for Improvement

Although the current study has confirmed the positive attributes of makerspaces, the case study research design as well as the review performed to validate the case study itself can be further enhanced by developing or incorporating other research designs into the overall investigation. In particular, a thematic analysis for the qualitative results can be accomplished. To further enhance the effectiveness of the survey, a reliability and validity analysis may be carried out to ensure the survey/questionnaire has been appropriately evaluated (and is meaningful).

This would add value to the generalization of the result obtained in the current work. The overall sample size of the research participants is less than 100 respondents and no control group exists. Future efforts should be focused on performing a more detailed survey covering a wider array of participants to further validate the survey results obtained. Additional, further work into this area would be to quantify the learning outcome attainment of students who utilized makerspaces as part of their project-based courses. The learning outcome data can then be compared to the learning outcome attainment data from previous cohorts for when makerspaces were not utilized.

5. Conclusion

It is undeniable that the maker movement, which has spawned the utilization of makerspaces to motivate young learners in enhancing their design skills is bearing fruit. At the beginning of this investigation the following research question was posed, how can makerspaces be used to motivate students in such a way that it promotes retention and more importantly, enhances the student learning experience? The investigation was able to infer that makerspaces enhance the students learning experience by providing them access to passionate facilitators, the seamless integration of safe lab facilities, equipment and learning spaces in a flexible manner. This results in them being hungry for more exposure to makerspaces. Makerspaces are suitably motivating for young learners and are able to extract creativity and innovation from the team of people that utilize it.

References

1. M. Tan, Y. Yang and P. Yu, The influence of the maker movement on engineering and technology education, *World Transactions on Engineering and Technology Education (WIETE)*, **14**(1), pp. 89–94, 2016.
2. National Research Council, *The engineer of 2020: visions of engineering in the new century*, The National Academies Press, Washington, D. C., 2004.
3. M. Galaleldin, F. Bouchard, H. Anis and C. Lague, The impact of makerspaces on engineering education, *Proceedings of the Canadian Engineering Education Association*, Dalhousie University June 19–22, 2016.
4. E. J. Van Holm, Makerspaces and contributions to entrepreneurship, *Procedia – Social and Behavioral Sciences*, **195**, pp. 24–31, 2015.
5. J. Moilanen, *Emerging Hackerspaces – Peer-Production Generation*, In: I. Hammouda, B. Lundell, T. Mikkonen, W. Scacchi (eds) Open Source Systems: Long-Term Sustainability (OSS 2012), IFIP Advances in Information and Communication Technology, **378**, Springer, Berlin, Heidelberg.
6. C. R. Forest, R. A. Moore, A. S. Jariwala, B. F. Fasse, J. Linsey, W. Newstetter, P. Ngo and C. Quintero, The invention studio: a university maker space and culture, *Advances in Engineering Education*, **4**(2), pp. 1–32, 2014.
7. A. Wong and H. Partridge, Making as learning: makerspaces in universities, *Australian Academic & Research Libraries*, **47**(3), pp. 143–159, 2016.
8. The Edge Markets, https://www.theedgemarkets.com/article/cover-story-malaysian-maker-revolution, Accessed 29 June 2019.
9. L. Low, J. Ganesan, S. Syazana and L. Wee, *Mapping creative hubs in Malaysia*, British Council, April 2017.
10. Malaysian Communications and Multimedia Commission (MCMC), *Digital lifestyle Malaysia. MyMaker and society initiatives 2017 report*, Digital Lifestyle and Society Department, Technology and Society Division, 2017.
11. Vulcan Post, Is Your Idea The Next Tesla? These 4 M'sian spaces have the tools for you to build it, https://vulcanpost.com/636099/malaysia-makerspaces-innovation/, Accessed on 31 May 2019.
12. Me.reka website, https://mereka.my/, Accessed on 25 May 2019.
13. FabSpace website, https://www.fabspacekl.com/, Accessed on 25 May 2019.
14. Khazanah Research Institute, *The school-to-work transition of young Malaysians*, December 2018, ISBN 978-967-16335-6-4.
15. W. Roldan, J. Hui and E. M. Gerber, University Makerspaces: Opportunities to Support Equitable Participation for Women in Engineering, *The International Journal of Engineering Education*, **34**(2B), pp. 751–768, 2018.
16. G. Amouzad Mahdiraji, E.C.Y. Chung, S. Narayana Namasivayam, M. Hosseini Fouladi, *Engineering Grand Challenges in Scholar Programs*, Springer Nature, Online ISBN: 978-981-13-3579-2, 2019.
17. M.Y. Ze Siin, S. N. Namasivayam, M. Hosseini Fouladi, M. A. Mohd Zali, L. C. Quen and M. C. Hang, Utilisation of the Conceive-Design-Implement-Operate framework in a mechanical engineering capstone project, *International Journal of Mechanical Engineering Education*. https://doi.org/10.1177/0306419018783023, 2018.

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