Makerspace as an Environment to Cultivate the Maker Mindset among Industrial Design Student

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Abstract. One of the most fundamental meanings of being a human being is to make something. Maker movement which originated from the DIY movement as its name suggests is a unique combination of making things from artistry, form making, circuitry and craftsmanship and it is somehow related to the discipline of industrial design where creativity plays a more prominent role alongside with aesthetics, functionality and technological advancement in designing a creative and innovative product. Maker movement has built an extensive network by motivating and sustaining communities of builders, crafters and makers. By celebrating the arts, craft and engineering, it often consists of hobbyist, tinkerer, hacker, designer and artist who build an object or product in a playful and useful way. On the other hands, it reveals a unique set of values which emphasize on open sharing, learning and creativity over profit and also social capital. As a result of that, new ways of teaching and learning has emerged, which is the makerspace learning environment. There is a growing interest of an educator to adapt this kind of learning environment setting upon fostering creativity among students. Maker possesses of what we called a maker mindset which encompassed four aspects which are playful, growth-oriented, failure positive and collaborative. In this review paper, we will present the potential of makerspace as a learning environment that can cultivate the maker mindset for industrial design students and the potential adoption of its methodology to groom the student of industrial design to become more creative and innovative and its challenge. The expected outcome of this paper is to give insights to the reader and industrial design educator about the potential of makerspace learning environment upon cultivating the maker mindsets for industrial design students who are a vital aspect in promoting creativity among industrial design student to face the challenges in the 21st-century design world.

1. Introduction
Making is one of the fundamental activities of a human being. Maker movement as its name suggest came from the maker culture, which has a philosophical significance to the ability of human in creating, constructing and designing artefact [1] while its broad definition range from traditional woodworking, electronic prototyping, digital fabrication has to bring various professionals to join and embrace the spirit of making upon designing a functional device, gadgets and traditional artefact [2].

New prototyping processes that utilize additive manufacturing such as 3D printers, laser cutting machines and computer numerical control machines (CNC) proliferates in recent years. The
emergence of low-cost microcontrollers and microprocessors such as Arduino and Raspberry pi which utilizing open-source hardware and software concede new physical space for teaching and learning, which are referred to as "Makerspaces"[3].

Sharing is one of the main properties which built maker movement stronger and disseminating manifesto through sharing and development of a vast project collection and ideas repositories. As a result of the maker movement activities ranging from D.I.Y hobby making and sharing resulting in the making of the dedicated physical space known as makerspace. Makerspace originated from the development of M.I.T fab lab. A recent report from NESTA shown that makerspace has changed China from manufacturing country into the innovating country by integrating makerspace into its design and development ecosystem [4]. As the foundation of makerspace and maker education are stronger, there are lack of literature which give the reader some insight into this kind of teaching and learning environment and its sustainability ecosystem of design. This review paper will present some insight upon fostering students creativity by promoting maker mindset into industrial design students by promoting a makerspace learning environment and how the ecosystem of the maker movement is sustainable in the world of design.

2. Challenge of 21st century teaching and learning
As the fourth industrial revolution (4IR) progress with its robust technological advancement, there is a need to update and strategize teaching and learning, especially in higher design education. The Internet is an ideal tool for stimulating study [5]. It will also question us on how far did we prepare the undergraduates students upon achieving necessary skills demanded in the 21st-century design world.

Larson and Miller [6] highlighted that communication, collaboration and expertise in technology will be essential skills for 21st-century education whereas Trilling and Fadel [7] proposed the 7C skills which are:

1. Critical thinking and problem solving
2. Creativity and innovation
3. Cross-cultural understanding,
4. Communication, information and media literacy
5. Computing and ICT literacy
6. Career and learning self-reliance

There is a need for such skills mentioned above to be fostered in a conducive environment. The rapid change in how the artefact is designed and developed is imminent. There is a pressing need for the curriculum in higher design education to be redesigned to cater the student's need in vast rapid and emerging areas of STEM. One of the best candidates for redesigning teaching and learning in the area of design education originated from the maker movement, which contributed and drove the establishment of physical space called makerspace.

3. The maker manifesto and the maker mindset
Creativity is essential in 21st-century skills, and one of the factors contributing to creativity is the mindset [8]. Maker manifesto consist of 9 crucial pillars in the world of making which are make, share, give, learn, tool up, play, participate, support and change [9]. Cohen et al. [10] found that maker mindset consists of 5 crucial constructs which are resilience, growth mindset, creativity, willingness to tinker and collaboration orientation. Dweck [11] believe that changing students mindset significantly improve students performance.

3.1. Playfulness
Play is a complex construct that many studies have shown that it is a fundamental activity in the formation and development of children and adults [2, 12] argues that adult playfulness contributes to breaking old rules, relaxation of the employee and increasing creative performance among employees at the same time bringing fun into the workplace. It is spontaneous, expressive, funny and indulgence attitude that can increase job satisfaction and bringing positive moods whereas creativity. In addition
to that, playfulness in a group helps to build a joyful and relaxing atmosphere between individuals and team members [12].

It is also the primary purpose of learning of an individual with two essential elements of fun and interest. The above statement is very different from situations involving most hands-on class activities or problem-based learning activities where the primary purpose is set from the beginning. The ability to do work in external constraints is a vital skill in the career of a designer, but it is not always the ideal starting point for creating interest and excitement for a beginner or a student [2].

A conducive environment of fun and playful has many advantages in learning, including rigour, in dealing with challenges [13]. Besides, the environment promotes a wide range of experiments and experiences that are a prerequisite for developing and developing specific conceptual knowledge and adaptation to a skill [13].

3.2. Growth-oriented
Dougherty explains that a growth mindset is a mindset that encourages students to believe that they can learn anything [14]. Individuals who see intelligence as a fixed entity are a weak thinking strategy in learning, for example, avoiding the challenges that may lead to failure. However, individuals who think that intelligence is like a muscle developed by exercise activities emphasize adaptive learning that leads to acceptance of challenges. The development of such a mindset is more firmly based on failure because failure is interpreted as an indicator that more effort is needed than to consider it as an indicator of escape from problems or challenges [15].

3.3. Failure positive
Failure is not the right word to hear in the field of education, especially when it comes to institutions, students or administrators. However, according to the perspective and mindset of the creator, failure is celebrated [2]. Adam Savage, an individual involved in the Mythbuster television program, argues that the importance of failure in the process of creativity and the formation of one's personality and professionalism [16]. In general, the process of overcoming and adapting to various barriers is crucial in developing skills that adapt to expertise [17].

3.4. Collaboration
Collaboration elements include the sharing and collaboration between members within the makerspace, whether physical or virtual. However, this does not mean that in most projects, the creator engages in a team working together to achieve the same goal. Instead, these thoughts are more about sharing ideas, projects, and helping each other. Through the concept of Zone of proximal development derived from a constructivist theory which states that there is a stage where students should be helped through the scaffolding, which includes social reactions among the involved members. The concept of "scaffolding" is central in teaching and learning based on constructivist theory. Scaffolding is the cognitive support provided by lecturers to students to help them complete tasks that they cannot complete [18]. This concept of 'scaffolding' is closely related to Vygotsky's concept of the Zone of Proximal Development (ZPD). Vygotsky argues that ZPD is the distance between the ability to solve problems or tasks independently and the need for support in solving problems or tasks with the guidance of teachers, coaches and through collaboration with more capable peers or [19] in the context of makerspace it refers to interactions in the virtual world (social media). What Vygotsky is referring to is the study of scaffolding that has "asymmetric" interaction values, which means individual interactions with different values or levels of understanding and abilities. However, some researchers suggest an "asymmetric" interaction to the contrary. They argue that Learning also occurs in collaboration with students who share the same conceptual understanding. That is, learning and development of knowledge may also be due to 'symmetry' interactions [20]. Makerspace opens up this space for social interaction through a highly collaborative approach in fostering the same thinking that previous researchers have suggested [2, 14]. Although not everyone who does something shares their knowledge or creations, the existence of a large online community shows that many have done so [21].
From 5 notable construct mention above, an educator has to design activities in the makerspace teaching and learning environment to stimulate and change one's mindset to become maker mindset as to comply with the current 21st-century teaching and learning needs.

4. Makerspace: A space to learn and collaborate

Influence heavily by the constructivist and constructionism learning theory [22] and act as a conducive environment for project-based learning and experiential learning, makerspace provide a physical space for exploration, tinkering, idea generation and experimentation. Makerspace is a physical space dedicated to making artefact with tools and material for easy access, fast prototyping, testing and idea development of the design solution.

There are four types of makerspace according to Vuorikari et al. [23] which are making as learning space and making as a community as show in figure 1. This two type of making falls into the direction of makerspace whereas the other two types of making which are making as a methodology and making as a life skill falls into the direction of maker program. This paper focus on the making as a learning space which falls into the category of makerspace and intentional learning as proposed by Vuorikari et al. [23] and divided by the four quadrants as the upper part of the quadrant represent the intentional learning as intended when designing a curriculum for higher education.

![Figure 1. The makerspace four-quadrant [23].](image)

Frye et al. [24] proposed that the increasingly blurred differences between industrial design discipline and engineering design demand for a newly adapted teaching and learning model such as makerspace as the technological advancement and rapid change of cost, speed and material will influence the design process and also design education. Studies conducted by Abdulrahman [25] found that makerspace could be used in fostering student's creative thinking, critical thinking skills and problem-solving skills in physics by promoting and utilizing higher-order thinking skills. Schaefer et al. [26] found that an academic makerspace which focusing on design activities has a positive effect on improving student's design skills.

The core activities in makerspace aside form discussion and design critique among members is taken advantages of two significant technological advancements which are digital fabrication and electronic prototyping.
4.1. Digital fabrication and computer-aided education
Toward the end of the 2000s, Educators has begun to utilize digital fabrication in education. Around 2011 to 2012, museums, schools, community centres, and libraries announced plans to build digital fabrication and making facilities to became mainstream. Despite this resurgence of manufacturing labs and making in formal or informal settings, the ideas behind this development are nothing new. Digital fabrication itself stands from the three pedagogical pillars, which are experiential education, constructionism and critical pedagogy. Digital fabrication plays an essential role in catalyzing the maker movement. Recent studies show that the implementation of makerspace with activities such as 3D printing and the usage of CAD software such as SOLIDWORKS speed up the learning process [27]. Nevertheless, without proper computer-aided education, digital fabrication is only a tool. The main recipe is to strengthen computer-aided education as it will result in maximizing the full potential of digital fabrication.

4.2. Electronic prototyping and programming
Current industrial goods trend which integrates system or platform demand for an industrial designer to have an adequate understanding and skills ranging from electronics to computer science [24]. As the demand for an original product and system required the industrial designer to have adequate skills in programming, robotics and electronic, being able to integrate design solution with intelligent behaviour is a crucial skill for 21st century’s industrial designer [28].

The inclusivity of this new skills such as programming, electronic and robotics as opposed to the traditional norm of industrial design curriculum demand for tailoring the curriculum which introduces the students into new skills which permits the exploration of students creativity into new areas and possibilities. In addition to that, Experimental construction and prototyping can help the students to turn scratch ideas into a workable and feasible design solution.

5. The emergence of D.I.Y internet source
The internet has become the repositories and home for a new media ecology which is complex, flexible and self-organising [29]. Among the immense contribution of the D.I.Y community is the development of web-based project repositories ranging from audio and visual instruction, coding, material list into "how to". Open-source software and hardware help to strengthen D.I.Y community by supplying materials, tools and online platform.

Figure 2 shows the continuum of resource in exemplifying stuff, sharing and connection. Gerstein [31] proposed that education is now shifting from education 2.0 to education 3.0. Education 2.0 comprises of an andragogical and more constructivist learning approach compared to education 1.0 which classified as an essentialism or instructivism teaching and learning philosophical orientation. Gerstein summarized that the philosophy is shifting from pedagogy through andragogy and it is moving towards heutagogy and connectivism. It is the connectivism philosophy which drives the dissemination of ideas, innovation and invention through the web-based knowledge repositories such as Instructables, Pinterest, youtube and other kinds of mass media which act as a knowledge repositories as the students will act as a creator, user-led innovators, constructivist and connector.
6. Conclusion

Throughout this paper, we have highlighted the importance of makerspace as the physical space that can be utilised by the students to stimulate new ideas and in-situ tools and materials for fast prototyping, testing and collaboration. The process of documenting and disseminating information on the artefact is a sustainable process that enhances the ideas and solution repository to be used by other students who embrace the spirit of D.I.Y movement and the maker mindset which in turn strengthens relevant domain in learning according to Bloom's taxonomy which is cognitive, psychomotor and affective. D.I.Y websites also act as a repository of ideas, resources and know-how for students to explore various possibilities for design solution and ideas, in the long run, can act as a design stimulus for ideas generation for students in completing assignment and project following the project-based learning methodology. The role of lecturer/facilitator in managing problem-based learning in the makerspace environment demands a proper and details tailoring of students activities upon fostering students creativity and maker mindsets through makerspace environment. Through various interaction of students in the sustainable design ecosystem explained before, we hope that we can foster creativity by changing the student's mindset into maker mindset through the makerspace learning environment.

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References

[1] Howard C, Gerosa A, Mejuto M C and Giannella G 2014 The Maker Movement: a new avenue for competition in the EU Eur. View 13 333–40
[2] Martin L 2015 The promise of the maker movement for education J. Pre-College Eng. Educ. Res. 5 4
[3] Farritor S 2017 University-Based Makerspaces: A Source of Innovation Technol. Innov. 19 389–95
[4] Saunders T and Kingsley J 2016 Made in China. Makerspaces and the search for mass innovation Nesta
[5] Daud K A M, Rahman M B A and Samsudin M A 2013 E-Solms: Kajian tentang tahap pembelajaran terarah melalui sistem pengurusan pembelajaran berorientasikan pelajar TENIAT J. Antarabangsa” Creat. Futur. dan Waris. 1 179–91
[6] Larson L C and Miller T N 2011 21st century skills: Prepare students for the future Kappa Delta Pi Rec. 47 121–3
[7] Fadel C and Trilling B 2010 21st Century Skills: Learning for Life in Our Times. Educ. Rev.
[8] Sternberg R J 2006 The nature of creativity Creat. Res. J. 18 87
[9] Hatch M 2013 *The maker movement manifesto: Rules for innovation in the new world of crafters, hackers, and tinkerers* (McGraw Hill Professional)

[10] Cohen J, Margulieux L E, Renken M, Smith S F and Jones W M 2018 Measuring Maker Mindset: Establishing Content Validity with Card Sorting (International Society of the Learning Sciences, Inc.[ISLS]).

[11] Dweck C 2015 Carol Dweck revisits the growth mindset *Educ. Week* 35 20–4

[12] Yu P 2004 Enjoy fun at work: An explorative study of organizational playfulness *Kaohsiung Norm. Univ. J* 6 19–37

[13] Vansteenkiste M, Simons J, Lens W, Sheldon K M and Deci E L 2004 Motivating learning, performance, and persistence: the synergistic effects of intrinsic goal contents and autonomy-supportive contexts. *J. Pers. Soc. Psychol.* 87 246

[14] Dougherty D 2016 *Free to make: How the maker movement is changing our schools, our jobs, and our minds* (North Atlantic Books)

[15] Dweck C 2000 Self-theories: Their role in motivation, personality, and development

[16] Branwyn G 2009 Adam Savage, at Maker Faire, talking on the importance of failure

[17] Chi M T H 2011 Theoretical perspectives, methodological approaches, and trends in the study of expertise *Expertise in mathematics instruction* (Springer) pp 17–39

[18] Bruner J 1978 The role of dialogue in language acquisition *child’s Concept. Lang.* 241–56

[19] Vygotsky L S 1980 *Mind in society: The development of higher psychological processes* (Harvard university press)

[20] Littleton K and Light P 1999 *Learning with computers: Analysing productive interaction* (Psychology Press)

[21] Kuznetsov S and Paulos E 2010 Rise of the expert amateur: DIY projects, communities, and cultures *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries* pp 295–304

[22] Kurti R S, Kurti D L and Fleming L 2014 The philosophy of educational makerspaces part 1 of making an educational makerspace *Teach. Libr.* 41 8

[23] Vuorikari R, Ferrari A and Punie Y 2019 *Makerspaces for Education and Training: Exploring future implications for Europe* (Joint Research Centre (Seville site))

[24] Gärtner F, Pietzsch M and Frye A 2017 Interferences of industrial design and engineering in future design education *DS 88: Proceedings of the 19th International Conference on Engineering and Product Design Education (E&PDE17). Building Community: Design Education for a Sustainable Future, Oslo, Norway, 7 & 8 September 2017* pp 152–7

[25] Abdurrahman A 2019 Developing STEM Learning Makerspace for Fostering Student’s 21st Century Skills in The Fourth Industrial Revolution Era *Journal of Physics: Conference Series* vol 1155 (IOP Publishing) pp 1–6

[26] Schaefer D, Coates G and Eckert C 2019 *Design Education Today: Technical Contexts, Programs and Best Practices* (Springer)

[27] Khalifa S and Brahim T 2017 Makerspace: A novel approach to creative learning 2017 *Learning and Technology Conference (L&T)-The MakerSpace: from Imagining to Making!* (IEEE) pp 43–8

[28] Alers S and Hu J 2009 Admooe: A robotic platform for teaching creative programming to designers *International Conference on Technologies for E-Learning and Digital Entertainment* (Springer) pp 410–21

[29] Sharp D 2006 Participatory cultural production and the DIY internet: from theory to practice and back again *Media Int. Aust. Inc. Cult. Policy* 118 16–24

[30] Patton R M and Knochel A D 2017 Meaningful makers: Stuff, sharing, and connection in STEAM curriculum *Art Educ.* 70 36–43

[31] Gerstein J 2014 Moving from education 1.0 through education 2.0 towards education 3.0