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FOSTERING LEARNING COMMUNITIES THROUGH STUDENT-LED PROTOTYPING WORKSPACES

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ABSTRACT
Makerspaces or Hackerspaces are initiatives designed to bring together like-minded individuals, integrating with the wider community and across disciplines within educational establishments. This paper focuses on well-known academic makerspaces and initiatives in the UK, such as the Imperial College Advanced Hackspace (ICAH), and compares their approach with that of US equivalents, most notably the Invention Studio at Georgia Institute of Technology. With high demand on workshop space, prototyping and machine tools, as well as limitations on staff time and technical support in institutions, this paper investigates the benefits and challenges of implementing an accessible, student-led workspace initiative in a UK higher-education institution by comparing the hack/makerspace ideology and approaches between UK institutions and that of their US counterparts. The definition of a hackspace as well as socio-cultural and academic differences are explored. The paper concludes that, whilst there are benefits for both students, staff and the institution, there are notable differences in approach between the UK and US. Issues surrounding supervision and safety may require mitigation. New and expanding UK academic hackspaces (such as the ICAH) and, in particular Mechanical Engineering students, could benefit from the socially driven, bottom up management approach as seen in the US.

Keywords: Community learning, Peer learning, Fablab, Hackspace , Makerspace, Prototyping.

1 INTRODUCTION

A highlight of any Mechanical Engineering or Design programme is getting the opportunity to make things. Formula Student and Shell Eco-Marathon are reputable examples of students working together to design, build and test a race vehicle, but it seems that new generations of city dwelling students are now more familiar with maintaining bicycles and tinkering with electronics than building a racing car (Stanford University offers a bicycle frame design and fabrication technical elective) [1]. A reflection of these changes can be seen with 2nd year Mechanical Engineering students at Imperial College London who design, manufacture and race an e-scooter prototype; the context being that it offers a quick means of commuting onto campus. Despite the modern connection the task still uses traditional knowledge of machine component design, for example motors, bearings, shafts and transmission elements [2]. First year students also learn principles of the Bernoulli equation by making their own hovercraft vehicle, which culminates in a fun and engaging challenge [3]. Adapting to a new generation of student engineers is not only limited to project work, but also technology and learning spaces. Digital fabrication is becoming more commonplace in curriculums with Design-Make-Test projects [4]. Libraries are being used more as sociable learning and study spaces, with less emphasis on books. The Georgia Tech library has removed 95% of its physical collection using the Library Service Centre [5] to create more collaborative space. In 2012, the DeLaMere Science and Engineering Library at the Mackay School of Mines Building, University of Nevada became one of the first US academic libraries to offer 3D printing to its students [6]. Therefore it is important that the design and engineering students of today, are tasked with relevant, creative and challenging project activities whilst retaining core academic rigour and learning outcomes. New facilities and technologies give the graduates of tomorrow transferable skills for a rapidly changing industry. This paper aims to explore how students could be engaged and empowered to work on challenging, creative and high tech projects whilst establishing a sense of community through the use of academic hack/makerspaces.

2 FABLABS & MAKER/HACK SPACES VS TRADITIONAL WORKSHOPS

A 'Makerspace' can be defined as "*a physical location where people gather to share resources and knowledge, work on projects, network, and build*" [7]. They are regarded as community learning environments for experimentation and prototyping, where users can seek advice from experts as well as each other; their origins were non-academic in nature, with membership structures and engagement with the public and local communities. They typify millennial generation hacker culture and the maker movement, with conception credited mostly to MIT's first digital fabrication lab in 2002 [8]. However, the definition of a 'Fablab' is that it focuses more on digital fabrication, personal manufacturing technologies and the creation of a space where users can '*make (almost) anything'* [9]. Despite both using digital fabrication such as 3D printing, one can argue that Maker/Hack Spaces and Fablabs are ideologically different; with Maker/Hack Spaces focusing more on people, and a broader sense of community based learning. Fablabs tend to focus more on offering a broad selection of manufacturing technologies, pushing faster and more democratized personal fabrication. At Imperial College London, Mechanical Engineering student's benefit from a highly practical introduction to design and manufacturing, which integrates sketching, design process, engineering drawing and CAD modelling together with workshop skills. The students utilize the well-equipped and staff supervised Student Teaching Workshop (STW) and undergo a course in how to operate lathes, milling machines, CNC machines and other traditional metal and plastic fabrication techniques. The STW and its equipment are managed, maintained and supervised by technical staff. The IDEAS lab is more suited to craft projects, assembly and storage of project work as well as offering a brainstorming and idea generation space-as part of a wider network of facilities on campus. There is access to bandsaws, pillar drills, vac forming, resin moulding and sanders as well as some rapid prototyping machinery in the form of laser-cutting and 3D printing. The IDEAS lab is mostly unsupervised in which access to the mains power is turned off and only hand and cordless tools are permitted for use. The STW at Imperial College London is a source of praise, as is many practical workshops in other design and engineering institutions, such as Bournemouth University. The teaching and application of practical work with traditional manufacturing techniques are still relevant to students expectations as well as industry needs (e.g. Apple and Dyson) despite the influx of computer based technology and rapid prototyping [10]. As of April 2015, there were 97 Makerspaces recognized in the UK. Of a sample of 87 Makerspaces, 73% offered digital fabrication tools. 60% offered general hand tools and electronics, with 57% offering woodwork [11]. The IDEAS lab is recognized as a hackspace; students can come and go when they please and work on projects. It focuses on digital fabrication technology, woodwork and hand tools like the majority of makespaces-and health and safety issues arising from the use of metalwork and machining are mitigated by also having the STW which is supervised by experienced technical staff [10]. Equipment aside, a maker or hackspace focuses on community based peer learning, the key is to investigate how this can be instilled, integrated and managed in an academic environment-and if it meets the students expectations of what a design and engineering course should entail as well as being relevant for industry. Blikstein and Krannich describe Digital Fabrication workshops as 'the re-intellectualization of the shop class' [8]. How a makerspace or hackspace is perceived by students and academic staff is also important. In Nov 2014, the top reasons why people used makerspaces in the UK was to socialize (41%), learn (35%) and make (33%). 58% had some form of social area. Of the aspects of learning the majority of makerspaces (79%) offer informal help, with 68% offering formal training or classes. Therefore the ideology of hackspaces are at odds to formal, traditional workshops, in which the purpose is to be trained or learn on machines for manufacturing and making. Hackspaces aspire to offer more than that, a more relaxed socially driven space for a community to come together and learn informally from each other. There are currently plans to redevelop the scope of the IDEAS lab for the ICAH Mechanical Engineering hub and improve student engagement and use of facilities, which forms part of the investigative basis of this paper.

3 COMPARISONS OF MAKER/HACKSPACES IN ACADEMIA

The following section describes some notable and well documented examples of established academic hackspaces and makerspaces in UK and the US Invention Studio as a comparison of a different approach. It is not a broad study (and excludes Fablabs and non-academic hackspaces) but attempts to look at the inner workings and philosophy of a well-established UK sample to compare with US institutions (see Fig 1).

Figure 1. Academic hack/makerspaces (Top left) Map of ICAH, (Top right) Dyson Centre for Engineering Design, (Bottom left) Institute of Making (Bottom right) Invention Studio

3.1 Imperial College Advanced Hackspace (ICAH)-distributed innovation & incubation

Launched in 2014, the ICAH has grown to almost 1800 members [12]. The hackspace is open to all students and staff at Imperial College London who wish to become members, but not the general public or visitors currently. ICAH membership is subject to health and safety procedures as well as inductions for certain facilities, following terms, conditions and house rules; a breach of which can result in termination of membership and use of facilities [13]. The ICAH offers a diverse range of facilities including digital manufacturing, electronics and robotics, labs for medical research and biochemistry. The IDEAS lab is included in the hackspace as part of a distributed network of facilities around campus. The facilities are not located in one large departmental space, and inclusive use by the wider academic community is promoted. The ICAH is a more inward facing with a prototyping focus, designed for academic and incubator/start-up projects. Members can book access and receive inductions to 3D printers, desktop CNC machines, laser printers and vinyl cutters-as well as advice from hackspace fellows, ‘hackers in residence’, technicians, students and staff. Although most facilities are free to use, members can pay for additional consumables online or by donation. Although there is no evident social or peer learning element to the ICAH at the moment, there are currently plans to expand with an additional 6500 sq.ft of facilities at White City including an outreach maker space and large hackathon events.

3.2 Dyson Centre for Engineering Design-bringing students together

Launched in 2016, the Dyson Centre for Engineering Design is described as “*a modern workspace where engineering students can come together outside of the classroom to think, experiment, design, build and exchange ideas.”* [14]. Located at the University of Cambridge, the centre (at approx. 6000sq.ft) offers a broad range of facilities, such as 3D printing, laser-cutting, lathes, mills, benching and handtools, CNC machines, metalworking, plastic forming and a PC lab. The centre’s primary use is focused on engineering undergraduates, and participation in student clubs and societies is encouraged (including a 3D printing club). Students can work on personal projects, and there is outreach participation. Consumables are handled via forms and cash payments. Membership of the centre is not required, and it is governed through relevant health and safety forms and records. There is a centre manager, and supervision by trained staff and technicians. The use of 3D printers is open, but the use of laser-cutters and other equipment is supervised. The centre embodies the community and social elements of a hackspace, but there is no evidence that students have any involvement as members of the space or peer learning. Nonetheless, the centre is outward facing, encouraging creativity and tinkering, despite not acknowledging itself as any form of maker/hackspace.

3.3 Institute of Making-a well-established exemplar

The Institute of Making at University College London (UCL) opened in 2013, with membership open to all students and staff at the institution [15]. It offers typical makerspace facilities like 3D printing, scanning and lasercutting, workshop equipment and electronics but also pottery wheels and a kiln for ceramics and a sewing machine for textiles. The makerspace also has links to interdisciplinary materials research and boasts an extensive materials library, which acts as an opening to the open plan workshop-the prominent position and shutter doors allowing access to and from the street.. Induction is required to gain secure access to the space and facilities; with specific inductions for 3D printers and laser-cutters as well as one-to-one technical support (from members wearing red t-shirts) for machines like CNC's and lathes. Materials and consumables are not offered by the makerspace, and members are encouraged to purchase and bring their own. Despite its interdisciplinary nature, after 1 year of opening, it was found that 78% of its 2616 members were students and the most use of its facilities came from the engineering faculty (39%) [16]. Nonetheless, the Institute of Making has a very outward facing approach, with extensive public engagement and inclusive events and activities. Whilst it offers creativity and tinkering, it does have a more serious side with research projects associated with organizations such as the Engineering and Physical Sciences Research Council (EPSRC).

3.4 The Invention Studio-a student led approach

The Invention Studio [16], based at The Georgia Institute of Technology (Georgia Tech) was initially founded in 2009 and follows the principles of student ownership, freedom and safety. As of 2013, the space grew to 3000sq.ft with 1000 student users per month. The Invention Studio is divided into five different rooms specializing in rapid prototyping, wood, plastic and metal working, CNC machine tools, mock-up, assembly and testing. The spaces are located alongside other more traditional machine shop, lab and classroom areas, and is open to all staff and students on campus. The Invention studio is unique as an academic hackspace as it adopts a 'bottom-up' rather than a 'top-down' management and supervision approach. The student Makers Club 'own' and 'run' the space, and academic and technical support is peripheral, to the point that the facility could not run at all without student support. Some time is split between staff to support different aspects of the space, the most being 50% of allocated time for a technician to repair complex tools and 20% for workshop technician to perform training on complex machinery. Most of the student supervision and teaching support was driven by Undergraduate Lab Instructors (ULI's), which allows the makerspace to be constantly 'staffed' and 3-5 ULI's on duty at any given time. The ULI's are identified by distinct armbands, which also dictate experience and equipment training. Students who do not heed to the house rules or health and safety protocols are dealt with via peer-pressure and access to the space terminated (it is regarded as a privilege, not a right). A recent paper in 2016 [17] establishes that almost 70% of Prototyping Instructors (PI's-formerly ULI's) are Mechanical Engineering students, and that with a robust training program in place from 2014, recordable work-related injuries decreased. In 2014, a survey suggests that over 80% of alumni used the Invention studio for class related activities, with over 60% for personal projects. 60% of time spent in the studio was for creating, with 10-20% of time allocated for social activities, meetings and mentoring. Although social meeting space was deemed important, this aspect gained the least responses compared to more practical attributes such as provision of prototyping technologies and the attainment of career-specific skills. Although the Invention Studio does not seem to have a clear membership policy, it does exhibit the outward facing philosophy of a hackspace; but with the added benefit that students play a key part in how the space is run, supervised and managed. The students teach each other and learn from each other in an enabled and empowered peer-supported environment. Georgia Tech is not alone with this approach, the MIT Makerworkshop has a similar peer mentors supporting other students with workshop activities [18] and a distinct community driven approach [19]. The facilities at both institutions are supported and used by mostly Mechanical Engineering students.

4 DISCUSSION

Looking back at the examples of UK and US Maker/Hackspaces in academia, one can compare each based on specific attributes, to highlight the notable differences of approach as well as some similarities:

4.1 Space and Layout

In the UK, the Dyson Centre for Engineering Design is one of the largest single spaces (although the ICAH is planning to expand to a similar size). The ICAH offers a distributed network of smaller, efficient spaces and specialization. The approach is similar to the Invention Studio in the US which grew from 1600 sq.ft in 2010, to 3000sq.ft in 2013 (the average UK makerspace is approx. 2250sq.ft).

4.2 Use of equipment and tools

All of the UK hackspaces offer digital fabrication. Due to frequency and demand, this technology is becoming more democratized with less-restricted use of 3D printing and laser-cutting. There is no evidence in the UK of lathes or CNC machines being used in an un-trained or un-supervised manner. The US approach with the Invention Studio is unique in this regard as use of water jet cutting is permitted through support by PI's and videos. The empowerment of students to use equipment themselves allows better allocation of time from technical staff.

4.3 Cost of materials and consumables

The UK's ICAH and Dyson Centre of Engineering Design adopt a policy of paying for material (e.g. 3D prints) using online payment, cash and forms, whereas the Institute of Making encourage members to purchase their own material to bring to the makerspace. The Invention studio approach is a little more pragmatic, offering 3D prints to student projects for free and charging for research projects.

4.4 Membership, Access and Inductions

The UK approach to membership and induction is quite formal and facilities like The Dyson Centre of Engineering Design rely on safety forms and training records. The US approach at the Invention studio is that training is governed by student PI's. A common element across the UK and US spaces is that they have clear opening and closing times and that none of the spaces are used for formal teaching. The Invention Studio is open and inviting environment, which is similar to the Institute of Making.

4.5 Rules, Health & Safety and Supervision

The ICAH has clear membership rules and H&S policies in place; and ICAH staff supervise the space. Academic and technical staff supervise both the Dyson Centre and Institute of Making, but the Invention studio inverts this 'top-down' model for a 'bottom-up' student led approach-using PI's to guide, train and support the activities of other students in the space.

4.6 Teaching support, staff and overheads

All the UK spaces have, in some form, dedicated staff and technical support. Support staff at the Institute of Making are clearly identifiable with red shirts, and student PI's at the invention studio can be identified by armbands. This makes experienced members visibly clear and approachable. In the US, The Invention Studio is of particular interest as there are no full-time academic and technical staff, and yet the makerspace is constantly supported, supervised and maintained by student PI's.

4.7 Diversity, Accessibility and Inclusivity

In the UK, the ICAH is currently only open to students and staff (which will broaden at White City). The Institute of Making also engages in research activity as well as public engagement and outreach. In comparison, The Dyson Centre for Engineering restricts access to engineering students only. There are similarities in the US; The Invention studio is open to all students and staff on the campus but the MIT Makerworkshop currently limits access to Mechanical Engineering students. Diversity and gender are outside the scope of this paper and will be considered in future study.

4.8 Management, funding and growth

The Dyson Centre of Engineering Design and Institute of Making represent a significant amount of capital investment from external sources as well as refurbished space. The ICAH makes use of existing small spaces and facilities, until it expands with additional funding. It is similar to the US approach seen in The Invention Studio; which was initially formed by a handful of students and grew organically, with funding coming in via industry sponsors. The Invention Studio has a 5-6 year lead on ICAH and Cambridge, and is likely to have more experience growing and adapting its hackspace model (although The Institute of Making started life at Kings College London in 2010)

5 CONCLUSION

UK academic makerspaces, inspired by the US, could provide an enhanced sense of community with an engaging peer-to-peer learning environment. With correct protocols in place, a student led makerspace can be safely supervised and run without the dedicated time of staff. Despite different pedagogical approaches, the significance of such initiatives is widely discussed among US institutions [20]. Through informal learning, there are practical and social elements for project work and developing new skills. UK institutions can be assured that engineering workshops are still of value; and a student led makerspace could be a welcome addition to existing facilities. By empowering students, a UK makerspace could benefit, particularly in the field of Mechanical Engineering.

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