Space Driven Educational Innovation

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Conference Key Areas: How Learning space support innovative T&L, Innovation as the context for EE

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INTRODUCTION

In days long past, before the implementation of the scientific methods in engineering education, there was a lot of "shop work" in education. The implementation of the scientific methods, such analysis and mathematics resulted in a loss of building and designing in engineering programmes [2], [3]. In the 90's, however, under the influence of constructivist learning and student centeredness it was suggested by both industry and students, particularly in engineering, but also in general, that students should have more hands-on experiences [1]. In "The Engineer of 2020", it recognizes that creating, inventing, and cross disciplinary fertilization are essential skills for engineers [4b]. The National Research Council [4a] in education in the USA felt that the pace of skills learning was not fast enough and did not result in the required fluency to solve problems in a labour market setting with the technological developments and democratisation of production technology in mind [1]. It was felt learning to prototype and creating social communities in which learning could flourish, would be essential to bring learning up to speed with 21st- Century developments [3].

The Michigan Institute of Technology (MIT), Media lab was the first to establish maker spaces within higher engineering education. They created Fablabs around the US, with equipment for participants to tinker and engineer their "product" solutions. It became a huge success resulting in a network of over a 1000 fabrication spaces throughout more than 78 Countries [6]. These spaces span different and multiple disciplines as they are housed in colleges of architecture, design, engineering, and general university and community settings [7]. The developments from the first Fablabs to the exponential growth of learning/makers space is taking place much more rapidly.

Universities started to create libraries spaces, learning or design factories, innovation spaces and maker spaces. Each of the spaces had a slightly different purpose. The common denominator is that these are spaces in which students can (1) run and try their own projects, while (2) having expensive equipment available (machine driven locations), (3) the opportunity to meet, (4) co-participate and (5) ask guidance from academia and industry in the spaces available [8]. In Engineering terms Keppel [9] defines a space as 'spaces where both teachers, professional experts and learners optimise the perceived and actual affordances of the space.' These academic oriented spaces are mostly non-accessible for members outside their own community[3]

1 PROBLEM DEFINITION

Having a long tradition of design labs not embedded in the curriculum, the wish to embed maker activities into the curriculum, is a growing wish of the 4 technical Universities in the Netherlands Eindhoven University of Technology (TU/e), University of Twente (UT), Delft University of Technology (TU-D), and Wageningen University (WUR).

This informal investigation at TU/e, UT and TU-D was used to obtain an overview of the ongoing activities and concerns at our institutions. The investigative question we worked with is: "What key projects are currently running? and Which concerns need to be addressed to use design spaces for "curriculum" learning?

> "*Which questions need to be answered or researched to create or design effective spaces combining both the aspiration of hands on and curriculum learning, preparing our students with, amongst others, creative skills beyond the regular curriculum?"*

This question is not as simple as is presumed. To begin with it is not so clear how we should coin maker or learning spaces in our institutions. What type of spaces do we aim for? Which learning experiences are already in the curriculum or learning environment that might also be classified amongst "maker space like activities", but are presently not identified as such?

To gather data, around 10 key-stakeholders of the maker spaces in UT, TU-D and TU/e have been approached via e-mail, informally and occasionally via follow up phone calls. Addressing the following questions; What projects are currently ongoing and what are the project goals? Which concerns / questions are currently addressed in the projects?

In the analysis we decided to focus on initiatives that have their grounds in constructivist educational approaches to learning and have the aim to strengthen the link to the real world and innovation. Blikstein [2] and Libow Martinez & Stager [10] identify the educational philosophies of Dewey, Freire and Papert to be the driving forces, for the maker spaces phenomenon:

- J. Dewey stated that experiential learning should be connected to real world objects.
- P. Freire stated engagement with meaningful problems is a precondition for exploring possible solutions and finding viable new solutions to become empowered and learn.
- S. Papert states that construction taking place in the head improves and is supported, when also constructed in the world, supporting constructionist learning and knowledge creation, while strengthening learning, building and sharing objects and experiences about topics of enthusiasm and passion.

The key characteristics of "spaces" derived from this constructionist view within education seem to be:

- Meaningful real world challenge based problems,
- Experiential learning
- Construction of knowledge and creation of objects (affordances) in the world
- Intrinsic motivation
- Sharing

These characteristics were used as a first selection of relevant projects.

Secondly, we decided to categorise via a matrix model of academic (credited), (extra)curricular and personal design activities, designed by Ecole Polytechnique Français Lausanne (EPFL) as a basis for their discovery labs. EPFL frames the space driven organisation for higher education as interdisciplinary work realised in credited or non-credited courses and coordinated and non or semi -coordinated (interdisciplinary) activities (figure 1). Particularly, in the Thematic-context and Maker Space context it remains rather difficult to identify how it should be embedded and in what way in the Educational Context [11].

Thematic context – Part of the curriculum Ensure project outcome Skills practice linked to discipline or between different disciplines not too far apart. More importantly projects across different disciplines (living labs/architectural building (EPFL)	Credited	**Master projects for credit** **Project oriented learning activities often in competitions or to extracurricular for credit activities** Internship, IGEM, bioengineering world wide competition Solar Decathlon; sustainable building competition Honours projects for excellent students
Coordinated		**Non or Semi-Coordinated**
Student projects (associations) Student are organized in association to build the next Nuna, solar boats, often culminating in a competition Students are responsible for running the entire project but can ask help from staff/industry In TU Delft the Dreamhall is one such example.	Non - credited	**Maker spaces** Stimulating Bottom up student initiatives A meeting ground for exploring and making individual or team prototypes, 24/7 opening hours Offering workshops on e.g. mill, lathe, band saw, welding equipment, hand tools, and bench-top electronics Equipment Support space for capstone projects

Figure 1: Model adapted from EPFL Lausanne [11] , different spaces to stimulate discovery – learning.

2 RESULTS

The e-mails and calls resulted in an overview of ongoing or starting projects. Framed in the quadrants, we see the projects are predominantly as maker space and to a lesser extent thematic context induced. This means either it is not so clear yet how the link should be made between the curriculum and the innovation space and the institutions are still (on purpose or by accident) thinking about it as separate situations happening beyond the curriculum. Framing should be one of the issues addressed in creating a vision on maker spaces linked to the curriculum

Thematic context – - Describe good teacher coaching for interdisciplinary hand on projects in order to facilitate teachers better (G) - How to prepare teachers to provide effective guidance (staff development) (G/I) - Position of entrepreneurship in Engineering Education (B/I) - Developing a trajectory for hands-on physics learning, building science instruments for physics learning. (I/E) - Encourage innovative teaching methods (such as Student-Driven Learning) by the use of innovative learning spaces. (D)	**Credited**	**Master /BSc projects for credit** - Working on a model for multilevel, multi- disciplinary and multi-stakeholder assignments (V/I)
Coordinated		**Non or Semi- Coordinated**
Student projects (associations) - Bridging the gap and becoming a linking pin between industry, education and community (V/I) - Independent upskilling (in math and programming) as a facility to students (I)	**Non - credited**	**Maker spaces** - Collect international experiences on Innovative Learning Spaces (B) - Develop a Vision on hands on learning (V) - To translate the experiences from our experiments in innovative learning spaces towards the whole campus and its community (D) - To lower the thresholds between facilities such as the Design Lab, VR Lab, CotF, XP Lab and the rest of the campus (D) - How to guide students effectively in maker/learner spaces (teams in control and responsible for their own results) (G) - Handbook for teachers to organize design challenges / Inspirational booklet to inspire teachers (G) - Describe the possibilities of assessment within innovative learning spaces (I) - Describe the effect of learning spaces on student behaviour and effective learning (E)

Figure 2: Overview of projects within maker spaces at 4TU's*

*Note these project description or the project foci are not exhaustive and there are likely to be many more, we have not yet received or heard of.

At least 7 of the projects are from UT, 6 of the projects from TU/e and 7 from TU-D. Most overlap in questions or content addressed was found between UT and TU/e as these projects were more guided by support staff compared to TU-D, where we found more teaching staff experimenting with these forms of education.

We have further clustered the projects under the headings benchmarking (B= 2), vision (V= 3), implementation (I= 6), Guidance for teachers and students (G= 4), Dissemination of results towards stakeholders (D= 3) and the effect of the spaces on learning outcomes (E= 2).

The questions are often purely pragmatic or not even questions but rather ideas to be worked out for hands-on implementation. Some projects are mainly focused on the innovation spaces and some specifically on how to bridge the gap towards the regular curriculum (thematic context). Questions or concerns are particularly focused on Implementation and Guidance of teachers and students to make the most of the learning experience:

- What could be the strategic vision of our institution and/or how to effectively implement this in our context.
- What do we need to do in terms of staffing and staff development, student tutorials to run their own teams and entrepreneurial mindsets (needed to make this a success)
- What to do to make all our lab/maker space facilities built on the same knowledge framework and how can we co-create learning in the institution.
- What is the effect or learning outcome (added value for learning). What are effective ways to realise assessment.

To get a better insight in what the literature has to offer as a general answer to these questions we, in the remainder of this article, will discuss these questions and possible answers from the literature. Topics are strategic focus, visions on maker spaces, staff development and added value to learning. Albeit not exhaustively, we think this may give a peak insight into the state of the art on research in maker space research.

2.1 Strategic Foci

The unique institutional purpose of library, learning and maker spaces or any other type of learning encounters in space like environments is grounded in different strategic foci according to the literature. Policy arguments are amongst others stimulating;

- interdisciplinary learning, project oriented teaching, experimentation and prototyping [11] – Education Polytechnique Francais Lausanne (EPFL) ,
- providing educational support for each discipline, stimulating cross disciplinary dialogues– capstone design prototyping lab (Innovation studio Georgia tech), [1], [2]
- fostering close ties between students and employers by exploratory learning or design thinking methods – realised by hands on learning at TU/e and Aalto University which is an entrepreneurial, interdisciplinary hot spot (Aalto university) [12]
- Design thinking as problem solving approach advocated by Stanford D-school for business innovation(Potsdam, Paris, Stanford)
- Real world engineering experiences that integrates multidisciplinary design solutions to prepare students for the workforce – O.T. Swanson Multidisciplinary Design Laboratory at Rensselaer
- Empowering the learner in authentic learning and assessment, which have real life relevance and the application of skills [13], [14].

The additional perspective taken in the discovery learning labs (EPFL) is that it becomes permanently visible to the institution (1) where interdisciplinary spaces are used and (2) what for and (3) how one may get involved, (4) a wish to involve industry and (5) create a fertile ground for innovation. Key driving forces as stated above (derived from existing spaces) at the institutional level are: interdisciplinary learning, involving and bonding with industry and government, connecting science to society, realising a playground for innovation and preparing students for professional work. The educational philosophies of maker spaces are amongst other extensively described in [10].

TU/e, UT and TU-D are looking for one or more of these qualities. Yet the main strategic focus is on interdisciplinarity, involvement of industry to stimulate authentic learning and hands on learning. In TU/e the entire bachelor curriculum will focus more on hands on learning and innovation in challenge based innovation spaces.

UT is emphasizing the connection of science to society, the encouragement of innovative teaching methods (such as student driven learning). The UT is currently working to the transfer the experiences from innovative learning spaces to campus and staff development to increase the educational value of the space.

Whereas TU-D has an extra ambition to involve and bond with industry and preparing students for professional work in innovation spaces. It is amongst other exploring a concurrent design lab with the European Space Agency, creating a TEC Factory with SSR Mainports, urban living labs at the Amsterdam Metropolitan Solutions Institute and creating on campus opportunities for hands on experiences closely related to or integrated with the (interdisciplinary) curriculum.

2.2 Staff Development

For Maker spaces to be a success staff involvement and development seems to be crucial (this includes learning students to take responsibility for the maker space environment). It means that staff and students are trained in, amongst others:

- Using the machines in a safe way
- Doing collaborative teamwork
- Creating a mind-set of co-creation/entrepreneurship
- Creating educational experiments
- Having a well distributed guidance and support system to make experimentation possible
- Intermediary staff between industry and teaching staff, as well as between industry and students

Additional conditions should be met to create a maker space that is successful and should definitely not be underestimated [2],[12].

The UT, TU-D and TU/e are now focusing on using teaching scenario's and pedagogical methods suitable to use in the spaces or hands on experiences in the curriculum. UT's tacit experience was that operational boundaries should be taken care of and communication and collaboration is essential to make a maker or design space work for the wider curriculum.

2.3 Lab-spaces and a framework for knowledge transfer

In [12] [15] Mattila and Turner (p.202) point out the importance of having strong and weak ties for diversity to flourish. Strong or formal ties help to create a culture of knowledge transfer, yet weak informal ties, often in networks and or chance encounters, stimulate innovation. One of the precondition is a diverse population that may be encountered in this network.

As Hynes & Hynes [7] point out current maker spaces are white male oriented in their designs.

Having them close to a library may help to attract women, but to seriously attract more women and possibly other types of students beyond engineering, one also needs to consider ideas for storage, seating, and design aesthetic to create orderly, clean spaces that still welcome a sort of free exploration where you can mess about [7].

Mattila and Turner[15], equally point out the importance of identifying levels of collaborations, the dimensions of the collaboration e.g. which disciplines are involved, what type of relationships are created and what is the impact on the ecosystem. Is it different for each space or are there similarities which may be benefitted from, should there be a liaisons or a community engagement coordinators between the different types of facilities in the institution and to the external world to ensure exposure and continuous upgrading of innovative endeavors in collaboration with industry to benefit both the institution and society?

At the UT they found involving a wider network of teachers in some spaces is harder to realise, causing possibly less effective use of the spaces as there were fewer strong and weak ties available. At TU- D many initiatives create their own scenario, running the risk of only realising strong ties and creating too little diversity for the optimum innovation capacity.

2.4 Added Value for Learning and methods of Assessment

Formal methods of assessment are on a tense footing with maker spaces, as the informal learning mode of sharing, experimenting and failing is one of the key assets of the learning process going on in Maker space environments. Bjorklund states [12] that learning spaces allow for experimenting with new behaviour, skills or ideas and roles in a simulated environment. It creates a microworld were the members can act outside the organisational constraints, while still retaining legitimate membership. The key is to learn how to be acting differently to the challenge based problems on offer. After practicing, reflection, generalisation, and formulation of hypothesis, re-test in a laboratory or in the real life environment, collecting immediate feedback is essential. Critical reflection helps to quickly improve performance by creating more effective behavioural models, which are fed back into the knowledge system. It should built bridges between intuition and the formal aspects of science by being able to better explain, measure and predict the world around us [10]. Particularly, the latter can be measured effectively in more formal assessment initiatives e.g. micro-credentials, or badges that show the skills acquired in a maker space area, ranging from working on a machine like 3D printing, to a working methods such as design thinking, leadership in product design to social/teamwork skills for effective collaboration [16].

Somehow the application of science learned elsewhere should become visible in the learning results of students. Results are encouraging as initiatives state that consistent better results are achieved on capstone or other science courses due to the participation in maker space activities. Or so it is assumed [20]. Haptic learning is considered as one of the reasons for better results [17] (Minogue & Jones, 2006). At the UT this connects to the Twente Educational model [19] in which students work on modules and project based work.

3 DISCUSSION AND CONCLUSIONS

This research has been conducted in a maker space way, exploring and experimental, via informal networking and information gathering. As such it does not built toward any scientific contribution in maker space as phenomenon. The information is an attempt of overview in what our institutions drives to create the best possible education for our students. Equally, many of the studies consulted are based in tacit knowledge creation and practical experiences. Notwithstanding the usefulness and relevance of this knowledge, we should carefully weigh and deliberate what the scientific value and increase of learning outcomes are and make an effort to make evidence based decisions. It shows there are numerous questions that have not been answered yet at the Technical Institutions and that many of the questions we have at each technical institution have common denominators, such as the integrations of hands on learning experiences in the institutions, the position and added value of maker spaces vs thematic courses, the guidance of teachers and staff in realising the best possible learning experiences for students, the consolidation of the realized results for accreditation bodies, etc.

Making an artefact, as construction of learning, is a powerful, personal expression of intellect. Creating maker spaces is a powerful expression of an institutions footprint. It creates ownership of learning processes, even if it not perfect. However, like any individual persons, institutions are also subject to the “IKEA Effect”. The IKEA effect is when individuals value their own creation more, even if flawed, than those of experts [18]. Therefore Aalto University and MIT amongst others [21], wisely distribute a model that cannot make do without contextual adaptation [12]. Somewhere between these two truth will be our Maker Space. As in exploring the maker space questions together we may come up with the best possible scenarios.

SESSION SET UP

The Goal of the session is to identify the most important characteristics of the maker space in Higher education by using the Lego® Serious Play Method®. It will allow participants to share their expertise and co-create qualitative parameters for working in maker spaces. The workshop can be followed by max 20 persons and will last the allotted time.

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