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Technology-enhanced learning in Higher Education Insights from a qualitative study on university-integrated makerspaces in six European countries

Summary

New technological applications such as Augmented Reality or Massive Open Online Courses (MOOCs) lead to alternative ways of learning. In order to be able to use this to its potential, the promotion of digital competencies[1] and a corresponding amount of practical "learning-by-doing" effects is required (cf. Ecker/Campbell 2019, p. 154). For this purpose, spaces and framework conditions must be created for application-based learning, which is also increasingly required by the employment market. In this context, we take a closer look at a new emerging subculture in university infrastructure called Maker Movement (MM). Our research work aims at investigating the pedagogical potential of particularly university-integrated makerspaces (MS) to enhance experiential learning with digital tools. To decode the innovative potential, we collected qualitative data from nine in-depth, semi-structured interviews with lab managers and researchers at European MS in six different countries.

1 Introduction

Due to new technologies, knowledge is available to nearly everyone, everywhere. This also opens up new opportunities for the knowledge acquisition process in higher education in universities[2]. Teachers are no longer the sole sovereignty and suppliers of information. In addition, employers demand in skill has increased for university graduates with practical digital skills in order to be job-ready (cf. Okamoto et al. 2017). In this context, experiential learning formats such as project- or problem-based learning offers an opportunity to use the technological potential and learn more practically in higher education. In contrast to instructive learning (e.g. via lectures), experiential learning formats enable students to take an active role in the learning process. Teachers are more likely to act as a learning guide or facilitator. Even if the benefits of experiential learning approaches in enhancing life skills (e.g. problem-solving ability) is well-known, the majority of knowledge transfer is still realised via

[1] “Digital Competence is the set of knowledge, skills, attitudes, abilities, strategies, and awareness that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, le sure, participation, learning, and socialising.” (Ferrari, 2012).

[2] The term “universities” include both private and public higher education institutions and universities of applied science.

lecturing in university education (cf. Wurdinger and Allison 2017, Schmid et al. 2017). This implies an increasing need not only for more effective implementation strategies, but also for spaces of social interaction and experimentation. In this regard, we will look at the example of the MM as a new emerging subculture in university infrastructure and university-integrated MS. The paper aims at investigating the educational potential of MS for learning, teaching and knowledge creation in universities. For this purpose, empirical data was collected from nine in-depth, semi-structured interviews conducted with lab managers and researchers at European MS in six different countries: Denmark, Finland, Germany, Netherlands, Spain and Switzerland. Section 2 introduces to the global subculture MM and provides a definition of university-integrated MS. The third chapter gives a theoretical basis for further explanation of maker-based learning by the Experiential Learning Theory (ELT) according to David Kolb. Section 4 and 5 provides insights into the investigation approach and research findings. Section 6 concludes the paper.

2 The Maker Movement in universities

Originally started in the USA and developed out of the do-it-yourself (DIY) culture, the MM can be seen as a global subculture of the tech community. Cutler (2006, pp.236-239) defines the term as follows:

> *"(S)ubcultures are defined as groups of people who share norms of behaviour, values, beliefs, consumption patterns, and lifestyle choices that differ to varying degrees from those of the dominant, mainstream culture".*

The MM is an umbrella term for individuals who share a common mindset around the globe. The subculture, which is steadily growing in numbers, consists of people from different pathways and is based on a culture of sharing and supporting one another (cf. Wigner 2017). The maker mindset is characterised by building and creating things; failure-positive attitude and strong willingness to collaborate (cf. Martin 2015). With the aid of personal technology, like 3D printers, they produce artefacts in a playful and creative way, while using physical or digital forums to share their processes and products with others (cf. Halverson/Sheridan, 2014).
In this context, a MS is a physical community centre for creative production "where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products" (Halverson et al. 2014). They can have different organisational forms such as a part of a for-profit or non-profit organization, or hosted within educational institutions. The paper focuses on concrete MS which are affiliated with or hosted within universities. They differ in type of provided services, target group and purpose compared to MS outside of educational institutions. In this regard, a common concept of university-integrated MS has not existed up until now (Halverson/Sheridan, 2014). Based on current research findings and existing literature (cf. Krummeck/Rouse 2017; Halverson/Sheridan, 2014;

Barrett et al. 2015) we use the following criteria for the definition of university-integrated MS:

- Close connection to one or more universities (e.g. funding, organising or place);
- Main user group: university students and researchers but usually also accessible to other internal or external interest groups;
- Focus on educational and learning processes with a wide variety of objectives (such as business development, innovation, community, sustainability) and
- Integration in formal and informal learning sessions.

After the first definition has laid the foundation, the question remains how maker-based learning is arranged. The ELT provides an initial explanation.

3 The Experiential Learning Theory

Making is related to problem- and project-based learning (van der Poel et al. 2016, Fordyce et al. 2015, Forest et al. 2016). These learning approaches are summarised under the ELT. ELT aims at providing “a holistic model of a learning process and a multilinear model of adult development” (Kolb et al. 2001) and describes a learning process which is based on experiences. In this context, experiences could be gained in many diverse ways, such as by engaging in doing or making, but also by observing (Kolb 2014). ELT is built on the following propositions (Kolb/Kolb, 2005):

1. Learning is a process of adaptation to the world. It results from synergetic transactions between a person and the environment. It is best conceived not in terms of outcomes but much more a process of creating knowledge.
2. A reflection phase is an integral part of the learning process.
3. Learning is based on the resolution of conflicts or upcoming problems between dialectically opposed modes of adaptation to the world.
4. Learning involves the integrated functioning of the whole individual not only cognition but also thinking, feeling, perceiving, and behaving.

Influenced by Dewey’s theory on pragmatic idealism, Kolb (2014) defines four additional stages as part of the experiential learning approach. Here, he underlines the concrete experience of a person, a reflection phase, the formation of abstract concepts and a testing phase as crucial stages for the learning process. The main advantages of experiential learning are associated with the high learner activity and encouraged student interaction with each other and the content (Wurdinger/Carlson 2011). Furthermore, ELT addresses real-world problems and enhances interdisciplinary learning by using multiple subjects. Given the advantages of experiences for the success of the learning process, the connections between ELT and making via desktop fabrication technology will be further examined.

4 Proceeding and Approach

Related to the ELT, we will look at how maker-based learning is arranged. Nine in-depth expert interviews conducted with lab managers and researchers at European MS were carried in six different countries. Given the novelty of the concept of university-integrated MS, the chosen European approach allows us to gather as many impulses and suggestions as possible from experts at different practical and national levels. It enables us to gain impressions on different development statuses and perspectives on the impact of the MM on learning in higher education. The semi-structured interviews were held between the 15 of October and 10 of November 2019 via phone, skype or face-to-face. The interviews lasted between 60 and 90 min. Based on a conference participants list (FabLearn Europe Conference 2019), 17 experts were requested for an interview. The following criteria were applied to select the experts:

- Familiarity with the topic and the MM;
- practical lab experiences as a teacher, supervisor or (co)founder;
- diversity in type of university (e.g. private/public, university/ university of applied science, country).

The participants received the 12 guiding open and closed questions beforehand to ensure a common understanding on the topic. The interviews were opened with two descriptive questions about the MM and university-integrated MS. The second part of the interview thematically was addressed to the learning content and process in MS. In addition to that, the interviewees were asked for enablers to develop a robust maker community in university infrastructure and the meaning of an open MS for society. Finally, the experts were requested to give an outlook on the importance of makerspaces for future education and asked for existing socio-economic evaluated data. All interviews have been recorded and saved. The complete pool of questions can be viewed in the appendix.

5 Observation and findings

An essential prerequisite for learning in MS is a robust community. Thus, gained information was clustered systematically into the first-level segments “community-building” and “learning” related to the overall research focus. We mapped out the most crucial characteristics of each segment that originate in connection with the research interest. Firstly, we ask for enablers to maximize participation and learning in DIY-labs. Secondly, our research interest focused on the learning process and learning content but also degree of openness towards society in MS. The extracted sub segments were defined according to the text reduction procedure (cf. Froschauer/Lueger 2003). The research results have been summarised and enriched with the state of the art on this topic.

5.1 Enabler for a robust maker community

According to the experts, four elements were named as particularly essential for the development of a robust maker community in higher education institutions:

Top-down and bottom-up support
First, the experts underline the support from the university management e.g. by funding, providing infrastructure or structural integrating into teaching. Nonetheless, the process does not only require a top-down but also bottom-up commitment. A DIY-lab can only become a lively MS if they attract a group of individuals which are willing to be there and to realise new projects.

A common vision
Another point is a clearly communicated vision of values, objectives and principles. These help users to identify better with the maker community. A necessary degree of stability can be created only if the goals and values are clearly defined and articulated by both the subculture and the organization. Additionally, individuals can rather estimate if their personal (learning) objectives coincide with community goals. This confirms the findings of Krummeck/Rouse (2017) who described their efforts to support a robust maker culture in the Southern Methodist University, USA.

Encouraging ownership
One expert points out that a key to develop a community is a positively connoted understanding of different roles. For instance, at one specific lab, lab assistants are called “stewards” to strengthen the personal perception towards shared ownership. Staff members do not see their task just as a job but rather as a co-creator of the lab with certain responsibilities. In addition, realised work by users and staff members is exhibited at university to honor the achievements. This has also been stated as critical to building a robust maker culture (Krummeck/Rouse 2017).

Integration in non-formal and formal learning activities
The experts have a coherent opinion about the fact that the integration of MS into non-formal and formal learning activities is one of the most crucial factors for community-building. In this way students, researchers and other university members from different disciplines become aware of the potential of maker-based instructions and can better assimilate the connection to their studies and own interest fields. For example: At the medical faculty of Technical University Dresden (Germany) students realise 3D-print elements of the spinal column to learn how to place the spinal cord injection. The expert says that medicine students learn more than in traditional learning settings due to hands-on experience. This would motivate them for sustained participation.

5.2 Learning in university-integrated makerspaces

In this section, we wanted to investigate how and what students learn within a MS. We clustered the provided information into three sub segments: learning process, learning content and openness towards society.

Learning process in makerspaces

According to the experts, a fixed maker-based learning process doesn't exist. Instead, most interviewees describe a project-based and open development process. Students discover opportunities by themselves and teachers act as facilitators. This is consistent with the previous considerations on the ELT. The learners approach a problem or topic mainly autonomously or in group work and express their ideas via produced artefact in the physical world. One expert highlighted that this self-directed approach is experienced by participants as a totally new learning activity. Usually they are used to learning in the context of guided exercises. For this reason, the students usually have initial problems and skepticism but at a later stage they discover the underlying advantages of approaching a problem individually. Nonetheless, it became apparent that typical sequences of a design process are usually applied during learning by doing. The experts stated coherently that the learning process often starts with a problem identification phase or concrete experience, secondly searching for a solution to solve the problem or reflective observation, thirdly the implementation process e.g. via prototyping and finally, the reflection phase. Here, clear parallels to the four phases learning cycle by Kolb can be found. The experts underline that the process is rather iterative instead of linear and should always maintain flexibility to access different target groups. This broadly agrees with results from the world literature on making in higher education (cf. Halverson/Sheridan, 2014; Martin, 2015; Peppler/Bender, 2013; Cohen et al. 2017). Three respondents have additionally made a link to the design thinking method (see table 1).

Table 1: Characteristics of maker-based learning approaches

	Project- and problem-based learning approach	Teacher as facilitator	Student-driven and self-directed approach	Iterative and flexible learning process	Link to Design Thinking
Creativity lab Stuttgart, Hochschule der Medien Stuttgart, Germany	■	■	■	◺	◺
DDlab, Aarhus University, Denmark	■	■	■	■	◺

Fab Lab Barcelona, Institute for Advanced Architecture of Catalonia, Spain	■	■	■	■	■
Fab Lab Cottbus, BTU Cottbus, Germany	■	◺	■	■	◺
Fab Lab Siegen, Uni Siegen, Germany	■	◧	■	■	◺
Fab Lab Oulu, University of Oulu, Finland	■	■	■	■	■
Makerspaces, Pädagogische Hochschule St.Gallen, Switzerland	■	■	■	■	■
Makerspace Dresden, TU Dresden, Germany	■	◺	◧	■	◺
Stadtlab Rotterdam, Rotterdam University of Applied Sciences, Netherlands	■	◧	◧	■	◺

Agree ■ Agree partially ◧ don't agree ○ not mentioned ◺

Learning content

The specific learning content largely depends on the subject and the learning objectives. Nevertheless, certain areas of competence were mentioned commonly, regardless of the chair or subject. Hereby, the experts made a distinction between hard and soft skills. They say that university students learn fundamentals of electronics, the usage of desktop fabrication tools and programming. One expert explains that students learn in a creative way how technology can help to realise ideas, e.g. how electronics can form music, or how architecture students can use 3D printing for model building. In the context of digitization, these are crucial skills to shape the future. Interviewees also observe that besides the described hard-skills soft-skills are also taught. The majority of interviewees acknowledged improved problem-solving skills and a higher interest in technology amongst the participants. They gain an understanding of how technology is formed and how it can be used to solve certain problems. Two experts argued that learning in MS also leads to improved self-efficacy related to the social learning theory of Albert Bandura (1977)[3]. According to them, learners develop more confidence in their own skills and

[3] Bandura (1977, p.79) defines the term as follows: "An efficacy expectation in the conviction that one can successfully execute the behaviour required to produce the outcomes.". Thus, he makes a distinction between outcome and self-efficacy and underlines that individuals can influence their personal outcome by a high efficacy expectation.

capabilities due to the hands-on learning experience. Furthermore, cooperative learning atmosphere improves learner's teamwork capabilities.

Openness towards society

Finally, we investigated the degree of openness and what role this plays in the learning experience. In this regard, a controversial opinion among the experts exists. Six out of nine experts underline the necessity for complete openness towards society (e.g. schools, companies, political institutions) in order to expose different ideas and to enhance innovation. Additionally, the majority of experts point out the potential of integrating topics and impulse from civil society into higher education by opening up for external factors. Research and teaching could become even more participatory and practically oriented. Hence, students learn on practical examples given by the civil society as the project at the University of Cottbus (Germany) illustrates. Students from different disciplines developed a solar power operating bicycle pump station for campus to motivate for a more sustainable mobility behaviour among university members. Besides that, one expert forecasts an overall change in the understanding of academia. In his point of view, an open MS could become an enabler for citizen science due to a stronger participatory and interdisciplinary approach. On the contrary, three interviewees regard not only the advantages but also risks associated with an open MS. An opening towards external interest groups might lead to higher workload and bottlenecks. In their opinion, a university MS should rather target students and university members as there exist also alternative MS for civil society. One expert points out that an open MS might perhaps arouse an environment of experts with high technical skills in which non-binary individuals might not any longer feel welcomed.

6 Conclusion and forecast

Universities are key institutions for progress towards a networked knowledge society. It is the responsibility of the universities to offer infrastructures and educational formats that enable future graduates from a wide range of disciplines to help shape the technology-intensive world. There is an enormous need not only for consumers, but also producers, who have the skills to implement their own ideas for solutions toward the most pressing questions of our time with the help of technology. In this context, not only the content but also the teaching methods have to develop from an instructive (knowledge-centered) to a more constructive (competencies-based) learning approach. In this article, an approach for a more self and experience based learning on the latest production technologies was demonstrated by university-integrated MS. The expert results have shown that MS provides an ideal breeding ground and environment for technology-enhanced experiential learning approaches in higher education and enable a more student-driven, interdisciplinary and participatory learning experience. According to the interviewee, they could break down institutional and disciplinary boundaries and lead to a more extensive range of interdisciplinary degrees and education in the future. Depending on the overall objective, MS could serve as a vehicle for open science as a new knowledge creation approach. Real-world problems and the valuable know-how of society could be approached more effectively in academia via hands-on learning. This playful and critical entry into technology maker-based instructions might lead to higher student's self-efficacy and thereby to a greater individual's motivation shaping the digitization process in our society. The analysis of the interviews revealed that the integration of MS into higher education is not an unmanaged process. A successful implementation into formal and non-formal learning activities requires both the support of university management but also students, researchers and broader society who realise the potential of making for their own learning process and success. Further research is needed on concrete implementation strategies into existing formal learning formats.

References

Bandura, A. (1977). *Social learning theory*. Prentice-Hall series in social learning theory. Englewood Cliffs, New Jersey: Prentice-Hall.

Barrett, Thomas, Pizzico, Matthew, Levy, D, B., . . . C, W. *A Review of University Maker Spaces*. Retrieved from https://smartech.gatech.edu/handle/1853/53813

Cohen, J., Jones, W.M., Smith, S.; Calandra, B. (2017). *Makification: Towards a Framework for Leveraging the Maker Movement in Formal Education.* Waynesville, NC USA.

Cutler, C. (2006). *Subcultures and Countercultures*. In Encyclopedia of Language & Linguistics (pp. 236–239). Elsevier. https://doi.org/10.1016/B0-08-044854-2/01312-2

Schmid, U.; Goertz, L.; Radomski, S.; Thom,S. ; Behrens, J. (2017). *Monitor Digitale Bildung: Die Hochschule im digitalen Zeitalter.*

Ecker, B., & Campbell, D. F. J. (2019). *Was bedeutet Innovation an Universitäten? Durch welche Organisationsentwicklung kann eine Universität ihre Innovationsfähigkeit verbessern?* Zeitschrift Für Hochschulrecht Hochschulmanagement Und Hochschulpolitik Zfhr, 18(2), 43. https://doi.org/10.33196/zfhr201902004301

Ferrari, A. (2012). *Digital Competence in Practice: An Analysis of Frameworks.*

Fordyce, R. D. E., Heemsbergen, L., Mignone, P., & Nansen, B. (2015). *3D printing and university makerspaces: Surveying countercultural communities in institutional settings.*

Forest, C., Hashemi Farzaneh, H., Weinmann, J., & Lindemann, U. (2016). *Quantitative Survey and Analysis of Five Maker Spaces at Large, Research Oriented Universities.* New Orleans, Louisiana.

Froschauer, U., & Lueger, M. (2003). *Das qualitative Interview: Zur Praxis interpretativer Analyse sozialer Systeme* (1. Aufl.). UTB Soziologie: Vol. 2418. Wien: WUV. Retrieved from http://www.utb-studi-e-book.de/9783838524184

Halverson, E. R., & Sheridan, K. (2014). *The Maker Movement in Education.* Harvard Educational Review, 84(4), 495–504. https://doi.org/10.17763/haer.84.4.34j1g68140382063

Jordaan, D. W. (2017). *The open society: What does it really mean?* De Jure, 50(2), 396–405. https://doi.org/10.17159/2225-7160/2017/v50n2a11

Kolb, A. Y., & Kolb, D. A. (2005). *Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education.* Academy of Management Learning & Education, 4(2), 193–212. https://doi.org/10.5465/amle.2005.17268566

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development.* Second Edition.

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. 2001. *Experiential learning theory: Previous research* (2001).

Krummeck, K., & Rouse, R. (2017). *Can You DIG it? Designing to Support a Robust Maker Culture in a University Makerspace*. International Journal of Designs for Learning, 8(1). https://doi.org/10.14434/ijdl.v8i1.22702

Martin, L. (2015). *The Promise of the Maker Movement for Education*. Journal of Pre-College Engineering Education Research (J-PEER), 5(1), Article 4. https://doi.org/10.7771/2157-9288.1099

Okamoto, T.; Soga, N.; Kumagai, T.; Arai, H. (2017). *The Perceptual Gaps Between Companies' and University Students' Views on Fundamental Competencies*. The Review of Socionetwork Strategies, 11(2), 143–157. https://doi.org/10.1007/s12626-017-0008-z

Peppler, K., & Bender, S. (2013). *Maker Movement Spreads Innovation One Project at a Time.* Phi Delta Kappan, 95(3), 22–27. https://doi.org/10.1177/003172171309500306

Van der Poel, J.; Douma, I.; Scheltenaar, K.; Bekker, T. (2016). *Maker Education–Theory and Practice in the Netherlands: White paper for Platform Maker Education Netherlands.* Retrieved from https://www.onderwijsfilosofie.nl/platform-maker-education

Wigner, A. (2017). *The Maker Movement, the Promise of Higher Education, and the Future of Work.*

Wurdinger, S.; Allison, P. (2017). *Faculty Perceptions and Use of Experiential Learning In Higher Education*. Advance online publication. https://doi.org/10.20368/1971-8829/1309

Wurdinger, S. D.; Carlson, J. (2011). *Teaching for experiential learning: Five approaches that work.* New Delhi.

Appendix: Guiding interview questions

1. From your point of view, which attributes describe the maker-community?
2. Having your practical experience in mind, what would you add to the above provided definition of university integrated makerspaces?

3. Could you please describe typical examples of how and what are students learning in your university-integrated makerspace? Are there some best practices that you would like to point out?
4. Which steps describe the learning journey of students while making?
5. How do you (didactically?) organise the use of the makerspace in order to provide expertise? Are there differences when the use of the makerspace is organised from the university compared to the informal free use?
6. Do you collect the results/learning outputs in any way? Do you use them in order to improve your offers? Do you track/check/ (?) acceptance, motivation in any way?
7. What do you think which factors facilitate a robust maker community within a university-integrated makerspace?
8. From your point of view, do you think it is desirable to have an open academic makerspace accessible for different interest groups? Why?
9. What should be done/changed to make your university-integrated makerspace can be open and attractive to students from different disciplines and external actors?
10. From your point of view, do you think it is desirable to have an open academic makerspace accessible for different interest groups? Why?
11. What impact has makerspaces on university education now? What impact do you expect in 10 and 20 years?
12. Do you have any statistical data on participants learning in the makerspace (e.g. gender, age, study program etc.)?