How Makerspaces Help to Participate in Technology

Results of a Survey to Gain Data about Learners' Activities in Makerspaces

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***Abstract*—Makerspaces in the field of Engineering Education may serve as open labs for hands-on engineering and learning about new technologies, e.g., additive manufacturing. Being accessible for members of engineering departments as well as for other members of universities, 'makers' from various disciplines and technology experts meet one another. While exploring individual paths helping them to conceive, design, implement and operate their own products, learners apply different technologies, materials and methods that can be allocated in information technology, electrical or mechanical engineering or also educational and rehabilitation sciences. While individualized products and minimum lot sizes address new challenges in engineering in terms of flexibility but also sustainability, promising approaches e.g., FabLabs or Makerspaces – off the common qualification paths – should be explored. With regards to an increased share of information and communication technology within the work environments of the future, postulating a growing demand for new competence profiles and innovative learning scenarios, the implemented approach offers learning opportunities to promote creativity and foster the 'maker mindset'. The paper at hand therefore classifies common operating procedures within a specific makerspace based on the results of an accompanying evaluation, focusing on the learners' activities and the technologies involved.**

Keywords*—makerspace, learners' activities, creativity, entrepreneurship, engineering education

I. Introduction

The future work environments are predicted to require employees that are aware of reliable methods to acquire new expertise right away, possess skills to utilize the gained knowledge creatively, and have competencies to reflect about impacts of their performed actions [1]. Also, open learning venues that offer opportunities for cross-disciplinary co-creation are vital to learners' competence development and therefore seem to be a necessity for the successfully shaping of the digital revolution [2]. Here, so-called makerspaces might offer a decent answer in terms of an adequate learning environment. For the past years, the concept of making has been a publicly discussed topic, culminating in the assembling of makers in the maker movement. As a result of the public awareness, a so-called 'Maker Faire', a mix of exhibition and fair for makers, has even taken place in the White House [3]. As another result, makerspaces and fab-labs are spreading around the world. Publications originating from the maker movement as well as related web pages like [4] or [5] often emphasize that making can have a big impact on changing technology education. Pursuing this idea, we believe that the concept of making can also effect changes in engineering education, which contribute to a responsible way of teaching that emphasizes the meaning of peace and democratic acting.

The paper at hand presents a first approach to gathering data about the actual learners' activities while tinkering. Here, the '*Makerspace Engineering Education'* (M.EE) serves as a testbed to query young makers and derivate premises and thereby contribute to answering questions on how to support learners in the best possible way within open and co-creational learning venues like e.g., makerspaces, fabrication laboratories, hackerspaces, and innovation labs. Moreover, the paper describes, how makerspaces offer several opportunities to foster students from all disciplines in considering the global impact of their future professional careers as engineers by encouraging them to use and discuss new technology and its impact to our current and future socio-technical systems.

II. Co-Creational Learning Opportunities

In the context of important skills in a digital world, new learning opportunities, e.g., makerspaces, are requested to give a decent answer regarding the technological and productive change in economy and education.

A. A Brief History of Makerspaces

Makerspaces are workspaces that provide different tools and technologies to tinker around with the opportunity to meet other people and collaborate while working on projects [6]. As people can use tools and tech to create different things in other environments like open workshops, collaboration is the fundamental characteristic of making. This aspect can even be traced back to the Gowanda Ladies Social Society that was founded in 1873. Women used this group to work with fabrics as well as to meet one another and to talk about books [7]. It is easily imaginable that those women unintentionally adhered to some of the rules. Mark Hatch framed in his Maker Movement Manifesto about 120 years later: 'Make, Share, Give, Learn, Tool Up, Participate and Support' [8]. In opposition to these ideas, which have not changed much since 1873, tools and technologies have changed a lot in the last years of making. Nowadays, making is primarily associated with digital technologies like 3D printing, laser cutting or programming. Furthermore, designing new products with digital tools is a key characteristic of making [9]. Nevertheless, even today 'older' technologies like drilling, cutting or soldering have their application in the field of making.

Both cornerstones of the maker movement, technology and social acting, imply possible fields that may be interesting in the context of education. Because of that, many universities, as well as public institutions like libraries, open up makerspaces now [10]. Additionally, considering creativity as a stimulus for developing new products, the process of making fosters three basic skills needed by future engineers: technical knowledge, the ability to act in intercultural teams with different professional backgrounds and the ability to restructure knowledge and acquire missing knowledge and skills on their own. Nevertheless, by now there is still a lack of empirical data focusing the learners' activities in makerspaces, despite the fact that research in pedagogy and education is of in-depth and empirical nature. Undoubtedly, results of both implementation and evaluation studies in context with related makerspace approaches are present in scientific publications, e.g., [11], [12], [13], and [14], but those studies do not state in detail, which learner activities were performed in the described makerspaces.

B. How Makerspaces Contribute to Peace Engineering

A key element of Peace Engineering can be described as the willingness to cooperate in the development of approaches towards identifying sustained solutions for multi-dimensional issues, e.g., global prosperity for humankind [15]. On a small scale, this is what makers do: *thinkering* – creating solutions for problems across all disciplines in open and co-creational learning venues, following only a few premises [16]:

- Peers and collaboration
- Time, trial & error, and the role of persistence
- Failure is part of the learning process

Here, "Making, as a set of activities, is built on practices and mindsets that underscore the importance of collaborative and iterative construction of objects through the creative use of material and digital fabrication tools" [11]. Therefore, makerspaces as holistic places of learning offer an excellent approach to conceive, design, implement and built prototypes, work project-based and interdisciplinary, and solve real-world problems. In addition, practices and mindsets in the context of making activities potentially foster creativity and an awareness towards the importance of failure and iteration [17], [18]. Topics like mobility, sustainable development and health informatics combined with a diverse group of hackers, openness, inclusion and the individual empowerment towards new technology engage the presence of social, political and ethical points [19]. Additionally, e.g., Barton, Tan & Greenberg argued, based on their two-year long studies, that makerspaces offer an opportunity in promoting disadvantaged young adults in equity-oriented and meaningful learning. And as a result of the maker movement, the social, cultural and technological capital for success in e.g., STEM becomes accessible [11], [20].

Also, makerspaces as learning venues for co-creation represent a strong approach to social justice by transforming structural inequalities into infrastructure access [21]. Currently, makerspaces are about to migrate into higher educations' curricula in different subject areas, levels of involvement and varying subjects, e.g., addressing entrepreneurship and innovation [22] or Internet of Things and creativity [24]. Here, it is important to emphasize that the factor of success, regarding these open and co-creational workshops is more than just buying the digital toolset or connecting to the community of makers, is primarily a state of mind [25]

III. Makerspace Engineering Education

The Makerspace Engineering Education (M.EE) at TU Dortmund University was opened in August 2017. As a part of the faculty of Mechanical Engineering, it is affiliated to the Department of Engineering Education. To provide a broad range of opportunities for participating in making, there are different ways of choosing its equipment. For this reason, low-cost machines on a consumer level can be found in M.EE as well as machines for industrial use. All equipment was purchased through budgetary resources or with the help of the faculty of Mechanical Engineering. Altogether, the makerspace features opportunities for using machines in the following fields [26]:

- 3D Printing
- Laser Cutting
- CNC Tools
- Sensors
- 3D Scanning
- Soldering
- Hand Tools
- Robotics

Beyond technology, M.EE features a special area dedicated to fostering students' creativity. This area provides cozy sofas, where students can rest in groups and discuss current problems of their projects. Different magazines and books related to the maker movement and special issues of technology are available in the creativity area to encourage students' urge to start new projects.

In the opening hours of M.EE, all members and students of the Faculty of Mechanical Engineering at TU Dortmund University can use it to work on their own projects and use the different machines. Due to this, study programs in mechanical engineering, logistics, industrial engineering, automation and robotics as well as teacher education are covered. Going ahead, students from other faculties could be invited to use M.EE in the future, too. For this purpose, the makerspace is continuously rearranged to make all tools as accessible as possible for handicapped people. Besides their subject of study, two main groups of M.EE users can be distinguished: students who use the technology provided to build products for a specific course and those who work on their private projects. Both groups are treated equally except one small difference: users who work on their private projects have to bring material on their own, while users working on a university project for special courses are offered free material.

As the diverse group of users holds different experiences regarding the different technologies, there are several ways to enable the users to use all technologies correctly. As the empowerment of the users to work out needed abilities themselves is a main concept of the M.EE, the first approach is the idea of helping as little as possible. Therefore, users should freely explore the machines at first. If they have questions, there are manuals or video tutorials offered to the users. Additionally, there are student assistants working in the makerspace during opening hours. Those student assistants have been trained in using the technology as well as in teaching others how to use it.

Besides adhering to the lab rules, which mostly include a proper use of technology, users of M.EE are free to do whatever they like. This includes no such thing as a curriculum or defined learning outcomes. Several courses use M.EE as a workspace for their students but none has set fixed goals. Because of this, there also is no assessment of students' progress. Nevertheless, students are asked to reflect on their working progress in the makerspace towards the end of the courses.

IV. Methodology

From April to August 2018, an open survey was implemented via LimeSurvey covering the summer term. Users of the makerspace were asked to use a wall-mounted tablet computer located in the M.EE to give feedback. The survey is considered as a starting point for further studies on learning in makerspaces, e.g., on the acquisition of competencies. Therefore, identifying which actions take place in the makerspace is the major aim. Due to that, besides statistical data, the survey should gather information about students' acceptance of the makerspace and about the students' activities while working in the makerspace. According to that, the survey consisted of three main topics with one question each. Those questions offered answers with multiple selections. The following topics were surveyed:

- Use of technology: users were asked, which of the above-mentioned technologies they had used
- Intended use of the makerspace: students should declare if they worked on a university project or on their private project
- Purpose of using the makerspace: users should explain, which kind of activity they had fulfilled in the makerspace (e.g., 'Working together with others', 'Helping others' or 'Solving Problems')

In addition, the participants of the survey were asked about their gender and their subject of studies to gather data in context with the diversity of makerspace users.

V. Findings

This chapter describes the results of the survey split into three sections. While the first section gives a short statistical overview of the participants, the second section focuses on how students worked in the makerspace. The third section describes, which kind of technology was used by the respondents.

A. Gender & Subject of Studies

110 makers answered the question regarding their gender. 91 out of 110 makers were male, which results in a percentage of 83 %, 19 respondents (17 %) were female.

As illustrated in Fig. 1, with 40 % the biggest number of users in the makerspace aim to be teachers with a technical subject. This includes subjects like 'technology' in primary school and high school as well as subjects related to mechanical or electrical engineering in vocational schools. Students of mechanical engineering make up the second largest group, contributing to the M.EEs use with about 36 %. In contrast, the contribution of students, whose subjects are industrial engineering or logistics, amount to 3 %, making the smallest group of users of M.EE. About 7 % of the students working in the makerspace stated, that their field of studies is another than the mentioned. The opportunity of giving more specific information was not implemented in the survey. All in all, 14 % of the interviewed users declared that they did not study or did not give information about their subject of studies.

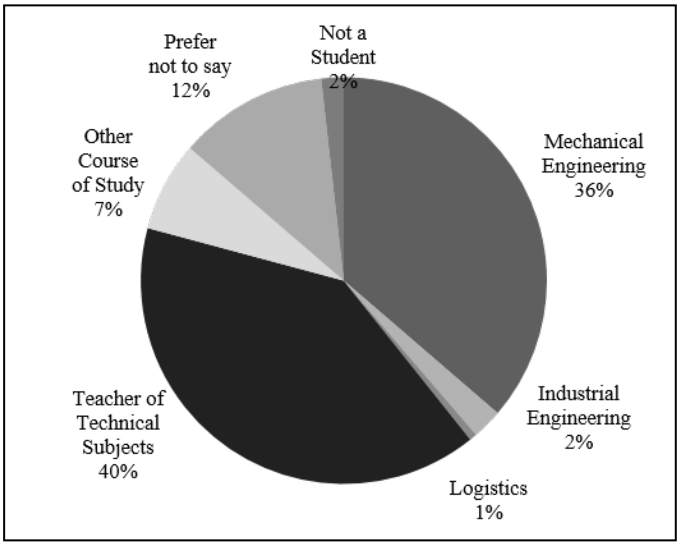

Fig. 1. Respondents' subject of study

B. Intended Use & Purpose of Using the M.EE

The participants of the survey were also asked whether they worked on their own project or in the context of an educational course. 65 % of the respondents stated that they have used the makerspace in context with an educational course, whereas 35 % stated they worked on their own projects. Having a look at the purposes of the users' visit in the M.EE, illustrated in Fig. 2, it becomes obvious that collaboration is a substantial component of making. This becomes apparent in 68 of 168 respondents who stated that they received help as well as in 76 interviewees who revealed that they collaborated with other users. Another essential identifier of makerspaces is visible in 42 respondents that were able to solve problems and 37 that stated that they have developed creative ideas within the M.EE. Also, 19 makers stated that they were able to help other makers. Only 13 respondents stated that they searched the internet or other sources for help or instructions. Also, seven out of these 13 respondents stated earlier that they did not collaborate with others but four out of those seven reported that their problem was solved. All in all, 36 of the 168 respondents were convinced that they had developed a novel idea.

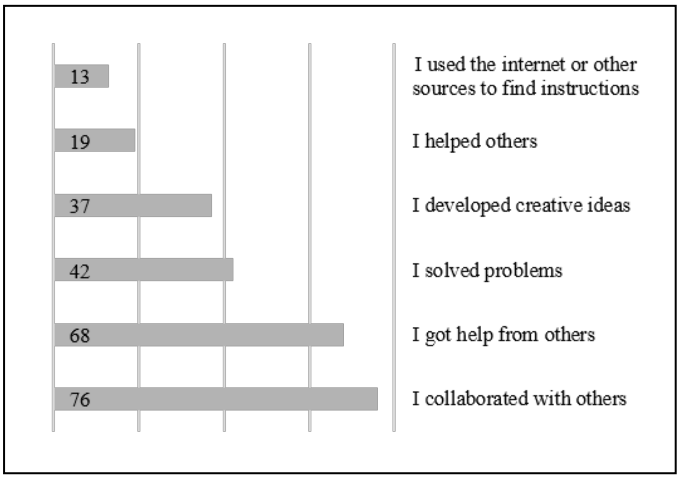

Fig. 2. Purpose of using M.EE according to respondents

C. *Usage of Technology*

Regarding the respondents of the survey, the use of 3D printers is the biggest activity taking place in M.EE. As shown in fig. 3, 51% of the interviewees declared, that they had used this technology. Following with 17%, the use of the laser cutter is the second largest activity performed in the makerspace. 12% of the users stated that they used single-board computers or microcontrollers like Raspberry Pi or Arduino, for example. The use of soldering forms to 9%, while the use of robotics makes up 7%. The use of sensors and virtualization technologies, like VR, are the least common among the users of M.EE, being used by only 2% each.

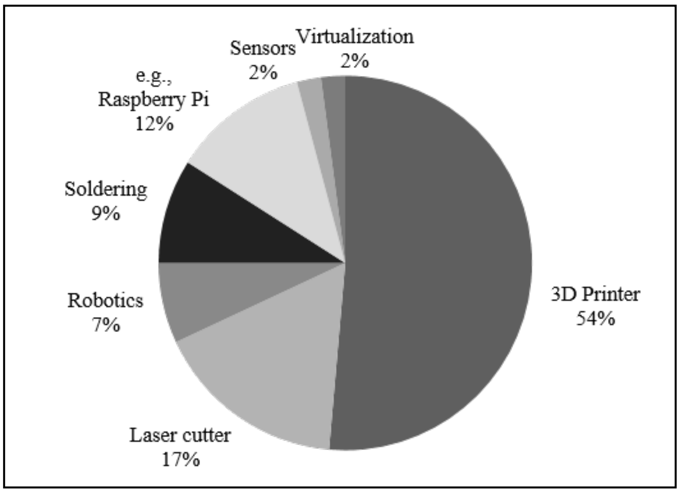

Fig. 3. Usage of technology

VI. Discussion of Results

Regarding the structure of the makerspace and its intentions, the results of the survey allow drawing some conclusions. Looking at the structure of users working in M.EE, it can be stated that the user community is not as diverse as intended. The share that female users hold, sums up to 17 % by now – thus almost matching the share of females in the Faculty of Mechanical Engineering of TU Dortmund University (18,0 % in 2017) [27]. It must be stated, that the share of women in M.EE must be increased in order to represent society in total and in order to encourage people of all groups to use technology independently. With a deeper look at the structure of the user community, we can assume that this evidence is owed to the fact that M.EE is not widely known throughout the campus of TU Dortmund University. This can be derived from the fact that only 7 % of the M.EE users state that their subject of study is another than a subject, which is related to the Faculty of Mechanical Engineering. Excluding those who did not share information about their subject, it can be stated that the use of the makerspace is not as widespread among different disciplines as it is desired. This also applies to the faculty itself. While the share of students of mechanical engineering is approximately the same as their share in the faculty (36 % in M.EE – 38,7 % in faculty), both industrial engineering (2 % in M.EE – 38,5 % in faculty) and logistics (1 % in M.EE – 19,7 % in faculty) are largely underrepresented [13]. In contrast, the share of students, who aim to be teachers of a technical subject, is significantly higher in comparison to its share in the faculty of mechanical engineering (40 % in M.EE – 2,9 % in faculty). This can be traced back to the area of responsibility of the Department of Engineering Education. The biggest share of courses offered by Engineering Education is directly linked to teacher's education while only a small number of courses attracts to other students of the faculty. The relatively high number of students of mechanical engineering in comparison to industrial engineering and logistics could result from the students' self-perception: while mechanical engineers are regarded as problem-solvers on a technically detailed level who like to tinker around, industrial engineers and logisticians are regarded more generalist [28].

The impression, that using the M.EE is not widespread among TU Dortmund University's students, intensifies looking at the intent of use the respondents stated. Only 35 % of the students use M.EE in order to create their own projects. Even though this share can be increased, it is explicable with the fact, that M.EE was opened up only one year ago. It was a kind of a strategy to include M.EE in as many courses of the Department of Engineering Education increasing the level of awareness for using M.EE in the students' spare time among all students.

Looking at the purpose of use, respondents stated that it can be assumed, that the makerspace contributes to the intended learning outcomes as described in section II. Social learning seems to play a crucial role as most students stated that they collaborated with other makers, got help from others or helped one another. Furthermore, the share of users who claimed to deal with creativity and problem-solving ('I developed creative ideas' & 'I solved problems') is noticeable.

The unequal distribution of technologies used in the M.EE can be traced back to the premises of the makerspace itself. 3D printing makes up the greatest share and is prominently placed in the M.EE. Therefore, it seems to be logical that students use this technology in a broad manner. This implies that the other technologies should be promoted more offensive to enable the users to use these as well. Therefore, the small number of users of both virtualization and sensors may be explained by the following assumptions. It can be assumed that a great share of users, who claimed to use microcontrollers and single-board computers, also used sensors but underestimated its meaning while answering the survey. Another possible explanation is that the users just begun to work with electronics and therefore did not have the courage to implement sensors. The small number of users in virtualization could be attributed to the fact that the technologies used for virtualization (VR glasses, programming and 3d modeling software) require a high skill level as well as a lot of time to achieve proper results. Student may be discouraged by this fact. At this point, more instruction and small examples of using virtualization should be presented in the M.EE to encourage more students to use virtualization technology.

VII. Future Work

While the performed survey was designed to attain first insights and qualitative data in context with the learners' activities in makerspaces, in-depth interviews with makers on a qualitative basis might be necessary to find out more about the actual activities that they performed while accomplishing their projects in the M.EE. Another possible approach of gaining access to the field could be to gather data about the learners' activities with the help of NFC-Tags and Big Data Analytics. In addition, concerning the current diversity of users, it may be necessary to enhance the present degree of popularity of the M.EE.

Furthermore, the survey will be revised and implemented on a Raspberry Pi server hosting the latest version of LimeSurvey. Supplementary questions regarding the learning processes and activities taking place at M.EE are expected to reveal more understanding about acquiring important skills in a digital world. The new server offers more possibilities of adjusting the survey to students' habits, so that hopefully more students will participate in the survey in the winter term.

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