Mapping the landscape of Makerspaces in higher education: an inventory of research findings

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Abstract

Purpose – The purpose of this study is to chart the development of Makerspaces in higher education (MIHE), by building a map of existing research work in the field. Based on a corpus of 183 manuscripts, published between January 2014 and April 2021, it sets out to describe the range of topics covered under the umbrella of MIHE and provide a holistic view of the field.

Design/methodology/approach – The approach adopted in this research includes development of the 2014–2021 MIHE corpus; literature overview and initial coding scheme development; refinement of the initial coding scheme with the help of a focus group and construction of the MIHE map version 1.0; refinement of the MIHE map version 1.0 following a systematic approach of content analysis and development of the MIHE map version 2.0; evaluation of the proposed structure and inclusiveness of all categories in the MIHE map version 2.0 using card-sorting technique; and, finally, development of the MIHE map version 3.0.

Findings – The research trends in the categories of the MIHE map are discussed, as well as possible future directions in the field.

Originality/value – This paper provides a holistic view of the field of MIHE guiding both junior MIHE researchers to place themselves in the field, and policymakers and decision-makers who attempt to evaluate the current and future scholar activity in the field. Finally, it caters for more experienced researchers to focus on certain underinvestigated domains.

Keywords Makerspaces, Higher education, Learning, Learning methods

Paper type Literature review

1. Introduction

When MIT founded the first Makerspace (Wilczynski and Cooke, 2017) within its campus, no one was expecting what would follow. Today MIT has 28 major Makerspaces scattered on its campus, naming this project as "Makersystem" (MIT Project Manus, 2019). At the same time, higher education Makerspaces, generally known as "Academic Makerspaces" are being developed rapidly in campuses around the world. The higher education making

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movement is a growing trend that arises principally from the need for universities to prepare students to cope with this highly competitive professional era (Julian and Parrott, 2017), combined with the need of exploring new approaches for curriculum modernization. As more higher education institutions introduce these spaces into their campuses, the greater the need for the research community to continue exploring their trends and topics that encompass them.

1.1 Maker education theoretical foundation

Review of the literature reveals that the educational field around Makerspaces is tied to constructivism and constructionism. Father of constructivism theory, Piaget emphasized the ineffectiveness of traditional teaching, adding the obligation of educational institutions to generate people that can produce new things, rather than the mere repetition of what previous generations accomplished (Fosnot, 2013). Papert, the originator of constructionism theory, as well as the main predictor of maker movement (Papert and Solomon, 1971), stressed the need to generate people who will know how to react to situations where they have not been previously prepared (Ackermann, 2001).

While constructivism describes the process of constructing knowledge inside the head of the students, Papert goes a step further by stating that the best approach of acquiring constructivism's theory goal is through active creation and sharing of something tangible, outside of student's head, which is the cornerstone of the constructionism framework (Papert and Harel 1991) . Constructionism acts as an umbrella over a lot of different pedagogical frameworks such as project-based learning, learning by doing, learning by example and problem-based learning that enables active learning. Constructionism theory lets students stand at the heart of the learning process where they can experience the concept of active learning in an authentic way (Rob and Rob, 2018).

1.2 Maker education and Makerspaces

Maker education is a term that the literature mentions Dale Dougherty (2012) as its inventor, who in 2005 having the goal to encourage high-tech fans to turn ideas into reality, announced the introduction of the Maker Movement in the USA. The Maker education is directly related to the learning of STEM (Science Technology Education Mathematics) and primarily takes the form of practical workshops generally with student-centered pedagogies, such as project and problem-based learning (Ying, 2018), and is usually conducted in places that promote authentic learning. These spaces are called "Makerspaces" while the people who participate in them are so-called "makers" (HSU *et al.*, 2017).

By definition, Makerspace is a multi-space that can consist of many sub-laboratories, in which experimentation, construction, invention and the acquisition of empirical knowledge are promoted. What makes these spaces special is that all of the above are achieved, always in the spirit of cooperation and solidarity elements that aim to establish communities and memories.

They focus on activities that mainly concern the construction of natural objects and practical workshops. Each Makerspace has its own character, but they retain the same idea, with the most important being providing open access to the general public regardless of age and occupation. It is notable that the motto of many Makerspace is common and states "All are welcome" (Drew Charter, 2019).

Additionally, Makerspaces are not limited to specific areas. Makerspaces can be found in schools, universities and libraries generally in any public or private facility.

1.3 Study rationale

In recent years, several studies have been conducted exploring MIHE effectiveness (Weiner *et al.*, 2018) revealing that Makerspaces in higher education can guide positively in the educational process in modernizing curriculum as a tool for the enhancement of teaching and can offer significant developmental experiences for a wide body of students, which can be difficult for a curriculum or course to offer on its own (Choi *et al.*, 2021). In addition, research demonstrates that graduates involved in Makerspaces were recruited quicker than others (MIT Project Manus, 2019). At the same time, literature reveals that there are still many challenges in managing these spaces in terms of participation (Betser *et al.*, 2016), making MIHE accessible and sustainable to be used by a wider audience (Bouwma-Gearhart *et al.*, 2021) and the necessity of developing laws and internal mechanisms (Dong *et al.*, 2022).

Although there is a wide research direction on exploitation of Makerspaces in education, K12 (Schad and Jones, 2020), maker platforms (Lin *et al.*, 2020), early entrepreneurial education (Schön *et al.*, 2018), student views (DOĞAN *et al.*, 2020), exploration of learning process (Lee and Kim, 2019), self-efficacy (Hilton *et al.*, 2018a) and participation challenges (Josiam *et al.*, 2019), there is not a recent review of the findings of research community in the field of Makerspaces specifically in higher education.

As the research literature constantly grows, the more the difficulty of researchers and practitioners to define the issues and trends across the field of MIHE. This study examines the recent scholarly activity, and maps the trending landscape of MIEH, which is critical for empowering academia with directions for future research.

The review of this study can be of value to higher education stakeholders, including educators, policymakers, researchers and learning experience designers by providing insights as to the various contexts that MIHE had been studied by researchers in recent years. It is hoped that future recommendations from this review will contribute to the effort of the research and academic community in the challenges of modernizing the curriculum, enhancing universities in their entire academic activity by applying new ways of communication, knowledge transfer and develop specific practical guidelines that under specific circumstances could let the implementation of Makerspaces and making activities in institutionalized settings.

1.4 Study objectives

Within in this context, our current study objectives are as follows:

- Generate a map, based on the categorization of existing literature review in the field of MIHE.
- Explore the main research objective of each category.

Following the thorough study of 183 research papers, journals and conferences, we adopted a bottom-up approach to address the above objectives and classify the topics that researchers undertake in the area of MIHE.

This classification aims to provide a holistic view of the MIHE topic providing guidance to new researchers who would be interested in dealing with the topic of MIHE to be introduced into the subject and the objectives of existing research, while at the same time, proficient researchers can focus on domains which require further investigation.

2. Methodology

As mentioned above, the purpose of this study is to map the current MIHE research using a systematic six-stage approach (Figure 1). Similar methodologies to the ones used in this study have been used in the past in the field of HCI (Zaphiris *et al.*, 2006) WEB (Yeratziotis and Zaphiris, 2018), ICT (Nisiforou and Zaphiris, 2020) and CALL (Parmaxi *et al.*, 2013). All data in the corpus were classified in the map following an expert-centered approach (using a focus group and the card-sorting technique). In the sections below, a detailed description of the adopted methodology follows.

2.1 Corpus

The framework of this study was set by developing the MIHE corpus which included 183 manuscripts published between January 2014 and April 2021 in journals and publications devoted to MIHE using Google Scholar search-engine (Gehanno *et al.*, 2013).

Both higher education and Makerspaces use different terminologies; therefore, our search strategy commenced initially by mapping our keywords. To develop our search strategy, we used the model of "Concept mapping" (Novak, 1990). We created two keyword categories, "Higher Education Terminologies" called Keyword/Search String 1 and "Makerspace Terminologies" called Keyword/Search String 2. Each category had its corresponding synonyms (Figure 2). For every search, we used together search strings from both keyword categories.

During the initial search, we found more than 7,000 articles. We then narrowed down search results by publishing date to restrict the results to the past 5 years, resulting in 4,920

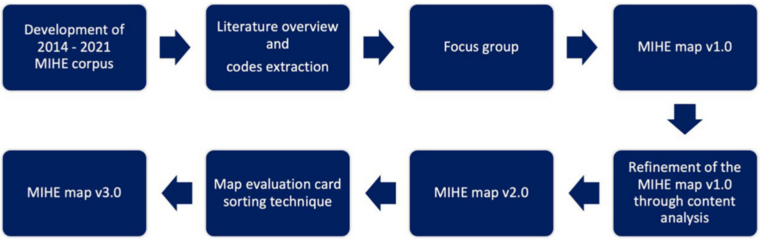

Figure 1.
Six-stage process adopted for the elaboration of the MIHE map

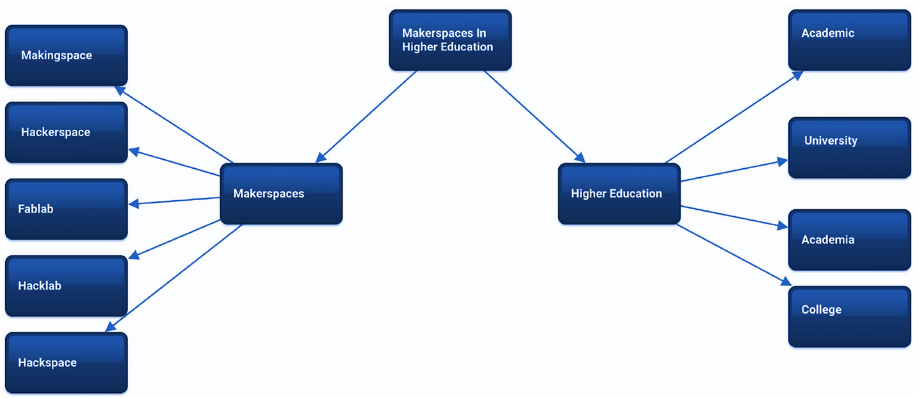

Figure 2.
Makerspaces in higher education concept mapping search strings used

articles. To maximize our search effectiveness, we studied Google Scholar's ranking factor. A study on Google Scholar's algorithm conducted by Beel and Gipp (2009) concluded that Google Scholar's highest-ranking factor is based on the article's citation count. Based on that, we reviewed the results of the first ten pages (Gao *et al.*, 2012; Lai and Bower, 2020) that were cited at least one time. Following 30 search combinations, using a keyword from both categories, we ended up with 183 manuscripts.

Then, each publication was thoroughly studied, with emphasis on abstract, introduction and conclusion to identify the keywords that describe the content of each publication. This whole process allowed us to proceed to the initial categorization of the articles.

We then narrowed the search for manuscripts of the aforementioned period to identify the research work of the past seven years and at the same time to be able to identify future research needs. Although the Google Scholar search does not represent all possible publications in the field of MIHE, the broad research focus on the study of Makerspaces suggests that they are likely to represent a substantial body of relevant studies.

2.2 Literature overview and initial coding scheme development

To familiarize with the 2014–2021 MIHE corpus, an initial overview of the 183 manuscripts were held, aiming to elicit their basic themes. To this aim, keywords were extracted from the title, abstract and keywords of each publication. The output of this stage was a collection of 19 keywords that described the basic themes of the corpus. The collected keywords were then used to develop an initial coding scheme with 15 code categories.

2.3 Focus group

A focus group was then hosted as a means to refine the initial coding scheme. Focus group is a valuable tool for generating data, orienting and exploring new research areas from the participants' own standpoint (Cohen *et al.*, 2013). The focus group was conducted with four academics and the researcher who were all employed in higher education, as lecturers and special teaching personnel. The goal was for the professionals to verify, expand or limit the initial coding scheme.

In this study, the focus group selected randomly 15 manuscripts (8.2%) from the indexed corpus and coded them either by using existing code categories or by generating new ones. Throughout this session, five new code categories were generated, thus expanding the initial 15 code categories to 20.

2.4 Makerspaces in higher education map version 1.0

The code categories were then organized into a map with an eye to meeting two criteria: internal homogeneity within the generated categories and external heterogeneity among categories (Patton, 2002). During the construction of the map, some categories were divided into subcategories, when the data imposed so. The subcategories were kept when differences among other subcategories were bold and clear. The output of this stage was the MIHE map version 1.0, which included 7 categories and 19 subcategories.

2.5 Refinement of the Makerspaces in higher education map version 1.0

The categories of the MIHE map version 1.0 were refined in a cyclical manner working back and forth between the data and the map to "verify the meaningfulness and accuracy of the categories and the placement of data in categories" (Patton, 2002, p. 466). Each publication was assigned to one of the categories, giving careful consideration to the wording of the title, abstract and keywords, as well as to the content of the introduction, conclusion and future implications/

considerations (if any). Each publication was included in only one category, based on the main focus of interest, because we seized for a clear-cut taxonomy – following the process adopted by Zaphiris *et al.* (2006). Saturation was reached when all manuscripts of the corpus could be classified into the existing categories, without any incongruity. The output of this stage was a revised map with 6 categories and 18 subcategories (MIHE map version 2.0).

2.6 Card sorting in predefined categories

The MIHE map version 2.0 was further refined, and the categories were cross-checked independently using the card-sorting technique (Plate 1). Card sorting is a useful technique in resolving disagreements on categorization by identifying trends and insights in the way people group and label content (Morville and Rosenfeld, 2006).

A total of 25 articles (13.6%) were chosen randomly from the 2014 to 2021 MIHE corpus and categorized for a second time by three new academics and the researcher. Researchers agreed on the main categorization and sub-categorization in 83.3% of the cases. Disagreements in the sub-categorization of five publications were resolved by discussing the classification differences, identifying the purpose and the contribution of those publications until full agreement in the classification was reached.

By the end of this stage, the MIHE map version 3.0 was established, which included 6 categories and 18 subcategories, that is, 6 major topics and 18 subtopics.

3. Map of Makerspaces in higher education

Once the data have been categorized, the researchers could count the number of studies included in each category, therefore, the most and least researched topics in the field. Figure 3 shows the MIHE map version 3.0 with the 6 topics and 18 subtopics. In Table 1, the detailed distribution of articles in the elaborated categories is presented, along with the number of studies included in each category.

The categories cover a wide range of topics related to MIHE. Not surprisingly, the use of Makerspaces in higher education has been studied by different researchers in different contexts. Two noteworthy topics arising from 2014 to 2021 MIHE corpus relate to "Framework of Planning Makerspaces in Higher Education" with 32/183 articles and "Enhance Teaching and Research using Makerspaces" with 19/183. These two topics occupy almost 30% of whole research conducted in the period from 2014 to 2021, a fact which is in line with Wong and Partridge (2016) research findings, that there is a "push" to establish Makerspaces in higher education institutions. There is also an increased interest in topics dealing with "Academic Recognition" and the "Preparation of transition from education to labour market". In addition, our study identified emerging categories dealing

Plate 1.
Card sorting in predefined categories

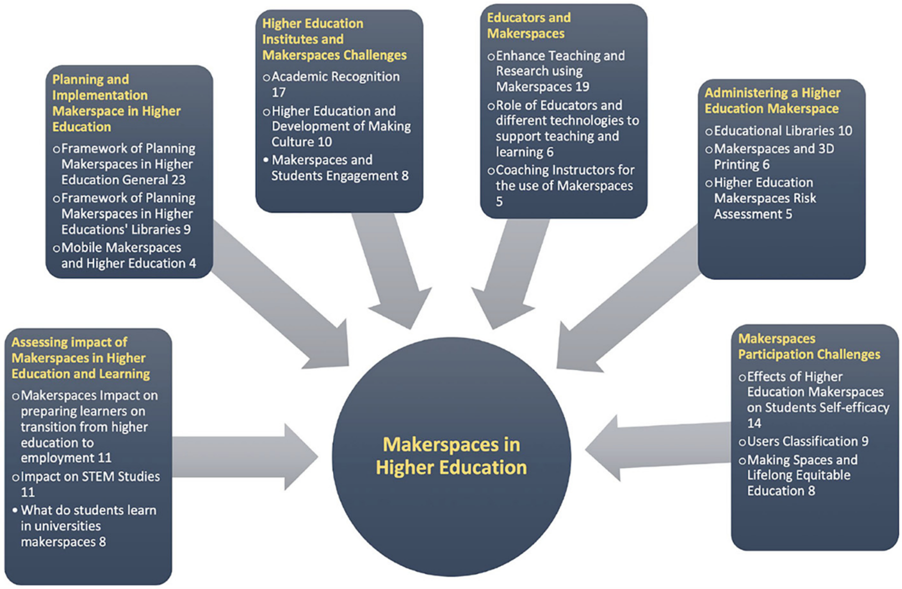

Figure 3.
MIHE map version 3.0

Table 1.
Distribution of studies in the elaborated categories of the map

Categories	Total number of research studies included in each category
Planning and implementation Makerspace in higher education	36
Higher education institutes and Makerspaces challenges	35
Makerspaces participation challenges	31
Assessing impact of Makerspaces in higher education teaching and learning	30
Educators and Makerspaces	30
Administering a higher education Makerspace	21
Total	183

with MIHE, such as "Higher Education Makerspaces Participation challenges", "Impact of MIHE on Students Self-Efficacy", "Development of Making Culture" and "Lifelong Education".

4. Synthesis of the findings of the Makerspaces in higher education map

As discussed above, the MIHE map includes six topics related to MIHE. Because space does not permit a thorough research review, we focus on synthesizing key issues arising from the corpus. Accordingly, the synthesis is organized using the concepts that evolved in the MIHE map.

4.1 Planning and implementation of Makerspaces in higher education

The growth of the Maker movement worldwide has forced the academic community to engage with and explore its integration into higher academic institutions. A project to succeed, a multidimensional research must be first carried out.

The main research objective of this category is the description and examination of various strategies for planning and implementing Makerspaces in higher education. More specifically, the researchers in this group aim to explore various frameworks of implementing Makerspaces throughout a campus planning (Choy and Goh, 2016), funding (Gonzalez and Bennett, 2014), marketing (Nowlan, 2015), facilities management (Zhang *et al.*, 2016), promotion (Herron and Kaneshiro, 2017), current trends and goals (Davis, 2018), student involvement (Tomko *et al.*, 2021) and equipment (Levy *et al.*, 2016) are among the main topics that have been thoroughly analyzed, in order to outline the required frameworks for the successful implementation of Makerspaces in Higher Education.

Additionally, research studies that fall into this category evaluate current Universities Makerspaces with respect to the Universities' implementation choices opted for their Makerspaces, whereas Kitts and Mahacek (2017) stress out that even though a framework can be consultative, the final choices must be made based on the realities of each university and their schools independently.

The main common finding of this category studies, highlights the importance of collaboration between various departments including schools, teachers, students, librarians during the planning and implementation of a new Makerspace. The collaboration of all the aforementioned stakeholders, ensures the establishment of a space that would enhance learning and literacy, maker culture, outreach and diversity. In contrast, the lack of cooperation condemns Makerspaces' viability.

4.2 Higher education institutes and Makerspaces challenges

The main research objective of this category is the evaluation of Makerspaces in institutionalized settings, such as academic recognition, students' engagement and making culture development.

It is accepted that accreditation is one of the main goals of higher education institutions as it is the method by which each curriculum and of the academic institution get certified in terms of their quality. Makerspaces and academic recognition have been questioned by many researchers.

The articles included in this category explore the academic benefits of Makerspaces in higher education. Burke (2015) highlights teamwork, Wallace *et al.* (2017) explored the benefits on problem-solving and knowledge sharing while others like Weinmann (2014) concluded that even if Makerspaces contribute effectively on practical skills, it is a trade-off between theory lectures and practical application.

A comprehensive study was conducted by Ylioja *et al.* (2019) calculating the workload of Makerspaces, based on the European Credit Transfer and Accumulation System (ECTS). The main objective of the study was to correlate the deliverables that were requisites to pass the corresponding courses with ECTS, concluding that the integration of Makerpsaces and Making Activities into formal curriculum is feasible.

Research in this category also focused on the Making Culture challenge. Several studies have been published examining the process of developing a making culture in higher education institutes. The evidence to date (Forest *et al.*, 2014) suggests that concepts of the culture of ownership, personal awareness and responsibility are necessary for the success of a making space. At the same time, library activities proved to be effective in fostering Making Culture among students (Beavers *et al.*, 2019).

Finally, this category includes studies which aim to foster student's engagement in Makerspaces. Student activation (Kaul, 2020), student-managed Makerspaces (Sullivan *et al.*, 2016) and outreach (Lotts and Maharjan, 2018) are among the key points described in the literature review. Student-centered Makerpaces need to be approached with caution, because there are many risks involved (Davies, 2017).

The major summary of recommendations of manuscripts that belong to this category highlights the crucial prerequisite of academic institutions and the research community to develop appropriate assessment tools and measures of the impact of Makerspaces on students, because the existing assessment of learning outcomes is usually based on subjective criteria. This will refute the doubts and concerns about the suitability of Makerspaces in institutionalized settings. In addition, another important finding turns out that different sizes of Makerspaces focus on different students population.

4.3 Participation challenges

The main research objective of this category is the assessment of participation challenges in Makerspaces, including the effects of learners' motivation impact on self-confidence, expectancy of success and anxiety (Morocz *et al.*, 2016).

This category incorporates studies which aim to evaluate the impact of Makerspaces on students' self-efficacy and belonging (Andrews *et al.*, 2021). Morocz *et al.* (2016) study showed correlation between Makerspace involvement and self-efficacy, and, at the same time, confirms that anxiety factor is a deterrent to student participation in Makerspaces (Hilton *et al.*, 2018b). Additionally, research studies that fall into this category have a comparative aspect, in the sense that they investigate the relation between freedom of movement and participation (Tomko *et al.*, 2017).

Additionally, equitable lifelong education is also under the microscope of research to identify the factors and changes required to be made; to strengthen the equal contribution of both genders. Studies demonstrate inequality in participation between men and women (Roldan *et al.*, 2018). Major importance is attached to the development of a framework that will contain the prerequisites of creating and managing a Makerspace to be accessible to all (Klipper, 2014) and at the same time various policies not become an obstacle to participation (Whyte and Misquith, 2017).

Finally, the users' classification is also under investigation by researchers, as part of the Makerspaces Participation Challenge (Saracino, 2021). Even if the advancement of available technologies can be beneficial for more technologically advanced Makerspaces, studies found that this does not guarantee participation.

Hynes and Hynes (2018) study titled "If you build it, will they come?" presents clearly the research community questioning. Hynes and Hynes (2018) apply environmental preferences predictors to classify the users and design Makerspaces, where Hilton *et al.* (2018a) study what influences students to participate by integrating a qualitative approach searching for relation between involvement and exposure. Among the attempts to engage a wider audience to Makerspaces, Shapiro (2016) suggested re-conceptualization of Makerspaces mission and marketing goals.

The main finding of the studies that fall into this category reveal that active participation in MIHE is correlated to specific design considerations, level of motivation, anxiety and the sense of community. The higher level of motivation a student has, the greater his participation will be. However, this is also related to the student's anxiety level, especially in terms of equipment usage that the student will encounter in a Makerspace. Based on this, researchers suggest the need for training and mentoring to alleviate the issue of anxiety. It is also suggested to strengthen the sense of community through signals of approachability and structured help-seeking. Finally, academia suggests that Makerspaces that are in order and clean state, through ideas for storage, seating and design aesthetic, get a higher rate among its users and ultimately enhance the participation.

4.4 Assessing impact of Makerspaces in higher education teaching and learning

We live in an increasingly competitive labor market environment where there is a need for university graduates to have the skills that can enable them to enter and survive in this new era. In this new order of things, universities must have the mechanisms for the continuous modernization of their curricula and teaching methods.

The main research objective of this category is the examination Makerspaces impact in teaching and learning. This is achieved by examining three basic pillars, impact on STEM studies, transition from higher education to employment and, finally, what students really learn in a Makerspace. The major research goal in this category is to assess Makerspaces' impact on various competencies and soft skills such as problem analysis and solving, teamwork, investigation and entrepreneurial skills (Galaleldin *et al.*, 2016). Among the technologies that have been explored by researchers, in terms of investigating Makerspace's impact on learning, are open-source software (Perquin, 2019), 3D printing and laser cutting (Tan *et al.*, 2016).

Additionally, researchers in this category sought to evaluate the impact of Makerspaces on preparation for professional careers. More specifically, Haji and Filippi (2018) discuss the positive impact on finding a career job, for students participating in MakerWorkshop (MIT Project Manus, 2019). At the same time, Flota *et al.* (2019) study suggests an alternative summer break internship in University Library Makerspace. Additionally, two studies (Pittaway *et al.*, 2019; Sheshadri *et al.*, 2018) reveal a positive impact of Makerspaces on developing entrepreneurial skills.

In summary, the literature of this category reveals a positive effect on learning new skills and concepts as well as on the development of soft skills, such as creativity, communication and collaboration, even for students who do not have any background in science and technology. In addition, academia highlights the different influence of making, between students of different majors, something that requires more in-depth understanding. Last but too important, is the necessity of development of specific practical guidelines that can guide higher education policymakers to apply making in formal curriculum.

4.5 Educators and Makerspaces

The main research objective of this category is the examination of educators roles and responsibilities into the subject of MIHE. More specifically, this category includes studies which aim to:

- outline the coaching process to instruct academics and teaching assistants how to effectively use Makerspaces (McMordie *et al.*, 2016);
- exploring the benefits of Makerspaces in terms of teaching and research enhancement (Shelley *et al.*, 2018); and
- evaluate the duties of Makerspaces teaching personnel to support teaching and learning (Duhaney, 2019).

The literature in this category stresses the importance of teacher's role in the successful operation of Academic Makerspaces and the benefits they can bring to the educational process. However, for teachers to play a key role in Makerspaces, research community underlines the prerequisite of teacher's preparation. The integration of Makerspaces in the curriculum and the guidance in using Makerspaces is of the utmost importance on how to use Makerspaces, eliminate confusion, unclarity and misconceptions in what exactly happens in Academic Makerspaces.

4.6 Administering a higher education Makerspace

The main research objective of this category is the exploration of various administration challenges of multidimensional nature of Makerspaces. The articles of this group provide examples of such; safety considerations (Love and Roy, 2018), user agreements (Moorefield-Lang, 2015), safety procedures (Jariwala *et al.*, 2016) and risk factors (Fang *et al.*, 2019) and discussing ways to minimize the spatial risk factors. Based on Fang *et al.* (2019) research findings, major importance is attached to the construction of risk indicators for higher education Makerspaces, discussing and evaluating external, operational, managerial and marketing risks.

On the one hand, the multidimensional space "[. . .] High-End Technologies, Dangerous Machines, Inexperienced Users, Sensitive Personal Data [. . .]" (Weiner *et al.*, 2018) and, on the other hand, the need to maintain freedom of access and use. All these together result in a very complicated area in a university, in terms of operation and management, because the literature advises that freedom of access and use are two major factors for the unending participation in such spaces.

Research articles in this group also focus on the importance of professional development of universities' Makerspaces staff members (Horton, 2019). The fact that Makerspaces are in line with the continuous technological developments including 3D printers, Augmented Reality, evolving APIs, Artificial Intelligence and Machine Learning techniques (Julian and Parrott, 2017), highlights the need for expertise and constant professional development.

In summary, the main research finding of the studies that fall into this category is the need for continued training and professional development of staff, which ensures successful administration of Makerspaces. In addition, there is a correlation of the existence of appropriate user agreements, policies and safety plans with the effective management of Makerspaces. The recommendation of the research community is the direct involvement of the health and safety compliance departments that will be able to identify the various hazards and ensure a safe and user-friendly learning environment. In addition, literature suggests that the existence of specific safety procedures and training allows the student-run Makerspaces with the advantages that surround it.

5. Discussion

Higher Education Making Movement is a growing trend that arises principally from the necessity universities offer formal education in modernizing societies. As more universities and colleges introduce Makerspaces into their campuses, the greater the need for the research community to further explore Academic Makerspace trends and challenges that encompass it.

Overall, this study revealed a strong body of evidence that Academic Makerspaces will play a key role in the evolution of higher education, suggesting a positive impact on learning and teaching. At the same time, a few important aspects require further examination. The following recommendations have been developed through the analyses of the 183 publications, with the aim to guide further research in Academic Makerspaces.

5.1 Implications for practitioners

With regard to the implications of our research for practitioners and policymakers, we would suggest higher education stakeholders follow an action plan that focuses on five crucial implications, that, according to literature and our study findings, can guide the successful implementation of Makerspaces into higher education.

5.1.1 Redesign curriculums to be Makerspace-inclusive. The first implication is about the need of the redesign of curriculums according to specific practical guidelines, to be Makerspaces-inclusive.

The literature suggests that the entire curriculum should be redesigned with the participation of all of stakeholders aiming at the tangible collaboration of theory lectures and practical hands-on. It is a fact that the integration of Makerspaces in a curriculum – in the form of more practical workshops – presupposes the reduction of theoretical lectures. This is a big issue, especially in the theoretical courses. The integration of Makerspaces into an existing curriculum without correct modifications is doomed to fail. The expression "Trade-off" has to be eliminated when it comes to discussing implementing Makerspaces in curriculum, because research experiments evidence has shown many achievements of students participating in courses with making workshops (Wallace *et al.*, 2017), confirming the importance of the implementation of Makerspaces in institutionalized settings.

5.1.2 Makerspaces' staff continuing education. The second implication is about the importance of continued training and professional development of staff, which ensures thrive operation of Makerspaces. The rapid development of technological tools and machines that can be used in a Makerspace – such as 3D printers and small single-board computers – has reduced the initial investment of setting up an Academic Makerspace, although still not enough to guarantee the success of a Makerspace in higher education.

There are several references in the literature regarding the support needed on using and administering Makerspaces. Research community highlights the need for continuing education and professional development of staff involved in these spaces (Horton, 2019). In Bowler's (2014) research, the ultimate goal was to identify the skills, aptitudes and knowledge a Makerspace staff must have. Other research suggests that the professional development of Makerspaces' staff allows them to stay up-to-date on the latest trends, as well as influence positively on other colleague's engagement (Purpur *et al.*, 2016). Research on the same subject has shown that professional development can have a positive effect on staff confidence levels (Paganelli *et al.*, 2017). Additionally, Filar Williams and Folkman (2017), in their project titled "Making Makers," concluded that interpersonal making-trainings are more efficient compared to online, as participants expressed greater engagement.

5.1.3 Engage students. The third implication concerns the correlation of student's engagement level and their active participation into Makerspaces. The studies in the category "Assessing Impact of Makerspaces in Higher Education Teaching and Learning" seem to shape new paths in the field, exploring the multi-layered affordances of student's engagement in Academic Makerspaces in relation to the impact on various competencies, such as problem analysis and solving, teamwork, investigation and entrepreneurial skills (Haji and Filippi, 2018). In addition, research experiments acknowledge its potentially positive contribution to values such as the sense of belonging and study enjoyment (Berg *et al.*, 2020). However, the study of the existing literature demonstrates that the existence of such spaces is not enough to guarantee participation, because it requires a lot of effort and encouragement to be used, especially from teaching personnel. Ultimately for this to be successful, it would be necessary for staff, educators, policymakers and instructional designers to develop the required conditions and tools aligned with theory and pedagogy, that can influence students' participation into making activities, and therefore their engagement.

5.1.4 Engage instructors. The fourth implication has many similarities to the previous one, but this time the educators are the protagonists. Teaching personnel must first recognize the role and benefits of Makerspaces, to encourage the use of these spaces. First of all, the academic community and the quality assurance bodies of the higher academic institutions must be convinced of the benefits of using these spaces and that their addition helps to reach accreditation goals. Current research reveals the positive potential of Makerspaces in higher education for both teaching and learning; however, for this to be massively implemented by the teaching personnel, there is a strong need for pedagogy to frame Makerspaces use, specific assessment and measuring tools, with always in mind the instructors' role, needs and opportunities in mind during instructional and learning experience design process.

Academics should also be adequately trained in terms of effective use of Makerspaces (McMordie *et al.*, 2016) for enhancing their teaching and research activities (Shelley *et al.*, 2018), and encourage their students to actively use them too.

Academics training should not be limited to a purely theoretical background; on the contrary, great importance should be placed on new expertise and constant professional development, because Makerspaces are in line with technology and rapid technological development "[. . .] 3d Printers Augmented Reality evolving APIs, Machine Learning techniques [. . .]" (Julian and Parrott, 2017). From thereafter, policymakers need to develop specific instructor's training and professional development plans, to achieve higher expertise and confidence among educators that will ultimately lead to greater engagement to academic Makerspaces and making co-curricular coursework.

5.1.5 Use Makerspace and career prospects. The last implication is interconnected with all previous ones and concerns the correlation of academic Makerspace potential with students' career prospects. This study reveals an active research effort on evaluating the impact of Makerspaces on preparation for professional careers (Haji and Filippi, 2018). More specifically, Haji and Filippi (2018) study discussed the positive impact on finding a career job, for students participating in Maker Workshop (MIT Project Manus, 2019). At the same time, Flota *et al.*'s (2019) study suggests an Alternative Summer Break Internship in University Library Makerspace. Additionally, two studies (Pittaway *et al.*, 2019; Sheshadri *et al.*, 2018) revealed a positive impact of Makerspaces on developing entrepreneurial skills.

For this to be proved scientifically, it would be necessary for the development of appropriate assessment tools and measures of the impact of Makerspaces on students' career prospects, because the existing assessment of learning outcomes is usually based on subjective criteria.

5.2 Implications for researchers

5.2.1 Advance the Making Culture in academic Makerspaces. Amongst the topics that deserve further research interest is the exploration of methods for creating Making Culture in higher education to widen active participation in Academic Makerspaces. Although the trend of developing more and more academic Makerspaces will continue at a very fast pace, the formation of a Making Culture is a prerequisite for those academic institutions seeking to create an inclusive, exciting and cooperative culture of learning through making.

More cross-sectional and longitudinal studies should be conducted to identify the literacies and knowledge that higher education stakeholders need to develop to emerge victorious in active and wide participation challenges.

5.2.2 Leverage the academic effects of Makerspaces through elaborate designs of teaching and learning scenarios. Further research should also be conducted on how higher educations' academics and teaching personnel can develop their study programs curriculum to be more Makerspaces-inclusive. The employment of longitudinal studies shall facilitate an in-depth exploration of academic Makerspaces utilization in study programs curriculum and how academics and teaching personnel can develop skills to enhance their confidence in integrating MIHE into their teaching pedagogy.

5.2.3 Investigate academic Makerspaces effectiveness on professional career preparation through longitudinal studies. Apart from very few studies that have lasted more than a semester (Haji and Filippi, 2018; MIT Project Manus, 2019; Flota *et al.*, 2019), this study revealed the importance of further research to be done to establish whether Academic Makerspaces can boost students' career prospects.

The effectiveness of Academic Makerspaces on student's successful professional career preparation is a crucial area that deserves further research. More comparative cross-sectional studies could be conducted to explore whether the Makerspaces' potential for "[. . .] Collaboration, Prototyping, Questioning [. . .]" can positively affect students to acquire needed skills for a successful professional career. Based on the findings of this review study, the obligation of universities to practice students coping with this highly competitive professional era (Julian and Parrott, 2017) is critical.

6. Conclusion and future research

Maker Movement is a rapidly growing trend within academia. This study charts the research development of Makerspaces in higher education in past seven years (2014–2021) by applying a six-stage approach for conducting systematic review of the literature, resulting in the development of MIHE map v3.0.

This study reviews publications that were published during the past seven years guiding researchers who are new to the field to place themselves in the field and policymakers and decision-makers who attempt to evaluate the current and future scholar activity in the field of Makerspaces in higher education. In addition, this study discusses empirical findings through existing research covering topics such as planning and implementation of MIHE, higher education institutions administration and participation challenges and teaching and learning impact.

This study concludes with topics that need further exploration such the elaboration of Makerspaces through instructional designs, design learning experiences and the development of specific practical guidelines.

More specific future research is needed in the areas of:

- the advancement of making culture in academic Makerspaces to enhance active and wide students and teaching personnel participation;
- Makerspace's academic effects through design learning experiences by using Makerspaces in study programs curriculum in the form of making co-curricular assignments and group projects; and
- Academic Makerspaces effectiveness on student's professional career prospect through longitudinal studies.

All the above directions for further research can contribute to the effort of the research and academic community in the challenges of modernizing the curriculum and enhancing universities in their entire academic activity by applying new ways of communication and knowledge transfer.

7. Limitations of the study

The intention of this study is to chart the development in Makerspaces in higher education, by building a map of existing research work in the field, based on a corpus of 183 publications, published between January 2014 and April 2021. Even though it sets out to describe the range of topics covered under the umbrella of MIHE and provide a holistic view of the field, this study does not aim to provide a comprehensive definition of MIHE.

The data of this study are available to anyone that may be interested to conduct further research on the topics held under the umbrella of MIHE. The results of the current study are limited to this particular corpus; however, the categories may reflect both present and future trends in the field of MIHE.

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Further reading

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