Makerspaces as learning spaces for sustainable development. A systematic literature review

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Abstract

Makerspaces have emerged as dynamic environments that foster creativity, innovation, and hands-on learning experiences. This article delves into the function of makerspaces as educational environment fostering sustainable development. The study seeks to emphasize the importance of makerspaces in cultivating the skills and perspectives essential for sustainable development in the 21st century. By performing a systematic literature review, it examines how makerspaces empower individuals to engage with sustainable practices and contribute to broader societal and environmental goals. The article delves into the multifaceted ways in which makerspaces support sustainable development through experiential education, collaborative problem-solving, and the application of emerging technologies. Additionally, it highlights the potential for makerspaces to bridge the gap between formal education and practical sustainability challenges, ultimately promoting a more sustainable and equitable future. The aim of the study is to underscore the significance of makerspaces in nurturing the skills and mindsets needed for sustainable development in the 21st century. In this sense, we performed a systematic literature review of publications from the ERIC and Google Academic databases. 33 articles met the inclusion criteria. Their analysis reveals that makerspaces contribute as learning spaces to sustainable development, in various ways, educating participants about sustainable development, but also fostering innovation, debate and social action towards the global goals of sustainability and justice. Overall, this analysis underscores the significant potential of makerspaces as learning spaces for sustainable development and education for development. They can not only educate students about sustainable development but also inspire innovation, debate, and social action towards global sustainability and justice goals.

Keywords: sustainable development, makerspaces, learning spaces, education initiatives, innovation

1. Introduction

Education for development, education for sustainable development, and education for global citizenship are deliberate educational approaches addressing issues of global justice and sustainability (O'Flaherty & Liddy, 2018).

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The global movement towards education reform is eager to establish an innovative ethical groundwork, encouraging improvement through performance incentives (Ball, 2003).

In a context where policy and education intersect, education for global citizenship is gaining increasing attention. It focuses on developing analytical skills, global understanding, empathy, and effectiveness to promote sustainability and justice. The growing interest in education for sustainable development is due, among other factors, to the increasing cultural diversity in society and the efforts of international development organizations (Baily et al., 2017; O'Flaherty et al., 2017). These developments mark a crucial moment in which global inequalities are scrutinized with greater importance, and all individuals are called upon to contribute to the causes or solutions to these inequalities (Liddy, 2013; McMorrow, 2016).

The Sustainable Development Goals (SDGs) set by the United Nations promote the idea that all learners should acquire the knowledge and skills necessary to contribute to sustainable development (UNESCO, 2015), with the objective of improving the quality of life on a global scale (O'Flaherty & Liddy, 2018).

In this perspective, education for development and education for sustainable development (ED/ESD) have become key components in preparing individuals to understand and address global challenges related to sustainability. However, the design and use of appropriate research methods, as well as managing the complexity and diversity of learning resulting from ED/ESD, require continuous research and innovation (O'Flaherty & Liddy, 2018). This aspect becomes particularly important, especially within the framework of Sustainable Development Goal 4.7 (O'Flaherty & Liddy, 2018).

While traditional education has often focused on the environmental aspects of sustainable development, it is observed that makerspaces, as places of innovation and creation, can play a significant role in expanding the appreciation and understanding of sustainable development, including its social and economic aspects, as the SDGs aims and concept encounter.

Makerspaces encourage learners to engage more critically and emotionally, thus contributing to a more comprehensive understanding of the concept of sustainable development (Walshe, 2017). It is important to note that sustainable development is not an inherent concept in makerspaces. However, the maker movement represents an emerging market for providers of tools, materials, and activities that contribute to the formation of essential skills that ensure sustainable development. Thus, makerspaces can become places where sustainable manufacturing practices can be experimented with and cultivated. Through hands-on experience in creating objects, a more responsible culture regarding materials can be promoted, contributing to sustainable development (Thorpe, 2012).

Makerspaces are educational spaces that facilitate the meeting and cross-fertilization of ideas, knowledge, and practices, emphasizing the need for strategies to attract a wide variety of participants (Smith & Light, 2017).

Makerspaces have the potential to transform mindsets and influence sustainable development by stimulating innovation and entrepreneurial practices, while providing a space where even those who are not creators, repairers, or hackers can engage in discussions and actions related to how things are made and their impact on society and the environment (Smith & Light, 2017).

This article will also address the contribution of makerspaces to public debate and partnerships for sustainable development. This is achieved through alliances built around debate topics, the specific contexts of makerspaces, and the resources they can bring to promote sustainability on a global level. Examples of relevant themes include technological citizenship, where rights and responsibilities related to technological advancements are deeply discussed, and ecological citizenship, which explores the connections between humans and the environment within complex ecosystems (Smith & Light, 2017).

The exploration of makerspaces as learning laboratories for sustainable development delves into significant and established themes, elucidating the intricate intersection of makerspaces, learning, and sustainable development. These key themes, such as Educational Impact, Sustainable Practices in Makerspaces, Community Engagement and Collaboration, Empowering Participants, Innovation for Sustainability, Assessment of Learning Outcomes, Teacher Training and Professional Development, Policy Implications, and Global Perspectives, collectively provide a holistic understanding of the multifaceted impact of makerspaces on sustainable development within the educational context.

Strengths associated with each theme contribute to the comprehensive exploration. For instance, the focus on the Educational Impact theme provides clarity on how makerspaces contribute to skill development and a nuanced understanding of sustainable development concepts. The Sustainable Practices in Makerspaces theme emphasizes the integration of eco-friendly materials and technologies, showcasing a commitment to environmental responsibility. Community Engagement and Collaboration recognize the social aspect of sustainable development, while Empowering Participants underscores the transformative potential of makerspaces on both personal and community levels.

Innovation for Sustainability acknowledges makerspaces as hubs for creative solutions to environmental, social, and economic challenges. Assessment of Learning Outcomes introduces crucial methods for evaluating the impact of makerspaces, while Teacher Training and Professional Development recognize the role of educators in guiding sustainable makerspace projects. Policy Implications address broader institutional contexts, advocating for the inclusion of makerspace-related skills in educational policies, and Global Perspectives provide a cross-cultural understanding.

Weaving these themes together enhances our comprehension of makerspaces' impact on sustainable development, offering actionable insights for educators, policymakers, and researchers. The article further explores the global movement

towards education reform, emphasizing an innovative ethical groundwork for improvement through performance incentives. It highlights the rising importance of education for global citizenship and sustainable development, aligning with the United Nations' Sustainable Development Goals (SDGs).

Traditional education's focus on environmental aspects is contrasted with the emerging role of makerspaces as places of innovation and creation. Makerspaces, through hands-on experience, promote a more responsible culture regarding materials, contributing to sustainable development. The potential transformative impact of makerspaces on mindsets, innovation, and civic responsibility is explored, emphasizing their role in public debate and partnerships for sustainable development.

In conclusion, the article aims is to underscore the significance of makerspaces in nurturing the skills and mindsets needed for sustainable development in the 21st century. More than that we will see how makerspaces contribute to sustainable development, addressing innovation, responsibility, and civic engagement. Through an in-depth analysis of relevant literature, case studies, and grounded theory, it endeavors to illustrate makerspaces' crucial role in creating a more sustainable, fair, and inclusive world. The selected sources, including academic journals, books, and research from reputable institutions, ensure the credibility and reliability of the information presented in the article

In this context, it is important to explore how makerspaces can contribute to sustainable development, addressing aspects related to innovation, responsibility, and civic engagement. A deeper analysis is needed to understand how makerspaces can become catalysts for positive changes in sustainable development, both by fostering innovation and promoting values of sustainability and global citizenship. In this article, we will explore how makerspaces contribute to sustainable development through various ways in which these spaces facilitate learning, stimulate innovation, and promote civic responsibility. We will investigate the crucial role that makerspaces can play in sustainable development, in creating an open community, and in generating solutions for global challenges. Through an analysis of relevant literature and case studies, we will attempt to illustrate how makerspaces can contribute to the development of a more sustainable, fairer, and more inclusive world by addressing the research questions: Do makerspaces contribute as learning spaces to sustainable development?

Do makerspaces have a role as learning spaces in sustainable development?

The grounded theory in defining the study's concepts was used based on the research methodology and the study's purpose. Classical theory in defining concepts in terms of essential and non-essential features, for example, to define the concept of makerspace, the essential characteristics would include educational space, a place where sustainable manufacturing practices can be experimented, etc. Grounded theory involves defining concepts through specific procedures and measurements. For example, to define the makerspace and its approaches in ESD, specific codes, concepts and categories have been derived in the systematic analysis of the literature undertaken, in our attempt to match

the two new fields of study, looking at types of technologies offered, potential of contributing to the different aspects the sustainable development addresses etc. Grounded theory approach allows us to define concepts in relation to others, relating to the environment in which the concept is used.

These sources are relevant and reliable for this article because they provide a well-rounded understanding of the topic, combining theoretical perspectives with practical applications and real-world impact. The rigorous review processes associated with academic journals, books by established authors, and research from reputable institutions contribute to the credibility and reliability of the information presented in these sources.

2. Methodology

2.1 Search and Inclusion Methodology

A comprehensive initial search was conducted to locate studies that explored themes related to how makerspaces could be learning spaces for sustainable development. Electronic searches were performed in two educational databases, Google Scholar and ERIC, as they are databases specialised for education (ERIC) and comprehensive in the way that reunites also studies and scientific reports, beside the peer review articles and publications.

The search algorithm included the following terms: "makerspaces," "sustainability development," "learning spaces," "education for sustainable development". In addition to the search algorithm restrictions, we also imposed the condition that the studies searched for should be within the time frame of 2003-2023, as both concepts, ESD and makerspaces are new developments in education mainly growing up in the last 20 years.

To include studies in the subsequent analyses, we considered 3 criteria:

a) the study must address a subject related to education for sustainable development in makerspaces as learning spaces and/or a related concept (e.g., sustainable development, educational creative spaces, etc.);

b) description of the nature of the tools used in the analysis/diagnosis of makerspaces as learning spaces for sustainable development and/or the related concept;

c) the study specifies the basic theory from which it started in defining the concepts.

All for the article aim, to underscore the significance of makerspaces in nurturing the skills and mindsets needed for sustainable development in the 21st century

2.2 Procedure

In the first stage, duplicate studies were removed using Mendeley Desktop reference management software, version Desktop for macOS 10.13 (High Sierra). Subsequently, for each of the two research questions, as no suitable coding example was found for the synthesis of literature, we created our coding and analysis grid, considering the following: the research question or issue addressed by the study; what are the key concepts and

how are they defined?; key theories, models, and methods used; whether the research uses established frameworks or adopts an innovative approach; and how the study contributes to the understanding of the subject, among other aspects. In creating the coding grid, we also took into account the recommendations from AERA for reporting research results in Standards for Reporting in Empirical Research in Social Science Research Publications (American Educational Research Association, 2016). Following this procedure, we identified 18 relevant articles in Google Scholar and 15 articles in ERIC. The coding grid was completed by two independent evaluators.

3. Research Findings

After analyzing the information from the studies identified as relevant, several key aspects and conclusions regarding the contribution of makerspaces as learning spaces for sustainable development can be observed:

1. *Relevance of Education for Sustainable Development (ESD):*

The information emphasizes that ESD represents deliberate educational approaches that focus on issues of global justice and sustainability. They are responses to challenges related to cultural diversity, inequalities, and sustainable development, with the Sustainable Development Goals promoted by the United Nations supporting them as an integral part of shaping the future for all individuals. In the social sphere, this study aims to contribute to public policy makers, since they can learn about the competences related to the SDGs that can be developed in higher education and its operationalization and propose educational regulations accordingly (Dias et al., 2022). In China educational sectors promoted ESD because sustainable development has been emphasized in the national political strategy (Li et al., 2022). The Sustainable Development Goals set out by the United Nations advocate that all learners will have the knowledge and skills needed to promote sustainable development (O'Flaherty, Liddy, 2018). Also, Education for sustainable development (ESD) persists as an important concept within international policy and yet, despite considerable debate, there remains a lack of consensus as to a pedagogy for ESD in schools (Walshe, 2017). Management education needs to not only embeds sustainability and responsible management throughout, but that plays a crucial and active role on a global stage in moving the SDGs forward (Weybrecht, 2017).

2. *Transformation through Education:*

There is a global movement in education reform aiming to build a stronger ethical foundation, supported by performance incentives. This involves changes in educational policies to promote the development of critical skills, empathy, and effectiveness, with an emphasis on sustainability and justice. In responding to globalisation, Irish curricula advocate active learning and cooperative groupwork methods in second-level schools but there are many difficulties in implementing them (McMorrow, 2006). Curriculum and education policy makers should take the necessary steps to ensure that the generic skills so characteristic of the TY (transition year) experience become key elements in the learning experience of all students (O'Flaherty, Gleeson, 2017). Thorpe (2012) highlight

five specific methods that designers use in working for social change. Education at a Glance addresses the needs of a range of users, from governments seeking to learn policy lessons to academics requiring data for further analysis to the general public wanting to monitor how its country's schools are progressing in producing world-class students (Indicators, O. E. C. D. 2012).

3. *Addressing Global Inequalities:*

Inequalities worldwide are being scrutinized with greater importance. ESD plays a crucial role in addressing these inequalities by promoting understanding of each individual's role in causing or preventing them. This involves a reworking of the relationships between individual commitment and action in the organization (Ball, 2003). The higher educational institutions can assume a prominent position in the 2030 Agenda implementation for sustainable development of the United Nations, especially in the Goals 4 and 10, quality education and reduced inequalities, respectively (Daú et al., 2023).

4. *Direct Contribution of Makerspaces to Sustainable Development:*

Makerspaces are creative and innovative spaces that can significantly contribute to sustainable development. They facilitate the creation of sustainable prototypes and models, the use of renewable energy, stimulate the circular economy, and promote repair and recycling practices. Moreover, these spaces engage people in discussions about how products are produced and used and their impact on the environment, about passion for do (Gurjar, 2021). The makerspace serves as a specialized learning environment (Becker, Jacobsen, 2023) and makerspaces are viewed as epistemic environments beneficial to knowledge-building, of STEM (Falloon et al., 2020).

5. *Role of Makerspaces in Public Discourse and Partnerships for Sustainable Development:*

Makerspaces can contribute to public debates and build partnerships for sustainable development. By exploring topics related to technological citizenship and ecological citizenship, these spaces can influence decisions and norms related to sustainable development.

Actors who consciously and visibly strive to enact the espoused Fab Lab ideology, i.e. offering access to empowering, distributed technologies that enable people to meet their own local needs by design, appear better able to identify and tackle the environmental sustainability issues as they arise (Kohtala, 2016). Makerspaces aim to revolutionize the current higher education by providing a means for students to be directly involved in many scientific projects and develop various kinds of skills (Zhan et al., 2022).

6. *Community Building and Diversity:*

Makerspaces bring together people with diverse interests and skills, promoting a culture of change and sustainable development. This involves efforts to ensure inclusion, diversity, and the building of an open community. Furthermore, the use of creative spaces in educational contexts supports the development of 21st-century skills (Konstantinou, et al., 2021). Economic structure is found to have exerted some influence on the resistance and recoverability of certain regions, in general 'region-specific' or 'competitiveness' effects appear to have played an equally, if not more, significant role

(Martin et al., 2016). Overall, this information suggests that both education for sustainable development and makerspaces play a significant role in promoting sustainable development, encouraging creative and innovative approaches, and bringing people together in a collective effort to address issues related to global justice and sustainability.

7. *Innovation in Makerspaces:*

It is indicated that makerspaces are not just spaces for production but also places of innovation. They can bring together people and unconventional technologies to solve various issues, including those related to sustainable development.

Makerspaces are not only places of manufacture and creation, but also centers of social innovation. They can support innovation in multiple forms, contributing to sustainable development and an innovative democracy. For example, the similarities between sustainable development and an innovative STEM makerspace consist in promoting critical thinking, responsibility, creativity, multidisciplinary collaboration, careful choice of pedagogy, thus contributing to the preparation of young generations to address the complex challenges of the future (Soomro, et al., 2023). Increased enthusiasm with STEM and Arts fields indicates to us the power and potential of makerspaces in the future of education (Jordan et al., 2021). Social innovation is an important instrument for understanding how contemporary societies deal with social change and how social practices and policies intended to combat poverty and social exclusion are developed and implemented effectively (Moulaert, 2013). Also Smith (2017) says that social innovation requires a transformation in innovation practices.

8. *Openness to the Public and Debates:*

The literature emphasizes that makerspaces can be open not only to creators and technicians but to a wider audience. They can organize debates and discussions on subjects like technological citizenship and ecology, contributing to increased awareness and engagement. Thus, establishing a connection with innovative democracy and prioritising DE-related research and reflection (Baily, O'Flaherty, Hogan, 2017). Turkey's Ministry of National Education started to establish makerspaces called Design and Skills Labs (DSLs) in every public school across Turkey by 2023 (Demirata, Sadik, 2023). Double-dividend employment generating and footprint reducing achieve sustainability in ways that enhance well-being (Schor, White, 2010).

9. *Potential of Makerspaces for Social Transformation:*

Makerspaces can have a significant role in transforming society by encouraging sustainable resource use, innovation, and entrepreneurship. They can serve as incubators for solutions to social and environmental issues and Melo & March (2023) highlights the need for deep learning through technology. For example, in Jordan, specific sustainable development activities in makerspaces established as learning spaces significantly contribute to improving higher education, economic development, and laying a solid foundation for the future. Here, makerspaces not only develop skills but also build bridges between academia and industry, contributing to a more prosperous and balanced future echilibrat (Almajali et al., 2023).

Framing the makerspace mindset with platforms for creativity illuminates the potential for making and learning to grow creative, curious individuals who together will form an engaged society of learners at large (Culpepper, Gauntlett, 2020).

Community-based digital fabrication workshops (such as Hackerspaces, FabLabs and Makerspaces) are innovative spaces where people come together to learn about and use versatile digital design and manufacturing technologies and create things in collaborative projects. Some spaces are run voluntarily, whilst others receive institutional support (eg from universities and libraries), but all share an ethos towards providing workshops that can be freely (at least in parts) accessed by the wider public (Hielscher, Smith, 2014). Also, Smith & Light (2017) revealed the need for strategies that counter the incumbent social structures that influence ostensibly 'open' makerspaces, and thereby enable the tools and capacities available to work on more sustainable developments.

Overall, this analysis underscores the significant potential of makerspaces as learning spaces for sustainable development and education for development. They can not only educate students about sustainable development but also inspire innovation, debate, and social action towards global sustainability and justice goals.

4. Discussions

ESD is essential for addressing issues of justice and sustainability on a global scale. The Sustainable Development Goals promoted by the United Nations support ESD as a crucial part of individual formation. It is essential to find ways to support the planet's resources while ensuring the well-being of a growing population (Dias et al., 2022). The way learners think and act will bring significant changes in organizations worldwide (Weybrecht, 2017). In the context of looking for more educational solutions for ensuring a sustainable development in all its complex environmental, societal, economic and inclusive dimensions, the article advanced the solution of makerspaces as creative and integrative learning environments having the potential to contribute to the sustainable development desiderata. The aims was to provide a deep perspective on the contribution of makerspaces to sustainable development, pointing towards:

Transformation through Education:

A global movement to reform education is observed, encouraging the development of critical skills, empathy, and effectiveness, with a focus on sustainability and justice. The ambitious goals for the global community's future., and among them the one of ensuring sustainable development througn quality education inclusivity, equity, and lifelong learning opportunities for all (Goal 4) (OECD, 2015), forces looking for new ways of ensuring education of future generations. In the future of education, transformation is also driven by the increased enthusiasm for STEM and arts domains found in makerspaces through the transformative impact of artistic practices (Jordan et al., 2021).

Addressing Global Inequalities:

ESD plays a crucial role in addressing global inequalities, promoting an understanding of each individual's involvement in this issue. The increased emphasis on global

inequalities is an evolution with the growth of cultural diversity in society and the efforts of international development organizations (Baily et al., 2017; O'Flaherty et al., 2017), and all individuals are called to contribute to the causes or solutions of these inequalities (Liddy, 2013; McMorrow, 2016). Markerspaces, as (non/)formal learning spaces, have the potential of being open to everyone, as collaborative spaces.

Beside their inner potential, the studies analysed in the literature review highlight the fact that makerspaces can have a *direct contribution* of to sustainable Development in many ways:

Makerspaces facilitate the development of sustainable prototypes and models, promote a circular economy, and stimulate discussions about the impact of objects on the environment. Makerspaces have the potential to transform mindsets and influence sustainable development by stimulating innovation and entrepreneurial practices, offering a space where even those who are not creators, repairers, or hackers can engage in discussions and actions related to how things are made and their impact on society and the environment (Smith, Light, 2017).

Therefore, makerspaces can and should play a role in the *public discourse and partnerships* for sustainable development:

These spaces can influence decisions and norms related to sustainable development by exploring topics related to technological and ecological citizenship. Makerspaces encourage learners to engage more critically and emotionally, thus contributing to a more comprehensive understanding of the concept of sustainable development (Walshe, 2017). The increase in cultural diversity in society and the efforts of international development organizations (Baily et al., 2017; O'Flaherty et al., 2017) are developments in which global inequalities are analyzed with greater importance, and all individuals are called to contribute to the causes or solutions of these inequalities (Liddy, 2013; McMorrow, 2016). Makerspaces bring together people with diverse interests and skills, promoting a culture of change and sustainable development. Overall, the analysed studied offer arguments for the p*otential of makerspaces for social transformation*: Makerspaces are not only for production but also for social innovation, bringing together people and unusual technologies to solve various problems, including those related to sustainable development. They can play a significant role in transforming society by promoting the sustainable use of resources, innovation, and entrepreneurship, building bridges between the academic world and industry.

The makerspaces are suitable places to foster *innovation*. Innovation actually takes a plurality of specific forms and appears in a variety of spaces for a variety of purposes (Smith, 2017). The dominant image and practice of innovation focus on creating links with technology-based firms working with research institutes and investors, aided by a political environment that facilitates systemic interaction between these institutions, aiming at economic growth (Martin et al., 2016; OECD, 2010). However, innovation can also occur in other situations involving unusual combinations of people and technologies pursuing different purposes. The global current of innovation as a basis for sustainable

development is an example (Smith et al., 2017), and the social innovation agenda is another example (Moulaert et al., 2013).

By synthesising the potential contributions of makerspaces as learning spaces to the sustinable development, the article has the merit of advancing potential solutions of conceptualising education in formal and nonformal contexts, advocating for considering the ways in which the learning environments have the caractheristics of makerspaces. Using the grounded theory approach, the analysis differentiate main ways and arguments for which makerspaces can contribute to ensuring education for sustainable development.

However, the study does not provide insights in how this aspect can be acomodated, further research being needed. The study has also the limit of a relative small number of studies identified in the minimal synthesis of literature undertaken, and a more extensive exploration, in more databases is advicible to be performed, since there may be relevant studies that were not included in our analysis, which could lead to an incomplete perspective on the contribution of makerspaces to sustainable development.

Also, the results of this study are based on a literature analysis and do not capture the variety and specificificy of makerspaces in various contexts or regions. Not all makerspaces may have the same influence on sustainable development, therefore, more research either meant or mapping and surveying patterns, or aimed to provide inspiring study cases should complement this first analytic attempt. This analysis indicates the need for further research to better understand the specific impact of makerspaces on sustainable development in different contexts. Case studies and comparative analyses could shed light on how makerspaces can be optimized to maximize their contribution.

The results pave the way for the development of educational and environmental policies that promote the use of makerspaces for sustainable development. Governments and organizations can explore ways to integrate ESD concepts into their education systems and support makerspaces in their communities.

The implications of this study emphasize the importance of education and training within makerspaces to develop critical skills and promote global and sustainable citizenship. Educational institutions and organizations should develop ESD-centered educational programs and encourage teacher training in this regard.

Makerspaces can become catalysts for innovation and social development, promoting sustainable solutions to societal and environmental issues. Communities and organizations can explore partnerships with makerspaces to develop solutions to current problems.

Cultivation of innovative democracy because public debate and participation can be encouraged through makerspaces, contributing to a more open and inclusive decision-making process regarding sustainable development.

This study highlights the importance of balancing 21st-century skill development with environmental protection. Thus, young generations can be prepared to address the complex challenges of the future in a sustainable way.

Makerspaces can function as bridges between academia and industry, facilitating economic development and promoting a more prosperous and balanced future. These implications suggest that makerspaces have the potential to bring about significant changes in the field of sustainable development, education, and innovation, contributing to the construction of a more equitable and sustainable future.

5.Conclusions

This study was conducted with the rationale that education for development, sustainable development represent an essential educational approach and aspiration addressing global sustainability, necessitating educational solutions that substantially contribute to this aspiration. With its mission to promote understanding and responsibility towards sustainable development, integrative educational interventions have become increasingly relevant in the context of growing cultural diversity and the emphasis on development and justice.

Changes in policies and the Sustainable Development Goals established by the United Nations provide clear evidence of commitment to these ideas. However, to ensure their success, adequate design, appropriate research methods, and innovative approaches are required, considering the complexity and diversity of learning in these areas. In this article, we proposed exploring the contribution of makerspaces to achieving education for sustainable development.

Makerspaces, although not initially focused on sustainable development, have the potential to significantly contribute to this goal. By providing an environment where sustainable prototypes can be created, sustainable energy solutions can be explored, recycling businesses can be supported, and communities interested in sustainable development can be developed, these spaces can play an important role in promoting a more environmentally conscious and material-conscious culture, as studies and publications in the last 20 years have highlighted. The 33 publications analyzed have shown that makerspaces can contribute to ESD and sustainable development in multiple ways: they are multifunctional educational spaces, not just for creators or technologists but can involve participants who are not directly involved in the production process. These spaces can organize activities and events to engage the wider public in discussions about how objects are made and used, with a focus on sustainable development and civic responsibility. Additionally, makerspaces can play an important role in public debates and the creation of alliances for sustainable development. By engaging in these debates and collaborating with other communities, these spaces can contribute to creating the conditions for sustainable development worldwide, with examples of topics related to technological and ecological citizenship.

Furthermore, makerspaces as creative educational spaces with the potential to foster innovation, an essential ingredient in sustainable development, are incubators for economic development, interaction, and social inclusion. Makerspaces are not only beacons of innovative democracy but spaces where participation, deliberation, and the

new community in technology development are open. Therefore, they can be instructive for innovative democracy and the transformation of social innovation Smith (2017).

In conclusion, makerspaces represent fruitful places for exploring the norms, incentives, and practices of complex communities, bringing together technology, resources, and environments in an open and accessible space. These places can be catalysts for social innovation and can provide meaningful learning and education about sustainable development. Thus, in this regard, makerspaces have the potential to significantly contribute to sustainable development, and this analysis emphasized the importance of makerspaces in promoting sustainable development and developing the skills necessary to address the challenges of the future.

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