A DESIGNER'S UNDERSTANDING OF THE MAKER MOVEMENT

von Platen, Vilhelm;
Kitani, Yoji

Kyoto Institute of Technology

ABSTRACT

The maker movement has garnered interest from many disparate fields, from engineering to business management, to behavioural science, to city planning. The reason for this interest no doubt stems from the promised potential of the maker movement to revolutionize not only product creation and manufacturing, but in extension the economy around it. This paper examines existing literature across disciplines for evidence of what the maker movement has achieved so far, with a focus on implications for the field of Industrial Design.

Keywords: Maker movement, Entrepreneurship, Collaborative design, Innovation, Industrial design

Contact:
Järnefors von Platen, Vilhelm Gustav Henrik
Kyoto Institute of Technology
Japan
d2882501@edu.kit.ac.jp

Cite this article: von Platen, V., Kitani, Y. (2023) 'A Designer's Understanding of the Maker Movement', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.11

1 INTRODUCTION

The maker movement with its wide-reaching vision of technological emancipation and revolutionary mode of production is promising to change the way we make artifacts, moving conception, design, and production of material artifacts into the hands of the user. But what does that mean for the people that are already occupied with the creation of products? In this literature review, we aim to create an understanding of the maker movement from the perspective of industrial design. In order to achieve this, we aim to answer three questions (1) What is the promise of the maker movement, (2) What is the current status of the maker movement, and (3) in what ways does it relate to the field of industrial design? The paper is structured into three parts: First a general description of the maker movement, its promise, and potential. Second, a description of the actual impact of the movement so far. Third, a discussion on how the maker movement relates to the field of industrial design.

1.1 Method

This study was conducted as a structured literature review (Webster and Watson, 2002) with source material collected first through a broad search in Google scholar, as well as the databases Elsevier, Emerald, Springer, and Sage, followed by a deeper search in journals in the field of design. The resulting articles were reviewed and citations in and of those articles were considered, with relevant ones added to the list of papers reviewed.

2 THE MAKER MOVEMENT, ITS POTENTIAL, AND PROMISE

The term "maker movement" is widely attributed to Dale Dougherty, founder of Make magazine, that describes participants of the movement as enthusiasts and tinkerers closely aligned with new technologies and digital tools, people that feel the need to engage with objects not only as consumers (Dougherty, 2012). The movement is not precisely defined but rests on a set of overlapping initiatives and ideas. (Ferretti and Lente, 2021) The movement is further summarized by (Browder *et al.*, 2019) as (1) diverse actors interact and collaborate through social exchange in (2) knowledge creation and sharing spaces while (3) using technological resources to produce material artifacts.

2.1 History of the maker movement

The maker movement has been described as a continuation of earlier Do It Yourself (DIY) culture such as the counterculture of the 1960's, Silicon valley's computer enthusiasts in the 1970's, and zine culture in the 1980s. (Anderson, 2012; Dougherty, 2012) Parallels to counterculture have been drawn further back to the Luddites of the 19th century and the Arts and Crafts movement at the turn of the 20th century, where each movement has provided an answer to technological changes that in turn drive societal change. (Dellot, 2015) While the maker movement exists as a continuation of other DIY cultures and as such has no start date, a time of notice is 2005 that saw the introduction of Make Magazine (Dellot, 2015; Rosa *et al.*, 2017)

2.2 Participants of the maker movement

The maker movement is described by its proponents as an open movement where anyone with an idea can participate without prior knowledge, and that the scope of potential participants is universal, as everyone is in some way a maker (Anderson, 2012; Dellot, 2015; Dougherty, 2016; Hatch, 2014). In practice, the maker movement has received criticism for being an overwhelmingly male domain (Chachra, 2015; Quattrocchi, 2013). Statistics from Maker Media (*Maker Market Study: An In-Depth Profile of Makers at the Forefront of Hardware Innovation*, 2012) confirms this view and also shed some light on educational background, showing that 81% of makers are male, with 97% having attended or graduated college. A demographic study of participants in the Bay Area Maker Faire (*Maker Faire Bay Area Attendee Study*, 2012) shows similar results with 66% being male and college graduates and higher making up more than 87% of adult visitors. This is also mirrored by data of participants in maker spaces in Korea (Kwon and Lee, 2017), where 96.8% of participants were male. In the same study, 71% of participants held a college degree or higher, with 86,4% in engineering and 9.1% in arts and design, suggesting that participants generally had familiarity with creating objects from academic study.

https://doi.org/10.1017/pds.2023.11 Published online by Cambridge University Press

2.3 Modes of operation of the maker movement

What sets the maker movement apart from earlier DIY movements is the use of advanced programmable tools such as 3D printers and laser cutters, as well as the use of the Internet for sharing information and designs, designs that can sometimes be commercialized. (Anderson, 2012; Dougherty, 2016)

2.3.1 Tools of the maker movement

The maker movement is characterized by using digital programmable tools, such as 3D printers, laser cutters, and CNC routers, but also programmable electronics, like Arduino and Raspberry Pi. Makers are however not limited to the use of digital tools, but also make use of more common shop machinery, such as band saws, sanders, and sewing machines (Dellot, 2015; Hatch, 2014; Lang, 2013)

2.3.2 Shared spaces and spaces for sharing

The maker movement is often connected to physical shared spaces for making, tinkering, and hacking physical objects. These spaces are known as makerspaces, fablabs, and hackerspaces, sometimes interchangeably, depending on the direction of each individual space. Besides working as places to physically work on projects, these spaces work as venues of knowledge sharing, both informally and in formal ways, through workshops and seminars. (Dellot, 2015; Hatch, 2014; Rosa *et al.*, 2017) Besides physical sharing spaces, virtual sharing spaces exist where makers can freely share both knowledge (i.e. instructables.com) and designs (i.e thingiverse.com). (Dougherty, 2016; West and Kuk, 2016; Wolf and Troxler, 2016)

2.3.3 Stages of making

Dougherty categorized making activities into three stages of making: Zero to maker, maker to maker, and maker to market. (Hagel *et al.*, 2013; *Impact of the Maker Movement*, 2013) Zero to maker denotes a stage of learning, where anyone with an idea takes part of information and activities in the movement in order to gain the skills necessary to materialize the idea. Maker to maker denotes sharing activities, both in the sense of sharing the learnings and design outcomes of maker activities, but also collaboration on projects both online and in real life. Maker to market denotes the process of commercializing maker projects. Dougherty notes that going all the way to commercialization is optional and not necessarily the end goal of the maker movement. (Hagel *et al.*, 2013)

2.3.4 DIY principles of making

As a DIY movement born out of counterculture, makers use principles and strategies that make personal production affordable to a layperson. Camburn and Wood (2018) found and sorted DIY principles into five major categories: Repurposing – using commercial products in novel ways to decrease development effort and cost (also referred to as hacking), Satisficing – a minimum viable quality approach to achieve desired function, Stencilling – creation of patterns or jigs to simplify creation of complicated parts, Standardizing – using the same processes and strategies for as many parts as possible in order to decrease production complexity, and Layering – using materials that complement each other's properties to achieve the desired mix of properties.

2.3.5 Scaling of the maker movement

While traditional manufacturers increase scale by increasing production, the distributed character of the Maker Movement rather puts emphasis on training and scaling the number of Makers. (Tabarés and Kuittinen, 2020) The same adaptable production strategies and tools that help makers gain entry to niche markets where they can compete on novelty and customization, also prevent them from efficiently scaling up, keeping them in smaller, long-tail market segments with low-volume, high-margin production. (Doussard *et al.*, 2018) The parallel between making and open-source software is limited by the physical nature of maker objects, as they need material resources, packaging, storage, and distribution, none of which exhibits the infinite scaling of open-source software. (Li *et al.*, 2021) One pathway to scaling that is often brought up in connection to the maker movement is crowdfunding, where an entrepreneur publishes a description of a potential project on a crowdfunding website (i.e. Kickstarter.com or Indiegogo.com), where supporters of the project can give a pledge that is transferred to the entrepreneur once the project reaches a set threshold. (Anderson, 2012; Jensen and Özkil, 2018; Lang, 2013)

https://doi.org/10.1017/pds.2023.11 Published online by Cambridge University Press

2.4 Motivations of the maker movement

The motivations of the maker movement vary between makers, from commercial to idealistic to recreational (Dougherty, 2016) Makers are generally not motivated by economic or entrepreneurial factors but rather by innovation, passion for technology, and social progress (Tabarés and Kuittinen, 2020) mirroring previous DIY movements, that served functions such as an agency of independence, self-reliance, self-identity, and an alternative to passive consumption (Atkinson, 2006). Ferretti and Lente (2021) show the emphasis on making as a hobby foremost. Kwon and Lee (2017) studied what motivations affect making and found that gaining use-value encourages community participation, which in turn encourages making. Extrinsic and status motivations do not necessarily encourage community participation but do encourage making.

2.5 The promise of the maker movement

The maker movement and its associated technologies have been described as the new industrial revolution. (Anderson, 2012; Berman, 2012; Dougherty, 2016; Gershenfeld, 2005; Hatch, 2014; Lang, 2013; Maietta and Aliverti, 2015) The general idea behind this description is, as described by Langley et al. (2017), that "New digital fabrication technologies are enabling a new wave of citizen design, experimentation, and innovation.", as new digital manufacturing technologies have become available to the layperson, the design and manufacture of physical objects will move into the domain of the user. This line of thought is not unique to the maker movement but ties into several concurrent discourses, that can further explain the idea of the maker movement as the new industrial revolution:

2.5.1 The maker movement and user innovation

User innovation refers to the innovation that is performed not by producers but rather by the users of products, outside the control of a product's original producer. These innovations are often shared with the original producer, shared openly in a user community, or commercialized by the innovators themselves. (Baldwin *et al.*, 2006; Baldwin and Hippel, 2011; Gambardella *et al.*, 2017; Hippel, 2005) The innovations are often made by lead users that have identified new problems and have the capability to solve them (Hippel, 1987). This is mirrored by the concept of "the creative consumer" (Berthon *et al.*, 2007), where consumers adapt, modify, or transform products for their own needs, without input from the product's original producer. Both concepts closely resemble the maker movement, where the maker takes the role of the lead user or creative consumer, and with a DIY/hacker ethos modifies existing products or creates new ones to better suit their needs.

2.5.2 The maker movement and mass-individualization

Mass-individualization describes the process of creating individualized products from open hardware platforms and functional modules, analogous to smartphones and software applications, where each configuration is uniquely configured by the user through a user interface. (Koren, 2010; Koren *et al.*, 2015; Sikhwal and Childs, 2021) There are several parallels between mass-individualization and the maker movement, with regard to open hardware platforms, modularity, and individualized manufacturing. Modular approaches are used extensively in the maker movement, for example in the use of modular electronics based on the open hardware platforms Arduino and Raspberry Pi. Where the maker movement diverges is by removing the middleman manufacturer, instead having both the design, configuration, and manufacturing of a product made by the maker herself.

2.5.3 The maker movement and distributed manufacturing

Distributed manufacturing refers to production of physical goods that is geographically distributed and located close to consumers, enabled by new production technologies and IT systems, and enabling personalized products. (Koren, 2021; Matt *et al.*, 2015; Srai *et al.*, 2016) Local distributed manufacturing is a core feature of the maker movement, either by using local makerspaces or personal desktop CNC tools like 3D printers or laser cutters. In this sense, the maker movement could be seen as extremely distributed, as they are producing in direct contact to the final user, which is the maker herself. Some makers extend their manufacturing capability to others including businesses, by offering it as a service on internet platforms. (Hamalainen and Karjalainen, 2017)

https://doi.org/10.1017/pds.2023.11 Published online by Cambridge University Press

2.5.4 The maker movement and Industry 4.0

Industry 4.0 is a collective term for emerging technologies that have been predicted to disrupt industrial production. It is often used interchangeably with the term *The Fourth Industrial Revolution*, which describes a wider field of impact, incorporating economic, political, and social dimensions in addition to the industrial dimension of Industry 4.0, while being driven by the same emerging technologies. (Philbeck and Davis, 2018; Schwab, 2016) The technologies thought to drive Industry 4.0 varies by publication, however, Culot et al.(Culot *et al.*, 2020) present three sets of common descriptions from their meta-study of definitions for the term:

- *Key enabling technologies* like digitalization, connectivity, the internet of things, and cloud computing;
- *Distinctive characteristics* like virtualization, real-time information sharing, autonomy, and interoperability;
- *Possible outcomes* like higher productivity, flexibility, and mass customization/personalization.

Some of these descriptions could also describe the maker movement, and as Oliveira (2020) argues, the Maker movement can be seen as a subset of Industry 4.0.

3 THE IMPACT OF THE MAKER MOVEMENT

When describing the revolutionary economy of software innovation and distribution on the internet, Anderson (2012) asks us to "Just imagine what a similar model could do in the larger economy of Real Stuff". While it is not difficult to imagine the potential that the maker movement could bring, we have been promised a revolution, what has become of it?

3.1 Criticism of the scope of the maker movement

Turner (2018) likens the spokespeople of the maker movement to puritan pastors, selling a millenarian dream of personal enlightenment and self-sufficiency, where "The angry God of Puritan America has been replaced by the awful winds of economic change. The Puritan's spiritual search for God's grace inside oneself has been replaced by the displaced worker's search for signs of the spirit of entrepreneurship, creativity." (Sivek, 2011) notes about MAKE Magazine that it is a demonstration of technological utopianism in the way it represents the movement's ability to solve humanity's ecological and social problems through technology. On the same theme, (Morozov, 2014) criticises the over-selling of the movement's capabilities, likening it to the Arts and Crafts movement and its inability to create any lasting change other than aesthetic. On the generously wide definition of makers in Chris Anderson's book "Makers", he notes "There's nothing in this book about mythmaking, but that surely qualifies as well".

3.2 A personal revolution

Much of the promise of the maker movement revolves around the possibilities afforded to the layperson by new technology and the knowledge on how to use it to create artifacts. The possibility of commercialization of those potential artifacts is suggested but rarely insisted upon. In their study of the maker movement demography (*Maker Market Study: An In-Depth Profile of Makers at the Forefront of Hardware Innovation*, 2012) Make Magazine and Intel found that 49% of what participants make was used only by the participant or the participants family, indicating that half of the results of the maker movement stays personal. Moreover, when the participant's objects were used by others, they were mostly used by people close to the participant, like co-workers, other makers, and the local community.

3.3 Enabling new business and distributed small-scale production

While it is not a requirement of the maker movement to aim for commercial endeavours or to scale up at all, Studies have shown that the development of affordable digital technologies and sharing spaces allows makers to generate new business opportunities (Halbinger, 2018; Holm, 2015; Langley *et al.*, 2017; Mortara and Parisot, 2016), opportunities that maker-entrepreneurs can develop into sustainable businesses (Bergman and McMullen, 2020; Troxler and Wolf, 2017). Further practical evidence is given by projects that are, or at some point have been, embedded in the maker movement and benefitted from it. The projects listed below show different examples of projects with lasting impact, both commercially and in non-commercial ways:

https://doi.org/10.1017/pds.2023.11 Published online by Cambridge University Press

3.3.1 The Roost Laptop Stand

The Roost Laptop Stand by James Olander started as prototypes at a local Makerspace, and got a first production run funded through Kickstarter, and was eventually produced at the same Makerspace where it was prototyped. Subsequent versions were still prototyped using Makerspace tools, but production was shifted to conventional injection moulding. (Youderian, n.d.)

3.3.2 Prusa Research

Prusa Research was started by Josef Prusa, building on the open-source RepRap project, and becoming one of the most well-known manufacturers of 3D printers in the world and one of the fastest growing tech companies in central Europe. Prusa Research still manufactures most of its components on the same type of desktop 3D printers as they sell to consumers, and ship over 9000 printers per month while still sharing all design files for anyone to use. ("About us | Original Prusa 3D printers directly from Josef Prusa", 2022)

3.3.3 COVID-19 pandemic response

During the early stages of the COVID-19 pandemic, insufficient stocks and disrupted global supply chains led to a shortage of personal protective equipment worldwide. Makers around the world responded rapidly with design and local distributed production of face shields, facemasks, and medical gowns counting over 48.3 million pieces that were distributed to local hospitals and communities in the months before global production and distribution scaled up (Cavalcanti *et al.*, 2021).

3.4 Proliferation of makerspaces

A measure of the impact of the maker movement is the proliferation of maker spaces, of which there are several types that can overlap, making the following listings non-exclusive, while also non-exhaustive. Make Magazine ("Makerspace Directory", n.d.) currently lists 1012 active makerspaces, The Fab Foundation publishes a non-exhaustive list of Fab Labs connected to their network, totalling over 1500. ("Fab Lab Network", n.d.) and hackerspaces.org ("List of Hacker Spaces", n.d.) similarly lists 836 active, and 361 planned hackerspaces, suggesting that there is an ongoing expansion.

3.5 Conflicts between culture and commercialization

While we have seen examples of projects originating in the Maker Movement become commercial successes, most of these projects sooner or later experience contested logics between community and sharing on the one hand, and commercialization and financial stability on the other (Langley *et al.*, 2017; Troxler and Wolf, 2017). Many of the projects eventually drop the maker movement ethos in favor of traditional corporate structures, as the commercial demands grow. (Langley *et al.*, 2017)(Li *et al.*, 2021) In this sense, we could say that the commercial success of these projects is both due to and despite their Maker Movement origins. Li et al. shed further light on the reasons for abandoning Maker Movement principles, primarily a change in target customers (from other makers to the general public), Competition (as opposed to collaboration in the maker movement), Quality improvement (going from DIY target to consumer expected quality) and fundraising (going from self-financed to financers expecting return on investment)

4 IMPLICATIONS FOR THE FIELD OF INDUSTRIAL DESIGN

4.1 Overlaps between the maker movement and the field of industrial design

There are many similarities between makers and designers in the sense that both are occupied with the shaping of physical objects. In his book "Makers The New Industrial Revolution" Anderson (2012) argues that everyone is now a designer by virtue of the accessibility to digital desktop manufacturing tools. Indeed, since the making of objects by means of digital tools necessitates the creation of designs for those tools to process, even by a designer's definition (Archer, 1984) we could call makers a subset of designers, albeit not by profession. Conversely, many designers are makers, 22% of participants at the 2012 Bay Area Maker Faire self-identified as designers (*Maker Faire Bay Area Attendee Study*, 2012), and almost 10% of participants in Korean makerspaces held a degree in art and design (Kwon and Lee, 2017) There are, however, crucial differences in design intent; in the case of the maker, designs are primarily created for the needs of the maker herself, as well as sharing, mixing and

https://doi.org/10.1017/pds.2023.11 Published online by Cambridge University Press

recreating by other makers (Anderson, 2012; *Maker Market Study: An In-Depth Profile of Makers at the Forefront of Hardware Innovation,* 2012), the designer on the other hand, designs for the production, marketing, and in the end, use by others.

4.2 Areas of particular interest to the field of industrial design

While the physical and economical means of production is available to anyone in the maker movement, the process of designing and producing objects is not immediately attained by the layperson. Being academically trained, industrial designers and design engineers have a unique opportunity to benefit from the advances of the maker movement. Below are three areas of particular interest:

4.2.1 Prototyping

The use of technologies associated with the maker movement, such as 3D printers and IC development boards (e.g. Arduino or Raspberry Pi) for prototyping by designers is commonplace today. Moreover, DIY strategies such as repurposing commercial products and satisficing component quality have been shown to improve prototyping. (Camburn and Wood, 2018)

4.2.2 Individualized design

(Myerson, 2017)identified a need for designers to scale down, to instead of learning just a little about very broad categories of people, learn a lot about a smaller group of people and concentrate on what makes them different instead of what makes them similar, adapting a people-based design instead of a market-based one, and while industrial design tools have been evolving and enabled *bespoke designs* (Campbell *et al.*, 2003), the economy and scale of Maker Movement technology can make *bespoke production* viable in more cases.

4.2.3 Entrepreneurship

(Bianchini and Maffei, 2012) foresees a path where designers become individual enterprises that form clusters where distributed production takes place through customizable technologies. On the same note, Bonfanti (Bonfanti *et al.*, 2018) identify both the use of advanced digital tools and involving customers in the design and production process for craft entrepreneurs to survive. The maker movement offers tools and platforms that make such enterprises viable with low barriers to entry.

5 CONCLUSION

5.1 Summary

The maker movement is a loosely tied and ambiguously defined movement that is characterized by the use of digital tools and knowledge sharing to create material objects. It claims to offer a pathway from first participation to commercialization in three stages; Zero to Maker, Maker to Maker, and Maker to Market, and its proponents have described it as the new industrial revolution, garnering interest from many different fields of study.

While the new industrial revolution promised by proponents of the maker movement might have been oversold, at least in its scope, the underlying developments and phenomena of access to cheap advanced digital tools and knowledge sharing platforms, in real life and through the internet, are still a force to be reckoned with, and it cannot be denied that at the tools and knowledge on how to make physical objects in a manner similar to professionals is now closer to the layperson than it has ever been before. Yet we can see that while the proponents of the maker movements see a path from idea to market, questions on how to navigate markets and manufacturing at scale are not answered through the movement, and maker entrepreneurs are generally confined to low-volume, high-margin markets.

The intersects between the maker movement and industrial design are numerous both in goals and practice. With the academic training of industrial designers and design engineers, the possibilities afforded by the maker movement can especially beneficial to actors in the field of industrial design. Likewise, many of the challenges of the maker movement can be taken as relevant to the field of industrial design as well, in particular concerning small scale production, production scaling, and DFM strategies for distributed manufacturing. Moreover, with the change in scope from the makers

https://doi.org/10.1017/pds.2023.11 Published online by Cambridge University Press

design for the maker herself to the designer's *design for others*, industrial designers and design engineers have an advantage as well as the incentive to tackle these issues.

5.2 Future research

The possibility of the maker movement enabling new kinds of entrepreneurship and economic development is one of the main reasons why the maker movement has garnered interest from scholars and policymakers alike. Yet previous research has shown that the process of scaling up from prototyping to commercial production is something where the maker movement does not offer clear direction. Industrial designers and design engineers have a unique opportunity to study the subject of scaling close to the product, being able to approach the issue already at the design stage with ample subjects to explore, for example: Can we develop design strategies to enable higher volume production with maker movement tools? Can we develop design strategies to increase part quality with the same tools? Can we develop design strategies to decrease part cost with those tools as well? Can existing DFM strategies be adapted to maker movement tools? Can we develop design languages that take advantage of the inherent aesthetics of desktop manufacturing? Answering questions like these would not only contribute to the knowledge pool of the maker movement but also expand designers' tools and entrepreneurial opportunities.

ACKNOWLEDGEMENTS

The authors would like to thank Professor Jaehyun Park for his support, as well as the reviewers for their suggestions.

REFERENCES

"About us | Original Prusa 3D printers directly from Josef Prusa". (2022), *Prusa Research*, available at: https://www.prusa3d.com/page/about-us_77/ (accessed 27 November 2022).

Anderson, C. (2012), *Makers The New Industrial Revolution*, First Edition., Crown Business.

Archer, L.B. (1984), "Systematic Method for Designers", *Developments in Design Methodology*, John Wiley & Sons, pp. 58–83.

Atkinson, P. (2006), "Do It Yourself: Democracy and Design", *Journal of Design History*, Vol. 19 No. 1, pp. 1–10, https://dx.doi.org/10.1093/jdh/epk001.

Baldwin, C., Hienerth, C. and Hippel, E. von. (2006), "How user innovations become commercial products: A theoretical investigation and case study", *Research Policy*, Vol. 35 No. 9, pp. 1291–1313, https://dx.doi.org/10.1016/j.respol.2006.04.012.

Baldwin, C. and Hippel, E. von. (2011), "Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation", *Organization Science*, Vol. 22 No. 6, pp. 1399–1417, https://dx.doi.org/10.1287/orsc.1100.0618.

Bergman, B.J. and McMullen, J.S. (2020), "Entrepreneurs in the making: Six decisions for fostering entrepreneurship through maker spaces", *Business Horizons*, Vol. 63 No. 6, pp. 811–824, https://dx.doi.org/10.1016/j.bushor.2020.07.004.

Berman, B. (2012), "3-D printing: The new industrial revolution", *Business Horizons*, Vol. 55 No. 2, pp. 155–162, https://dx.doi.org/10.1016/j.bushor.2011.11.003.

Berthon, P.R., Pitt, L.F., McCarthy, I. and Kates, S.M. (2007), "When customers get clever: Managerial approaches to dealing with creative consumers", *Business Horizons*, Vol. 50 No. 1, pp. 39–47, https://dx.doi.org/10.1016/j.bushor.2006.05.005.

Bianchini, M. and Maffei, S. (2012), "Could Design Leadership Be Personal? Forecasting New Forms of 'Indie Capitalism'", *Design Management Journal*, Vol. 7 No. 1, pp. 6–17, https://dx.doi.org/10.1111/j.1948-7177.2012.00029.x.

Bonfanti, A., Giudice, M.D. and Papa, A. (2018), "Italian Craft Firms Between Digital Manufacturing, Open Innovation, and Servitization", *Journal of the Knowledge Economy*, Vol. 9 No. 1, pp. 136–149, https://dx.doi.org/10.1007/s13132-015-0325-9.

Browder, R.E., Aldrich, H.E. and Bradley, S.W. (2019), "The emergence of the maker movement: Implications for entrepreneurship research", *Journal of Business Venturing*, Vol. 34 No. 3, pp. 459–476, https://dx.doi.org/10.1016/j.jbusvent.2019.01.005.

Camburn, B. and Wood, K. (2018), "Principles of maker and DIY fabrication: Enabling design prototypes at low cost", *Design Studies*, Vol. 58, pp. 63–88, https://dx.doi.org/10.1016/j.destud.2018.04.002.

Campbell, R.I., Hague, R.J., Sener, B. and Wormald, P.W. (2003), "The Potential for the Bespoke Industrial Designer", *The Design Journal*, Vol. 6 No. 3, pp. 24–34, https://dx.doi.org/10.2752/146069203789355273.

Cavalcanti, G., Cocciole, C., Cole, C., Forgues, A., Jaqua, V., Jones-Davis, D. and Merlo, S. (2021), *Design | Make | Protect: A Report on the Open Source Maker and Manufacturer Response to the COVID-19 PPE Crisis.*, Open Source Medical Supplies & Nation of Makers.
Chachra, D. (2015), "Why I Am Not a Maker", *The Atlantic*, 23 January.
Culot, G., Nassimbeni, G., Orzes, G. and Sartor, M. (2020), "Behind the definition of Industry 4.0: Analysis and open questions", *International Journal of Production Economics*, Vol. 226, p. 107617, https://dx.doi.org/10.1016/j.ijpe.2020.107617.
Dellot, B. (2015), *Ours to Master How Makerspaces Can Help Us Master Technology for a More Human End*, RSA.
Dougherty, D. (2012), "The Maker Movement", *Innovations: Technology, Governance, Globalization*, Vol. 7 No. 3, pp. 11–14, https://dx.doi.org/10.1162/inov_a_00135.
Dougherty, D. (2016), *Free to Make*, North Atlantic Books.
Doussard, M., Schrock, G., Wolf-Powers, L., Eisenburger, M. and Marotta, S. (2018), "Manufacturing without the firm: Challenges for the maker movement in three U.S. cities", *Environment and Planning A: Economy and Space*, Vol. 50 No. 3, pp. 651–670, https://dx.doi.org/10.1177/0308518x17749709.
"Fab Lab Network". (n.d.). *The Fab Foundation*, available at: https://fabfoundation.org/global-community/ (accessed 26 October 2022).
Ferretti, F. and Lente, H. van. (2021), "The promise of the Maker Movement: policy expectations versus community criticisms", *Science and Public Policy*, Vol. 49 No. 1, pp. 18–27, https://dx.doi.org/10.1093/scipol/scab053.
Gambardella, A., Raasch, C. and Hippel, E. von. (2017), "The User Innovation Paradigm: Impacts on Markets and Welfare", *Management Science*, Vol. 63 No. 5, pp. 1450–1468, https://dx.doi.org/10.1287/mnsc.2015.2393.
Gershenfeld, N. (2005), *FAB The Coming Revolution on Your Desktop – From Personal Computers to Personal Fabrication*, Basic Books.
Hagel, J., Brown, J.S. and Kulasooriya, D. (2013), *A Movement in the Making*, Deloitte University Press.
Halbinger, M.A. (2018), "The role of makerspaces in supporting consumer innovation and diffusion: An empirical analysis", *Research Policy*, Vol. 47 No. 10, pp. 2028–2036, https://dx.doi.org/10.1016/j.respol.2018.07.008.
Hamalainen, M. and Karjalainen, J. (2017), "Social manufacturing: When the maker movement meets interfirm production networks", *Business Horizons*, Vol. 60 No. 6, pp. 795–805, https://dx.doi.org/10.1016/j.bushor.2017.07.007.
Hatch, M. (2014), *The Maker Movement Manifesto*, McGraw-Hill Education.
Hippel, E. von. (1987), "Lead users: A source of novel product concepts", *Journal of Product Innovation Management*, Vol. 4 No. 2, p. 158, https://dx.doi.org/10.1016/0737-6782(87)90069-5.
Hippel, E. von. (2005), *Democratizing Innovation*, The MIT Press.
Holm, E.J.V. (2015), "Makerspaces and Contributions to Entrepreneurship", *Procedia - Social and Behavioral Sciences*, Vol. 195, pp. 24–31, https://dx.doi.org/10.1016/j.sbspro.2015.06.167.
Impact of the Maker Movement. (2013), Deloitte Center for the Edge & MakerMedia.
Jensen, L.S. and Özkil, A.G. (2018), "Identifying challenges in crowdfunded product development: a review of Kickstarter projects", *Design Science*, Vol. 4, p. e18, https://dx.doi.org/10.1017/dsj.2018.14.
Koren, Y. (2010), *The Global Manufacturing Revolution: Product-Process-Business Integration and Reconfigurable Systems*, https://dx.doi.org/10.1002/9780470618813.
Koren, Y. (2021), "The Local Factory of the Future for Producing Individualized Products", *The Bridge*, Vol. 51 No. 1, pp. 20–26.
Koren, Y., Shpitalni, M., Gu, P. and Hu, S.J. (2015), "Product Design for Mass-Individualization", *Procedia CIRP*, Vol. 36, pp. 64–71, https://dx.doi.org/10.1016/j.procir.2015.03.050.
Kwon, B.-R. and Lee, J. (2017), "What makes a maker: the motivation for the maker movement in ICT", *Information Technology for Development*, Vol. 23 No. 2, pp. 1–18, https://dx.doi.org/10.1080/02681102.2016.1238816.
Lang, D. (2013), *Zero to Maker*, Maker Media.
Langley, D.J., Zirngiebl, M., Sbeih, J. and Devoldere, B. (2017), "Trajectories to reconcile sharing and commercialization in the maker movement", *Business Horizons*, Vol. 60 No. 6, pp. 783–794, https://dx.doi.org/10.1016/j.bushor.2017.07.005.
Li, Z., Seering, W., Yang, M. and Eesley, C. (2021), "Understanding the motivations for open-source hardware entrepreneurship", *Design Science*, Vol. 7, p. e19, https://dx.doi.org/10.1017/dsj.2021.15.
"List of Hacker Spaces". (n.d.). *Hackerspaces.Org*, available at: https://wiki.hackerspaces.org/List_of_Hacker_Spaces (accessed 21 November 2022).
Maietta, A. and Aliverti, P. (2015), *The Makers Manual A Practical Guide to the New Industrial Revolution*, Maker Media.
Maker Faire Bay Area Attendee Study. (2012), Maker Media.

Maker Market Study: An In-Depth Profile of Makers at the Forefront of Hardware Innovation. (2012), Maker Media, Intel.
"Makerspace Directory". (n.d.). *Make Magazine*, available at: https://makerspaces.make.co (accessed 21 November 2022).
Matt, D.T., Rauch, E. and Dallasega, P. (2015), "Trends towards Distributed Manufacturing Systems and Modern Forms for their Design", *Procedia CIRP*, Vol. 33, pp. 185–190, https://dx.doi.org/10.1016/j.procir.2015.06.034.
Morozov, E. (2014), "Making It", *The New Yorker*, 5 January.
Mortara, L. and Parisot, N.G. (2016), "Through entrepreneurs' eyes: the Fab-spaces constellation", *International Journal of Production Research*, Vol. 54 No. 23, pp. 1–23, https://dx.doi.org/10.1080/00207543.2016.1198505.
Myerson, J. (2017), "Scaling Down: Why Designers Need to Reverse Their Thinking", *She Ji: The Journal of Design, Economics, and Innovation*, Vol. 2 No. 4, pp. 288–299, https://dx.doi.org/10.1016/j.sheji.2017.06.001.
OLIVEIRA, M.A.D. (2020), "Maker Movement as Part of Industry 4.0", https://dx.doi.org/10.14488/ijcieom2020_full_0010_37434.
Philbeck, T. and Davis, N. (2018), "THE FOURTH INDUSTRIAL REVOLUTION: SHAPING A NEW ERA", *Journal of International Affairs*, Vol. 1 No. 72, pp. 17–22.
Quattrocchi, C. (2013), "MAKE'ing More Diverse Makers", *EdSurge News*, 29 October.
Rosa, P., Ferretti, F., Pereira, Â.G., Panella, F. and Wanner, M. (2017), *Overview of the Maker Movement in TheEuropean Union*, Publications Office of the European Union.
Schwab, K. (2016), *The Fourth Industrial Revolution*, World Economic Forum.
Sikhwal, R.K. and Childs, P.R.N. (2021), "Towards Mass Individualisation: setting the scope and industrial implication", *Design Science*, Vol. 7, p. e16, https://dx.doi.org/10.1017/dsj.2021.18.
Sivek, S.C. (2011), "'We Need a Showing of All Hands'", *Journal of Communication Inquiry*, Vol. 35 No. 3, pp. 187–209, https://dx.doi.org/10.1177/0196859911410317.
Srai, J.S., Kumar, M., Graham, G., Phillips, W., Tooze, J., Ford, S., Beecher, P., *et al.* (2016), "Distributed manufacturing: scope, challenges and opportunities", *International Journal of Production Research*, Vol. 54 No. 23, pp. 6917–6935, https://dx.doi.org/10.1080/00207543.2016.1192302.
Tabarés, R. and Kuittinen, H. (2020), "A tale of two innovation cultures: Bridging the gap between makers and manufacturers", *Technology in Society*, Vol. 63, p. 101352, https://dx.doi.org/10.1016/j.techsoc.2020.101352.
Troxler, P. and Wolf, P. (2017), "Digital maker-entrepreneurs in open design: What activities make up their business model?", *Business Horizons*, Vol. 60 No. 6, pp. 807–817, https://dx.doi.org/10.1016/j.bushor.2017.07.006.
Turner, F. (2018), "Millenarian Tinkering: The Puritan Roots of the Maker Movement", *Technology and Culture*, Vol. 59 No. 5, pp. S160–S182, https://dx.doi.org/10.1353/tech.2018.0153.
Webster, J. and Watson, R.T. (2002), "Analyzing the Past to Prepare for the Future: Writing a Literature Review", *MIS Quarterly*, Vol. 26 No. 2, pp. 13–23.
West, J. and Kuk, G. (2016), "The complementarity of openness: How MakerBot leveraged Thingiverse in 3D printing", *Technological Forecasting and Social Change*, Vol. 102, pp. 169–181, https://dx.doi.org/10.1016/j.techfore.2015.07.025.
Wolf, P. and Troxler, P. (2016), "Community-based business models Insights from an emerging maker economy", *Interaction Design and Architecture(s) Journal*, No. 30, pp. 75–94.
Youderian, A. (n.d.). "Creating 'The Roost' Laptop Stand with James Olander".

https://doi.org/10.1017/pds.2023.11 Published online by Cambridge University Press