# *Complex digital learning environments in a postdigital age.*

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***Abstract***
*This paper develops and discusses a conceptual approach to understanding complex digital learning environments within networked learning. Based on previous studies focusing on makerspaces published within the networked learning community this paper explores the makerspace phenomenon in education and initially discusses and suggests that learning environments equipped with digital technologies such as makerspaces could be defined and approached as a 'complex digital learning environment'. The notion of complexity is particularly useful for understanding environments such as makerspaces because they integrate heterogeneous elements, technological tools, spatial configurations, pedagogical approaches, and social practices, that together shape learning opportunities and constraints. Makerspaces can be recognised as environments that provide access to various tools and digital technologies, enabling users to explore and make artifacts. Makerspaces appear in multiple forms within educational contexts exhibiting various configurations. Although the notion of educational makerspaces is subject to interpretations, they may often be associated with digital technologies such as 3D printers, laser cutters, microcontrollers and robotics. A range of actors across research, practice, and policy have argued that makerspaces in education may serve as a catalyst for unlocking possibilities for teaching and learning activities and outcomes. Interpretations of makerspaces in education may foster networked engagement and collaborative learning; however, they may also foster boundaries for both educators and the learners, both in terms of context, digital technologies and pedagogy. By conceptualising makerspaces as complex digital learning environments, the aim is to move beyond instrumental or purely spatial understandings and instead emphasise the dynamic interrelations between material, digital, and human actors. This perspective allows to foreground how networked learning unfold within and across these environments, and how they are conditioned by both enabling and constraining factors. In addition, this paper argues that emphasising the complexity and potential boundaries of physical digital learning environments may support a shared ground for networked engagement with possibilities and the boundaries of such settings when designing for learning. In particular, acknowledging boundaries such as institutional constraints, access to technologies, pedagogical preparedness, and digital literacy can help educators and researchers collaboratively negotiate design principles that are sensitive to local conditions while still fostering meaningful connections across networks. Thus, the conceptualisation aims to contribute to the networked learning discourse by offering an analytical lens for studying and designing learning ecologies that are simultaneously digital, physical, and networked.*

***Keywords***
*Makerspace, Networked Learning, Boundary objects, Digital Learning Spaces*

## Introduction

Digital technologies are an integrated aspect of various educational contexts, and continuous digital transformations of education have aimed at different variations of digitally supported teaching and learning (Facer & Selwyn, 2021; Säljö, 2010). Fawns (2019) argues that there are a number of agendas, expectations and understandings connected to the implementation of digital technologies in education. This resonates with the phenomenon of makerspaces, which has been suggested as a means for various educational ideas and purposes (Mersand, 2021; Peppler et al., 2016; Vuorikari et al., 2019). Within education, makerspaces reflects a wide range of formats and combinations of tools, technologies and materials (Blikstein, 2018; Martinez & Stager, 2013; Peppler et al., 2016). Makerspaces may be equipped with digital fabrication technologies such as 3D printers and laser cutters. Some makerspaces may also provide access to micro-controllers and programmable robotics and various crafting tools and materials (Blikstein, 2018). While the infrastructural configuration of a makerspace may



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afford access to various resources, these spaces may likewise support multiple forms of practices that can be viewed as learning environments (Halverson & Sheridan, 2014; Sheridan et al., 2014). The diversity of makerspaces in education in the postdigital age (Jandrić, 2023; Jandrić & Knox, 2022) echoes the contours of a complex digital learning environment. 'Complex' in the sense that a makerspace is open to wide interpretations of both pedagogy, technology and participation, which may foster potentials and challenges for learning. From a Deweyan perspective, such openness reflects the experiential nature of learning, where knowledge emerges through iterative interaction, inquiry, and reflection within a changing environment. Complexity, in this sense, is not merely a structural characteristic but a pedagogical condition that supports growth through the negotiation of meaning and practice across contexts. The term 'digital' emphasise that the learning environment expresses an intentionality aimed at the integration and use of digital technologies. Dron (2022) has argued that technologies like all other aspects of a learning environment have an impact on learning. With this notion in mind, it becomes relevant to consider how complex digital learning environments such as makerspaces are integrated in educational institutions. The complexity associated with digital learning environment becomes interesting from a networked learning perspective, as the area on research:

> focuses on understanding the qualities, opportunities, and challenges that connections between people and technology bring to learning and knowledge development. (Ryberg et al., 2025, p. 1).

Early definitions of networked learning, however, suggests that the concept was initially closely tied to ICT in education and to the facilitation of connections through specific technologies. As formulated by Goodyear:

> We define 'networked learning' as learning in which information and communications technology (ICT) is used to promote connections: between one learner and other learners, between learners and tutors; between a learning community and its learning resources. (Goodyear, et al. 2004, p. 1).

The integration of various digital technologies in education today, calls for exploration of definitions of digital learning environments expanding beyond early association with ICT tools. This attention is also reflected in the practice and research of networked learning bringing attention to the entanglement of Human/inter-personal relationships, Technology and collaborative engagement (Networked Learning Editorial Collective (NLEC), 2021). From this perspective, learning environments such as makerspaces can be understood not simply as sites where technology enables connections, but as complex and evolving configurations in which social, material, and digital relations are continuously negotiated. This paper is situated within a postdigital perspective on education, where digital technologies are understood as entangled with social practices, material arrangements, and learning spaces. In this sense, it aligns with Forsler et al., (2025), who conceptualise learning environments as sites where educational futures are imagined, enacted, and negotiated.

This paper suggests that physical learning environments such as makerspaces should be approached as complex digital learning environments. The aim is to draw attention to both opportunities and challenges that may arise while learners collaborate and interact with various digital technologies through experiential pedagogical approaches. More specific this paper focuses on how physical digital learning environments such as makerspaces are shaped by digital technologies, social interactions, and pedagogical practices. Within and across these diverse and intersected domains, it becomes increasingly relevant to observe and reflect upon the existing and evolving constellations of networks that unfolds and foster learning environments with digital technologies in education. Building on a networked learning perspective this paper explores the following research question; How can complex digital learning environments be defined and approached as a concept in networked learning?

## Makerspaces in education

The emergence of makerspaces in education has been associated with the phenomenon called the Maker Movement (Halverson & Sheridan, 2014; Sheridan et al., 2014). Broadly the Maker Movement refers to people engaged in making of artifacts (Halverson & Sheridan, 2014; Peppler et al., 2016; Sheridan et al., 2014). Scholars has traced the term and popularizing of the Maker Movement to the beginning of the 2000's (Halverson & Sheridan, 2014; Martin, 2015; Papavlasopoulou et al., 2017). The Maker Movement, together with ideas on making in education and makerspaces, has been suggested to offer various possibilities in education (Blikstein, 2018; Halverson & Sheridan, 2014; Martinez & Stager, 2013; Vuorikari et al., 2019).

## Research on makerspaces in the networked learning community

The development and implementation of digital technologies in education is mirrored in the networked learning community (Hodgson & McConnell, 2019; McConnell et al., 2012) and collectively this body of work offers a rich foundation for examining how digital learning environments are conceptualised, designed, and enacted across contexts. To build on existing work and discover how scholars in the context of networked learning have engaged with the phenomenon of makerspaces a focused search on the Proceedings of the International Conference on Networked Learning was conducted using the search string "maker space*" or "makerspace*". The search revealed 7 documents. Assessing these documents, four papers engages with and refers to makerspaces in education from different perspectives, including an empirical study on facilitators' and teachers' experiences (Koole et al., 2018), and a study on designing activities and tools for university students to support their creative and collaborative exploration of physical computing (Kaivo et al., 2020), as well as conceptual and pedagogical frameworks situating makerspaces within 21st-century learning (Kjærgaard & Dau, 2018) and media ecologies (Thestrup, 2022). Collectively, they highlight how makerspaces may function as formal and informal learning environments, shaping creativity, professional development, and critical engagement with digital practices. The identified studies leave a foundation for further exploration on how networked learning and engagement in makerspaces may be defined and articulated. Beyond the scope of the identified papers in the proceedings of the International Conference on Networked Learning an article (Spante et al., 2019) related to the phenomenon of makerspaces was identified in the book Networked Professional Learning (Littlejohn et al., 2019). Spante et al., (2019) highlights the complex nature of professional development for makerspace, emphasising the need to consider a range of interconnected factors.

## Complex digital learning environments

This paper draw upon the perspective that complex digital learning environments such as makerspaces are not merely constituted as a physical space, but also as a learning environments where different forms of engagement and learning intersect. It can be argued that a complex digital learning environment such as a makerspace are constituted through the interplay between existing boundaries and affordances of the physical space, digital technologies, pedagogy and content which are illustrated in figure 1. The figure is intended as a reflection tool to highlight the awareness of the networked elements that are in play in a complex digital learning environment such as a makerspace. The three circles in the center illustrates the interplay of the integration of content, pedagogy and technology in teaching within a complex learning environment. This identification is inspired by Mishra and Koehler (2006), which suggest that knowledge of content, pedagogy and technology is necessary for an educator to ensure a meaningful use of digital technology in their teaching. Further the figure conceptualises the interdependent networked connections between these three aspects. When designing for learning in a complex digital learning environment it can be argued that a lack of balanced insight into how these aspects are interwoven may result in digital technologies being implemented in ways that may not align with pedagogical intention. As Fawns (2022) suggest educators should consider:

> the diverse ways in which teachers and students actually engage with technology whilst learning (Fawns, 2022, p. 718).

The interplay of content, pedagogy, and digital technologies is enacted within a specific physical learning environment which plays a significant role in shaping the possibilities for interaction, collaboration, and engagement between the educators and learners. The outer dashed circle adds the aspect that complex digital learning environment are situated within interconnected elements including the institutional structures, educational ideas, and pedagogical intentions. The figure illustrates that educators must navigate within a complex interplay between content, pedagogy, technology and context-sensitive decisions that reflect both the intended outcomes and the physical space in which teaching and learning takes place. In this perspective, a makerspace could be approached as a dynamic node within broader networks of educational ideas, pedagogy, digital technology and social practices.

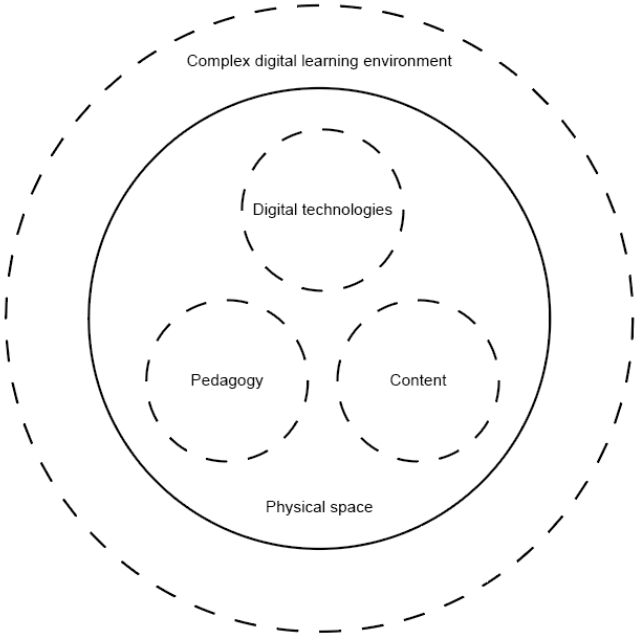


**Figure 1: Illustration of networked elements in a complex digital learning environment**

## Makerspaces and boundaries

In networked learning where digital technologies is used to promote interaction reflections on boundaries within practices are relevant (Dirckinck-Holmfeld, 2006). Drawing on Star and Griesmers (1989) concepts on boundary object it becomes possible to analytically observe and reflect on connections between artifacts and social worlds. Boundary objects:

> are weakly structured in common use, and become strongly structured in individual site use. These objects may be abstract or concrete. (Star & Griesemer, 1989, p. 393).

In a complex digital learning environment digital technologies can be observed to function as boundary objects that reflect aspects of multiple social worlds. Analysing digital technologies as boundary objects provides a lens for exploring how digital technologies are adapted and negotiated. From a networked learning perspective, this lens makes visible how learning emerges not only through connection, but through the tensions and misalignments that arise when different actors engage with shared artifacts. A digital technology may serve as a boundary object by being flexible enough to serve as an educational tool for an educator to teach a subject matter, while students may find the digital technology as a medium for creative expressions. Rather than assuming shared understandings, the boundary object perspective foregrounds how partial, overlapping, and sometimes conflicting interpretations coexist within the same learning environment. Although, the digital technology might have a shared identity and enabling collaboration within a makerspace there might not necessarily exist a full consensus on how it should be used. Further, a digital technology such as a 3D printer can, on the one hand, appear concrete when a physical artifact is manufactured, but at the same time, the internal processes and digital modelling can remain abstract for the learner. This duality between the tangible and the abstract may create differences in how participants understand and engage with the technology, depending on their prior experience, disciplinary background, or pedagogical perspective. These differences can be understood as boundary tensions, where the technology simultaneously enables collaboration and exposes gaps in understanding and expectations. In this regard, digital technologies in makerspaces can be understood as boundary objects that mediate collaboration across diverse social worlds:

> When a boundary object supports the collaborative process on the routine level, it functions at the syntactic level and the participants share the syntax; however, when there is a breakdown, the

> participants will have to go to the level of semantics or pragmatics in order to "repair" the knowledge boundary. (Riis & Dirckinck-Holmfeld, 2020, p. 163).

Thus, moments of abstraction or misunderstanding in relation to the technology can be seen as breakdowns that call for deeper negotiation of meaning. Such breakdowns are not necessarily failures of design but may be productive moments for learning, as they require participants to articulate assumptions, clarify intentions, and re-negotiate practices:

> Each social world has partial jurisdiction over the resources represented by that object, and mismatches caused by the overlap become problems for negotiation. (Star & Griesemer, 1989, p. 412).

This means that while the digital technologies may serve as a shared object of activity, different interpretations and understandings among educators and learners may require collaborative negotiation to align aims and practices. According to Akkerman and Bakker (2011) even though objects are designed to support dialogue between different parties, there is a risk that they either do not capture the intended meaning or become part of a specific practice, thereby blurring the intended purpose and meaning. However, Akkerman & Bakker (2011) emphasise that boundary crossing is a generative process, in which engagement across differences can lead to the emergence of new understandings, identities, and practices. From this perspective, boundaries in makerspaces can be seen as resources for reflection and transformation rather than obstacles to learning.

# Discussion and conclusion

This conceptual paper explores how complex digital learning environments can be defined and approached as a concept in networked learning. By examining the phenomenon of makerspaces in education through the lens of networked learning, this paper argues that these environments exemplify the characteristics of complex digital learning environments. The presented conceptualisation suggests that makerspaces are not merely physical sites equipped with digital technologies, but complex socio-technical environments shaped by multiple actors and pedagogical intentions. The complexity of such environments emerges from their openness to interpretation and the interplay between technologies, the spatial and institutional arrangements, and the pedagogical designs and practices that animate them. This complexity aligns with the relational orientation of networked learning, in which learning is understood as emerging through connections between learners, educators, technologies, and contexts (Goodyear et al., 2004; Hodgson & McConnell, 2019). Further it is proposed that both digital learning environments as they are constituted and digital technologies in makerspaces can be understood as boundary objects (Star & Griesemer, 1989) that mediate collaboration across different social worlds, such as those of educators, students, and institutional stakeholders. As Riis and Dirckinck-Holmfeld (2020) note, boundary objects may function smoothly at a syntactic level but require negotiation at semantic or pragmatic levels. Moments of misalignment for example, if the abstract workings of a digital technology are not fully understood by the participants highlight the need for pedagogical strategies that may foster shared reflective engagement. From a networked learning perspective, recognizing and engaging with these boundaries is not a limitation but a resource for learning. Boundaries invite dialogue and negotiation of understanding, processes which are central to collaborative knowledge-building. The conceptualisation also points to implications for designing for learning. Educators designing for learning in complex digital environments must navigate between physical space, content, pedagogy and technology. As Fawns (2022) reminds, pedagogical decisions should account for the diverse ways educators and students actually engage with technology. In conclusion, the notion of complex digital learning environments offers a conceptual analytic lens. It foregrounds the interwoven and situated nature of learning ecologies that are simultaneously digital, physical, and social. Future work may extend this conceptual foundation through empirical studies examining how learners and educators negotiate meaning and agency within these environments, and how institutional and technological conditions shape the networks of learning that unfold therein.

**References**

Akkerman, S. F., & Bakker, A. (2011). Boundary Crossing and Boundary Objects. *Review of Educational Research*, *81*(2), 132–169. https://doi.org/10.3102/0034654311404435

Blikstein, P. (2018). Maker movement in education: History and prospects. In M. J. De Vries (Ed.), *Handbook of technology education* (pp. 419–437).
Dirckinck-Holmfeld, L. (2006). Designing for Collaboration and Mutual Negotiation of Meaning – Boundary Objects in Networked Learning. *Proceedings of the Fifth International Conference on Networked Learning*. https://doi.org/10.54337/nlc.v5.9490
Dron, J. (2022). Educational technology: What it is and how it works. *AI & SOCIETY*, *37*(1), 155–166. https://doi.org/10.1007/s00146-021-01195-z
Facer, K., & Selwyn, N. (2021). *Digital Technology and the Futures of Education: Towards 'Non-Stupid' Optimism. UNESCO.* https://unesdoc.unesco.org/ark:/48223/pf0000377071
Fawns, T. (2019). Postdigital Education in Design and Practice. *Postdigital Science and Education*, *1*(1), 132–145. https://doi.org/10.1007/s42438-018-0021-8
Fawns, T. (2022). An Entangled Pedagogy: Looking Beyond the Pedagogy—Technology Dichotomy. *Postdigital Science and Education*, *4*(3), 711–728. https://doi.org/10.1007/s42438-022-00302-7
Forsler, I., Bardone, E., & Forsman, M. (2025). The Future Postdigital Classroom. *Postdigital Science and Education*, *7*(3), 682–689. https://doi.org/10.1007/s42438-024-00488-y
Goodyear, P. (2004). *Advances in research on networked learning*. Kluwer academic.
Halverson, E. R., & Sheridan, K. (2014). The Maker Movement in Education. *Harvard Educational Review*, *84*(4), 495–504.
Hodgson, V., & McConnell, D. (2019). Networked Learning and Postdigital Education. *Postdigital Science and Education*, *1*(1), 43–64. https://doi.org/10.1007/s42438-018-0029-0
Jandrić, P. (2023). Postdigital. In P. Jandrić (Ed.), *Encyclopedia of Postdigital Science and Education* (pp. 1–5). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-35469-4_23-2
Jandrić, P., & Knox, J. (2022). The postdigital turn: Philosophy, education, research. *Policy Futures in Education*, *20*(7), 780–795. https://doi.org/10.1177/14782103211062713
Kaivo, M., Cuartielles, D., & Spikol, D. (2020). Designing activities and tools to support university students' creative and collaborative exploration of physical computing. *Proceedings of the International Conference on Networked Learning*, *12*, 55–64. https://doi.org/10.54337/nlc.v12.8636
Kjærgaard, T., & Dau, S. (2018). 21 century learning skills revisited—A conceptual paper on leaving 'gaps' and going deep. *Proceedings of the International Conference on Networked Learning*, *11*, 72–79. https://doi.org/10.54337/nlc.v11.8740
Koole, M., Anderson, K.-A., & Wilson, J. (2018). Makerspaces as complex sociomaterial assemblages: Is networking the key factor? *Proceedings of the International Conference on Networked Learning*, *11*, 256–259. https://doi.org/10.54337/nlc.v11.8763
Littlejohn, A., Jaldemark, J., Vrieling-Teunter, E., & Nijland, F. (Eds). (2019). *Networked Professional Learning: Emerging and Equitable Discourses for Professional Development*. Springer International Publishing. https://doi.org/10.1007/978-3-030-18030-0
Martin, L. (2015). The Promise of the Maker Movement for Education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *5*(1). https://doi.org/10.7771/2157-9288.1099
Martinez, S., Libow, & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Constructing Modern Knowledge Press.
McConnell, D., Hodgson, V., & Dirckinck-Holmfeld. (2012). Networked Learning: A Brief History and New Trends. In L. Dirckinck-Holmfeld, V. Hodgson, & D. McConnell (Eds), *Exploring the Theory, Pedagogy and Practice of Networked Learning*. Springer New York. https://doi.org/10.1007/978-1-4614-0496-5
Mersand, S. (2021). The State of Makerspace Research: A Review of the Literature. *TechTrends*, *65*(2), 174–186. https://doi.org/10.1007/s11528-020-00566-5
Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record: The Voice of Scholarship in Education*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x
Networked Learning Editorial Collective (NLEC). (2021). Networked Learning: Inviting Redefinition. *Postdigital Science and Education*, *3*(2), 312–325. https://doi.org/10.1007/s42438-020-00167-8
Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2017). Empirical studies on the Maker Movement, a promising approach to learning: A literature review. *Entertainment Computing*, *18*, 57–78. https://doi.org/10.1016/j.entcom.2016.09.002
Peppler, K., Halverson, E. R., & Kafai, Y. B. (2016). *Makeology: Makerspaces as learning environments*. Routledge.

Riis, M., & Dirckinck-Holmfeld, L. (2020). Boundary Practices and the Use of Boundary Objects in Collaborative Networked Learning. In N. B. Dohn, P. Jandrić, T. Ryberg, & M. De Laat (Eds), *Mobility, Data and Learner Agency in Networked Learning* (pp. 155–172). Springer International Publishing. https://doi.org/10.1007/978-3-030-36911-8_10

Ryberg, T., Dohn, N. B., & De Laat, M. (2025). Networked Learning. In P. Jandrić (Ed.), *Encyclopedia of Postdigital Science and Education* (pp. 1–6). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-35469-4_86-1

Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning: Technologies, social memory and the performative nature of learning. *Journal of Computer Assisted Learning*, *26*(1), 53–64. https://doi.org/10.1111/j.1365-2729.2009.00341.x

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the Making: A Comparative Case Study of Three Makerspaces. *Harvard Educational Review*, *84*(4), 505–531. https://doi.org/10.17763/haer.84.4.brr34733723j648u

Spante, M., Johansson, K., & Jaldemark, J. (2019). MakerSpaces in Schools: Networked Learning Among Teachers to Support Curriculum-Driven Pupil Learning in Programming. In A. Littlejohn, J. Jaldemark, E. Vrieling-Teunter, & F. Nijland (Eds), *Networked Professional Learning* (pp. 223–237). Springer International Publishing. https://doi.org/10.1007/978-3-030-18030-0_13

Star, S. L., & Griesemer, J. R. (1989). Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420.

Thestrup, K. (2022). Connecting Workshops in Digital Education. *Proceedings of the International Conference on Networked Learning*, *13*. https://doi.org/10.54337/nlc.v13.8531

Vuorikari, R., Ferrari, A., & Punie, Y. (2019). *Makerspaces for education and training: Exploring future implications for Europe.* (EUR 29819 EN). Publications Office of the European Union, Luxembourg. doi:10.2760/946996