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LEARNING FOR THE COMPLEX OBJECT OF WORK IN A DIGITAL PRINTING NETWORK

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Abstract

This article investigates the learning of a digital printing network that was seeking sustainable collaboration in the textile, clothing, and interior printing industry. Digitalization is transforming work, giving rise to new types of networks and creating learning challenges for participants. The object of digital printing activity becomes heterogeneous, open-ended, and indefinite. The concept of the complex object of work, *which is based on cultural-historical activity theory, is introduced to examine the dynamics between the digitalization of work and network learning. Data were collected at the starting phase of the network collaboration, when participants discussed the future object of the digital printing activity. The participants were involved in design, textile manufacturing, digital printing, vocational education, and research, and consumer-customers were also represented. The authors argue that revealing the complexity of the object of work on multiple levels of learning is crucial to enhancing innovation in the networks of the digital age.*

Keywords

business ecosystem, cultural-historical activity theory, expansive learning, learning in networks, work-life learning

Introduction

Digitalization is transforming working life in multiple ways, and the topic has been discussed from different angles, such as the flexibility of work independent of place and time, the new tools of work, novel management approaches, the exponential growth of information and knowledge, and changes in work cultures (Nelson, Jarrahi, & Thomson, 2017; OECD, 2016). These transformations create the need for lifelong learning among citizens, employees, and leaders of organizations (Harteis, 2017). This article points out that the introduction of digital technology gives rise to new types of networks in industrial work—namely business ecosystems (Fragidis, Tarabanis, & Koumpis, 2007)—and creates learning needs for the participants.

The analysed case demonstrates that the digitalization of the textile, clothing, and interior printing industry intensifies the interaction of designers and producers and enables the active role and early involvement of consumers and students in the design and production network. This means that co-existing needs and expectations regarding the activity multiply and disperse, and the object of the activity in the emerging networks becomes even more heterogeneous, open-ended, and indefinite than before. In addition, digital technology has been introduced as a potential enabler of sustainable and local production in environmentally burdening industries such as printing (Fletcher, 2014; Gebler, Uiterkamp, & Visser, 2014). The present analysis interprets these developments as bringing about an extensive change in the object of the printing activity, which calls for the participants' learning.

The network project behind the case aimed at the development of an innovative business ecosystem within the textile, clothing, and interior printing industry that would mutually enhance the goals of both education and industrial activity in this field. On the educational side, the role of teachers of textile design was to guide students' coursework to present authentic prototypes for a consumer-customer service portal. The portal was an essential part of the object to be developed in the project.

The notion of *object of activity* will be applied in the analysis based on the culturalhistorical activity theory (CHAT) framework (Engeström, Miettinen, & Punamäki, 1999). We argue that opening up the complexity of the object of work (activity) is a way to analyse the multiple levels of learning (Toiviainen, 2003; 2007) emerging in the network's collaboration. This leads us to the theoretical reconsideration of the object of activity as being constitutive of the participants' motive formation (Leontiev, 1978) and learning (Engeström, 2015) related to the novel, digitally mediated activity. Here, we are not alone; recently, Sami Paavola and Reijo Miettinen (in press) have presented an activity-theory reconceptualization of the object of digitalized building information modelling in construction design.

In the following, we first give the necessary background on digital printing as a field of industrial activity. Then, we present the empirical case of the DigiPrintNetwork project in its search for the novel object of collaboration. The two sections that follow discuss the theoretical approach to the complex object of work as well as the multiple levels of learning in the age of digitalization. We then present the data and methods of analysis. The findings are reported in two sections—on the instantiations and the features of the object and on the levels of learning—to answer our two research questions. A discussion and conclusions close the article.

Background: Digital printing

Digital printing emerged in the 1990s as a prototyping tool. Unlike offset or indirect methods, the new technology transmits a digital file directly to the printing equipment. Digital printing has a higher per page cost than traditional offset printing methods do, but it avoids the cost of all the technical steps required to make printing plates (Tyler, 2005; Whitbread, 2009). Originally developed for paper printing, the versatility of the technology today allows digital printing on a variety of materials. Its application has expanded into the textile, clothing, and interior printing industry by producing, for instance, digitally printed carpets, flags, banners, and apparel.

Digital technology has become the leading printing technology, creating new markets and providing a springboard for product innovation. The storage of documents in digital form and the possibility to print on a variety of materials introduced major changes to the printing industry. Digitalization enables small-batch printing and printing on demand. It shortens the production chain and introduces just-in-time principles (Fenton & Romano, 1997; Fletcher, 2014; Tyler, 2005; Whitbread, 2009). Overall, digital printing, networking, and an orientation towards local production are often regarded as a route towards sustainable development (Fletcher, 2014; Tyler, 2005).

Digital printing technology expands the number of potential participants in business networks and changes their conventional roles. It may enhance designers' creativity and the innovation of novel and bold products (Parsons & Campbell, 2004). Printing houses have to adapt to short-run and lowbatch printing by introducing new business models and earning logic. Through digitalization, customers have become more active and involved in the design and printing processes. Digital printing is said to improve the quality of communication in business networks, paving the way for mass customization (Fenton & Romano, 1997; Tyler, 2005).

The DigiPrintNetwork project

The current study focuses on a business ecosystem in the textile, clothing, and interior printing industry which was constructed in the course of a public–private-funded research project. Business ecosystems are co-evolutionary business networks of organizations and individuals; they include designers, producers, suppliers, customers, and other stakeholders that interact to produce complex products and services (Fragidis et al., 2007). The project was coordinated by Helsinki Metropolia University of Applied Sciences and involved professionals from design, printing, material production, higher vocational education, and academic research as well as students and potential consumer-customers. This project built on the previous history of collaboration between education and industry; the teachers had dual roles as designers who worked in both production and research. The project offered participants the opportunity to look for novel ways of engaging students in business already during their vocational training and enhancing collaboration in both business and education.

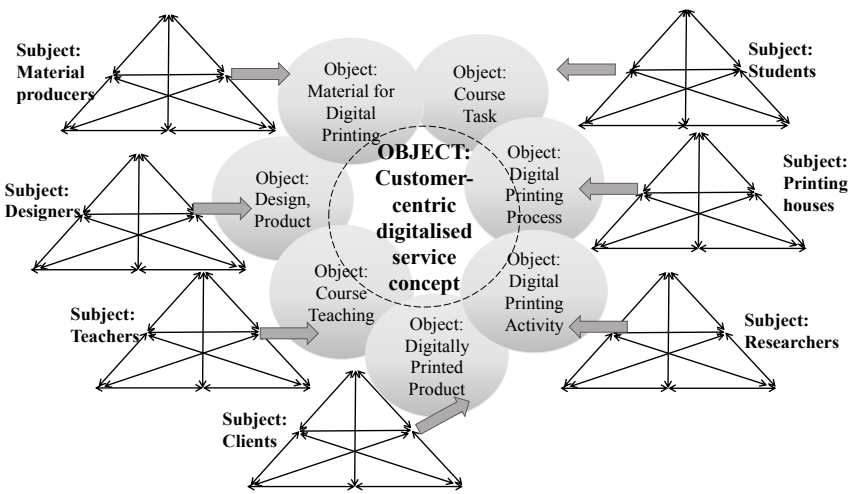

Figure 1. The DigiPrintNetwork business ecosystem: The setting of the project

In the course of five project workshops organized by researchers from Aalto University and the University of Helsinki, the members of the network developed a business and service model for this business ecosystem. The original idea was to create a web service for do-it-yourself customers (Hirscher, Niinimäki, & Armstrong, 2017) who would be able to create customizable products with the help of designers by using the services of the material

producers and printing houses. During the project, the original idea transformed into a service for students who needed a real-life context to learn the professional design activity as part of their studies. We opened the complexity of the object construction during the starting phase of the project. The shared object pursued in the project was a *customer-centric digitalized service concept*. The search for service concepts that use advanced information technology is typical for current business ecosystems. According to Fragidis et al. (2007), technological platforms perform a new business role as an intermediary for the realization of the configuration and operation of customer-centric business ecosystems.

Figure 1 depicts the network setting of the key participants, the objects of individual activities, and the potentially emerging shared object (in the centre). The triangles present each activity as a systemic model of six basic elements: the subject (who is acting), the object, the tools, the rules, the community, and the division of labour (Engeström, 2015). Here, the subject and the object are our focus.

The complex object of work in the age of digitalization

Despite the similarities among so-called practice-based theories (Nicolini, Mengis, & Swan, 2012), the concept of the object is special in the CHAT framework. It does not refer directly to the observable artefacts and infrastructures. Rather, the object represents the motive for the activity, answering why a given activity is needed and carried out in society (Leontiev, 1978).

Marx (1986) stated that in capitalism the object of the activity of production is an entity with inherent contradiction between its use value and its exchange value. This notion can be applied to the creation of the object at the intersection of digitalization and sustainable development. Industrial systems pursue the use value of digital innovations in advancing global sustainability, but utilize the exchange value of this connection in constructing their ecomodernist corporate ideology (Welford, 2013). The inner contradiction of the object is an important notion that we have applied in the analysis. It implies that complexity is more than an empirical notion of different ideas about the object that participants bring to the network.

A number of participants share a general object within a network, but it materializes in different forms. We distinguish between the generalized object of the historically evolving activity and the specific object as it appears to a particular subject, at a given moment, in a given action (Engeström, Puonti, & Seppänen, 2003). The object has multiple instantiations with specific features ranging from figurative, digital, and other representations to material-haptic realizations. These instantiations are always partial; they do not fully comprise the general object (Knorr Cetina, 2016).

The objects determine the horizon of possible actions (Engeström et al., 2003), but they do not determine the subjects' actions. People transform the object through collaborative activity by means of tools. This is the creative and transformative potential of human actions. In the CHAT framework, the diversity and multiplicity of objects and activities created in network collaboration can be analysed according to multiple levels of learning (Toiviainen, 2003, 2007).

Miettinen and Paavola (2018) have analysed how digitalization transforms the object in the design activity of the construction industry. Digital building information modelling facilitates the imagination, thinking, and collaboration of designers who are working on the ideal object. An ideal object refers to and represents a material object, but it is digitally modifiable and enables experimentation and simulation with different solutions in a manner that is not possible when moulding or constructing a material object or product.

Levels of learning in inter-organizational networks

We consider the complexity of learning in inter-organizational networks to be due to the multiple activities emerging on many levels among the network partners (Toiviainen, 2003). A researcher may follow the temporal-historical trajectory of collaboration and analyse the object creation on multiple levels of activity. The levels are not predetermined, nor universal. Once the levels have been identified at a certain point in history, they form a framework for analysing how the learning outcomes achieved on one level interact with, enrich, and mould other levels.

Learning takes place in a dialectical movement across the levels and across the objects and outcomes created. Transitions across the levels and the networks' innovativeness in creating intermediate levels are critical for learning (Toiviainen, 2003, 2007). For example, let us think of a project activity, a relatively durable practice that may be a continuation of successive public–privatefunded network projects. The object of the project activity is formulated in the project plan accepted by the funding agency. It covers the planned purpose of the project as well as the administrative and coordinative motives that maintain the accountability of the network. In addition to this level, the network aims to nurture innovation to materialize the plan and the partners create a variety of activities with new objects, such as developing collaborative design through novel technology. This may produce learning outcomes for those partners involved, but interaction with other levels (e.g. project activity, business modelling) will lead to the expansion of the object of the network.

Methods and data

Our research questions were the following:

1. What instantiations and features of the complex object of activity are coconstructed in the digital printing network?
2. What levels of learning does the complex object produce for the digital printing network?

The empirical data are from the network learning workshop that gathered all project stakeholders to discuss topical themes (Table 1). The participants included designers, digital printing houses, textile producers, consumer-customers, vocational teachers and students, and researchers (Figure 2).

CC=Consumer-Customer
DE=Design Entrepreneur
PC=Project Coordinator
PE=Printing Entrepreneur
R=Researcher
S=Student
TC=Teacher of Concept Planning
TE=Textile Entrepreneur

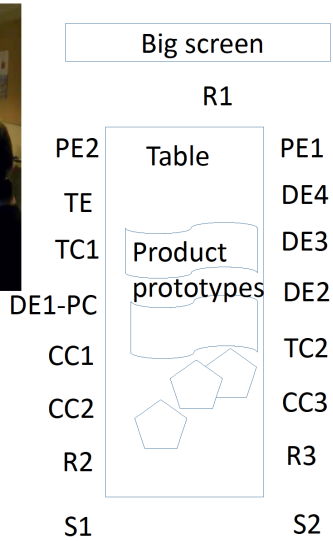

Figure 2. The workshop setting

The workshop programme was composed of three main thematic areas of discussion: 1) the requirements for a production process model for the network, 2) the first prototypes of the online customer-service concepts, and 3) the participants' expectations and values related to the project (Table 1).

Table 1
Themes and materials in the network learning workshop (duration 2 h 55 min)

Duration (min)	Theme	Material	Provider
13	Opening and orientation	– workshop programme – presentation round	Project coordinator Researcher Participants
47	Theme 1 Requirements of a production process model for the network	– generic model of the production process – product samples: wooden plates and wallpaper	Researcher Project coordinator – multiple roles as project coordinator, teacher, and designer
11	Break		
69	Theme 2 First prototypes of the online customer-service concepts	– prototypes of online service concepts	Students – coursework supervised by teachers
25	Theme 3 Participants' expectations and values related to the project	– thematic summary of the participants' expectations (interview data)	Researcher – discussion based on interview summary
10	The project's future actions Closing	– oral project information	Project coordinator Researchers

In CHAT methodology, a theory-driven set of principles—here, the object-oriented activity and levels of learning—guide the choice of specific methods (Engeström, 2016). First, we carried out a *thematic analysis* (Clarke, Braun, & Hayfield, 2015) of the transcribed workshop discussion data, distinguishing all discussion episodes in which we identified a representation of the object of activity as the theme of the discussion. The representations discussed varied from tangible product samples, such as wallpaper or a wooden plate, to rather virtual conceptual artefacts, such as a digital online service. We recognized them as *instantiations* of the object and named them accordingly (Figure 3, inside the circle). Next, we identified the themes that the speakers attached to the object-instantiations. These were the *features* of the objectinstantiations that the stakeholders found important and to which they related (e.g. durability, appearance, cost) in the context of the network activity (Figure 3, surrounding the circle). Thus, the features revealed something important about the role of the object-instantiations in the network. This phase of the analysis answered the first research question regarding the instantiations and features of the complex object of activity in the digital printing network.

For the second research question, we applied the concept of activity to analyse the objectinstantiations. We sought to determine which activities in the network the different instantiations represented. This interpretive process resulted in the definition of different objectoriented levels of activity and learning (Toiviainen, 2003, 2007).

The unit of data transcription was an object-oriented discussion episode. One episode contained discussion about one identifiable leading object. In reporting the findings, we had to shorten the illustrative excerpts to keep them readable and within space limitations. The points where the transcript has been cut are marked with dashes, and our clarifying notes are in brackets. The speakers are not individually identified. They are mainly named by their roles (designer, printing entrepreneur, consumercustomer, etc.); they are numbered only when more than one person with the same role is referenced in a single excerpt. Some designers also worked as teachers and vice versa, which is noted in the excerpts (teacher-designer) when giving relevant contextual information.

The first author of this paper chaired the workshop and was responsible for the interview data and discussion about the values and expectations. The workshop was recorded on video and transcribed. The second author prepared the transcribed data for analysis and carried out the first analysis of the instantiations and features of the object. The two authors collectively produced all of the other parts, including the research design, the interpretation of the findings, and the final analysis.

Ethical considerations

Project participants signed a consortium agreement containing the principles of data management. For this research, informed consent was obtained from all participants.

Findings

Instantiations and features of the object (RQ1)

As the general object of activity, the customer-centric digitalized service concept appears to have been instantiated in a variety of forms. In a specific action, the object turns a certain facet towards a specific participant (e.g. a concrete product and prototype). We identified 13 instantiations and a heterogeneous collection of features attached to the instantiations (Figure 3) in the workshop discussion analysed.

The following example is from a discussion episode in which we identified the objectinstantiation as a *process model as an operational scheme in network* and marked the features that the participants attached to it. The participants discussed the requirements for a production process model that was needed in the digital printing network. Much of the discussion centred around the design–printing interface and the operational move from the design to

the production phase, as the contributions of a printing entrepreneur and a designer show. A teacher joined the discussion and presented the idea of a gatekeeper as an element in the operational scheme. A designer-teacher responded and added features to the gatekeeper idea. The features identified are designer–producer interface, gatekeeper between designer and producer and between students and producer, creativity, customer requirements, marketability, producibility, educational perspective, pricing, and prototyping. The keywords in the excerpt are italicized.

> Excerpt 1.
> Printing entrepreneur: – Well, the designers; they design for a living, hopefully creative people. They are good at the creative job. But it's still another half of the project to manage to sell something that a customer wants.
>
> Designer: Well, when I contact firms, I know what kind of machinery they have. I know what they can do. Then I think about my design, how to present something that isn't that much present on the market, yet.
>
> Teacher: – When I teach the product development process - my experience in practice is that, in this kind of network, the role of a gatekeeper is extremely important, who is between designer and manufacturer and knows what a product description means. – If a designer sends material in the right form to the right producer, it goes smoothly as if there was no [mediating] network.
>
> Designer-teacher: In fact, we teachers are such gatekeepers. – On a course we purposefully go through everything, we tell what can be done and where. We take the students to a factory. We teach in practice designing for a certain production[line], concretely what you can do on a machine. – And [we teach] pricing and prototyping.

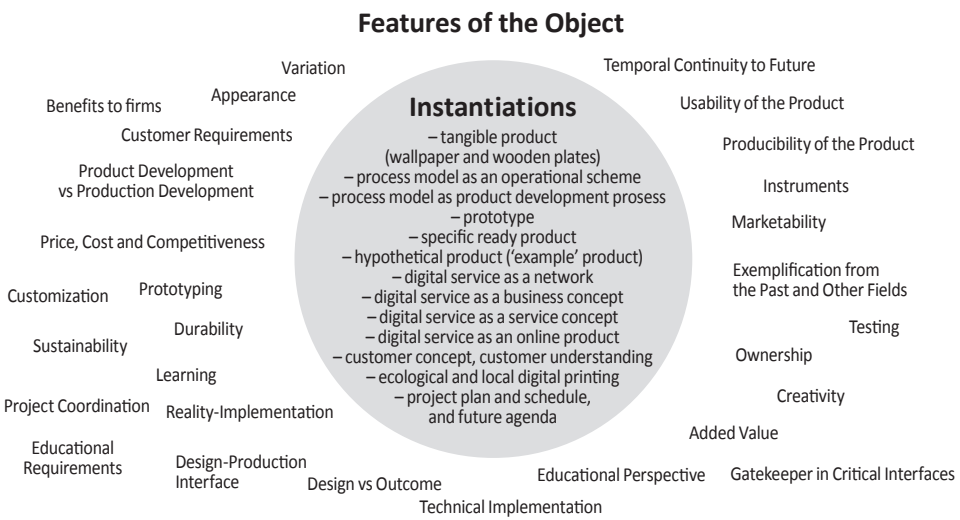

Figure 3. Complex object of activity as an interplay of instantiations and features

Levels of learning (RQ2)

In the second step of the analysis, we examined the instantiations and features of the object in order to identify the levels of learning (Table 2). The definition of the levels gave us insight into the initial learning challenges in the network, but it also provided us with a framework for further analysis of learning during the network project. The four levels are presented in the order of their empirical emergence in the project, which we observed through participation. Starting from the project activity and the organization of the network (level 1), the focus soon turned to the possibilities of the design activity to innovate and create prototype digital printing products (level 2). Subsequently, the network partners started to consider the requirements of the production process in materializing the designs (level 3). This would have meant only a situational reorganization of daily operations, however, without the development activity of the project. The project's aim was to conceptualize the network's collaboration to create a sustainable business (level 4).

Table 2
The levels of network learning in the digital printing network

Level	Leading activity • the object	Instantiations	Features (examples)
1 Project level	Project activity • creation of the digital printing network	– project plan, schedule, and future agenda – digital service as a network	– project coordination – educational requirements – benefits to firms – continuity
2 Product level	Design activity • products to consumer market	– tangible product – prototype – specific, finished product – hypothetical product, product idea	– prototyping – producibility – marketability – variation – appearance – price – durability
3 Process level	Production activity • production development • product development	– process model as an operational scheme – process model as a product development process	– design–production interface – product development vs. production – development gatekeeper – educational perspective
4 Concept level	Development activity for conceptualization • consumer-customer • customized product and service concepts to consumer market • business concept for network	– customer concept – digital service as a service concept – digital service as a business concept – ecological and local digital printing	– sustainability – added value – ownership – customization

The project level, with the project activity as the leading activity, formed the administrative context for the digital printing network's developmental efforts. The object was the formation and development of the network itself. The project was the most obvious level of activity connecting all network stakeholders. Important instantiations included the project plan and agenda that the participants collectively accepted when applying for the funding programme. However, participation and partnership were by no means self-evident; they were rather contested and negotiated. Becoming a learning network is a learning challenge. Learning to learn was a precondition for the other levels and involved ongoing discussion regarding common meanings, rules, the division of labour, etc. The educational feature appeared in the students' involvement, but also the entrepreneurs' and researchers' creative actions to acquire productive networking practices through learning. Excerpt 2 is an example of agreement on the next steps in the project workshop series.

> Excerpt 2.
> Project coordinator: *So, consumer research is the next [workshop and phase], with the idea of inviting [more consumer-customer] types of people. We are waiting for an invitation from* Researchers *2 and 3.*
> Researcher 3: *The coming year will be entirely devoted to consumer research. Today's discussion was really eye-opening in that respect. I have taken detailed notes.*

The product level emerges mainly in the designers' activity, but it involves the producers and consumers, as well. The object consists of the digital printing products and their different instantiations, from product ideas to prototypes and finished items. This level addresses questions such as what is needed and wanted, what is usable, and what is technically possible and sustainable to produce. A further important issue to consider is who the designer is. Is it a professional or an individual consumer? In Excerpt 3, the designer presented the problem of reproducing colours so that the printed product would not deviate from the original design. A colour chart on a computer screen is not reliable, and so test prints would be necessary, which would delay the delivery. She showed her colour experiments with wallpaper, after which the materials and colour specifications of products were discussed in the workshop.

> Excerpt 3.
> Designer: *Here, we can see one of the problems surely emerging in all digiprinting. – If – we've got to customize a model sent by a customer and print it in the original colours at the production plant, that means we need test prints, which delays the production process. Here, I have one example. – This is a breathable material printed with pigment colours that are even quite ecological. – A problem for our service will be that it's a challenge to print, let's say, wallpaper in colours that the customer has chosen on a computer screen.*

The process level featured production as the leading activity, and it oriented towards production and product development in the digital printing network. The instantiations of the object were typically models and modelling efforts to improve the mastery of the networked processes. Product development at the interface of design and printing activities was debated, and it seemed to form a grey area in which the digital printing entrepreneurs in particular experienced a lack of resources. An example of the features attached to the object is the discussion of a gatekeeper who would regulate the interfaces and communicate the requirements of production to design, and vice versa. This was presented in Excerpt 1, which illustrates the discussion of the object on the process level of the network's activity.

The concept level represents the development work – that is, the leading activity carried out by the whole network. Three conceptual instantiations were the customer concept, the service concept, and the business concept. On the concept level, learning culminated in the creation of the online service portal, seeking solutions to questions such as what kind of consumer-customers, products, and services and what earning logic and share of risks the digital printing network could base its future activity on. Considering the far-reaching effects on development work, this is the most demanding and, simultaneously, the most crucial level of learning for the digital printing network. The next example came from a discussion on the online service concept and the definition of a customer. A designer asked about the online service concept that the students had presented in the workshop, and a student replied. A consumercustomer commented on the service from her point of view and defined the customer concept by identifying herself as a self-taught user.

> Excerpt 4.
> Designer: *I am interested in the logistic problems of this model—how material is sent,—what materials are possible to use. – In what way can the customer or designer define the material, and how well does the system respond, or is the chat feature the solution [to the customer-service interaction]*?
> Student: S*till today, it's normally a physical place to go to—[online services] are not that good or well-functioning. Thinking of myself as a designer-consumer—I still want to go and discuss the process on the spot. How can we get to the phase where [everything is managed digitally], so that there's no need to go*?
> Consumer-customer: *[Online guidance] sounds really good. I don't have education in the field. I'm self-taught, or still learning by myself. – Started to upload my photos and art, or, first, started searching for where I could upload them.*

Discussion

Digitalization transforms work and creates new learning needs at all levels of society (Harteis, 2017). According to the mainstream discourse of adult education research and policymaking, the importance of job-specific skills is decreasing, while the general skills that secure adults' job mobility and employability are growing in importance (e.g. Gold & Bode, 2017). This article's activity theory discourse points out that the introduction of digital technology has given rise to new types of learning needs that cut across job-specific and general skills and involve a collective understanding and mastery of the object of networked activity.

This paper analysed the complex object of work in a digital printing network in order to gain insight into the learning of business ecosystems that connect higher education and industry. Digitalization is transforming the object of production in the textile, clothing, and interior printing industry in many ways. It facilitates the co-creativity and innovation of designers, producers, customers, consumers, and students, and it possibly enhances more sustainable development compared to offset or indirect methods. Coordinators and developers of networks, along with developmentally oriented researchers, require knowledge for the design of learning interventions that optimally and sustainably support the innovation activity of networks in current work life.

The first research question investigated the multiplicity of the instantiations and features of the object that the participants articulated when responding to the workshop initiatives (see Table 1). Instantiations varied from tangible products and prototypes to conceptual constructions for the digital printing network's future business activity. In the discussion, the participants enriched the object by articulating features and introducing new instantiations, thus adding to the complexity. For instance, they highlighted that the distributed transitions in a network require the sharing of product and production knowledge between designers or designer-students and manufacturers. This challenge created a gatekeeper feature – there are members of a network who have knowledge in different fields and direct the communication processes in the network among the different stakeholders. The gatekeeper is a familiar concept in social network analysis and studies of technological innovation; it can be seen that the advancements made in ICT have changed its function from a single person's assignment into a task divided among many specialists (Whelan, Teigland, Donnellan, & Golden 2010). In the digital printing network, the next step would be the digitalization of the gatekeeper function as part of the online services for consumers. This calls for the simultaneous development of the members' expertise and intelligent systems. Hakkarainen, Palonen, Paavola, and Lehtinen (2004) have described this kind of process as the development of a networked expertise that, supported by cognitive artefacts, co-evolves in network relationships through interaction.

The complexity of the object involves the variety of ways in which different actors relate to the instantiations and situated objects (Engeström et al., 2003; Knorr Cetina, 2016). We expanded this activity theory notion by analysing the features that the participants attached to the instantiations of the object. We defined the features as the qualities that the stakeholders found important and to which they related when articulating object-instantiations in the network. Through the analysis, we enriched our understanding of the features as carriers of values. The features that the participants attached to various instantiations of the complex object appear to embody their use values and their exchange values, which, in the Marxian sense, make the object-instantiations inherently contradictory. The idea of features as carriers of values is an extension of the activity theory understanding of inherent contradictions in the object of activity, which is recognized as a problematic field of study (Engeström & Blackler, 2005). Network partners may struggle to construct a tangible digital printing product embodying both creativity and marketability. They may innovate on the business concept of a digital service to cultivate education and learning or to increase a single firm's added value and competitiveness. An individual member of the network works on the contradictory values of the object, but the multiplicity of features also suggests that the use values and the exchange values are different for different participants in the network.

The second research question analysed the levels of learning that the complex object produced for the digital printing network. We scrutinized the seemingly diffused notions of the instantiations of the object and reconceptualized them in the context of the activity of the digital printing network. Different instantiations referred to different network activities and the objects of activity, creating learning challenges for the participants on many levels (Toiviainen, 2003).

The project level, the product level, the process level, and the concept level of learning emerged in the DigiPrintNetwork's workshop discussion as being intertwined and mutually related but partly found in tension-laden relationships. For example, strong concern regarding project-level planning may support a service's future concept-level design of a service, but it may also take a leading role, directing attention away from the tricky questions of sharing the service's future benefits and duties. In addition, developments on one level may lead to a mismatch with other levels. A previous activity theory study analysed how product concepts and production concepts develop asynchronously and in a tensionladen relationship, particularly in organizations that are undergoing a major change in production (Jalonen, Ristimäki, Toiviainen, Pulkkis, & Lohtander, 2016). This is experienced in organizations in the phase of technological innovation, when new products (here: product level) bring into question the logic of mass production (here: process level). Thus, the objects of different levels are competing for the network partners' attention and commitment, but, simultaneously, the levels constitute one another.

Conclusion

This paper is a contribution to research on learning and work from the perspective of work-life networks in the age of digitalization. The increasing digitalization of work connects industrial, educational, consumer, and research activities in novel and innovative ways. The empirical case was the DigiPrintNetwork project, which the initiators saw as an opportunity to develop and expand on a business ecosystem's activity in the textile, clothing, and interior printing industry. By applying the CHAT framework, we studied the co-construction of the complex object of work as a means of examining the network's learning. The analysis focused on the participants' co-construction of the multiple instantiations and features of the object and interpreted the instantiations and features as representing different activities emerging in collaboration. The outcome of this analysis is a CHAT framework of the levels of learning in which the learning dynamics are based on the co-construction of inherently contradictory, value-laden, and competing objects of activity at and across different levels.

This study was limited to the initial workshop that gathered all stakeholders of the digital printing network together to discuss the shared object of collaboration. Extending the analysis to all of the workshops in the project would presumably change the picture; it would add objectinstantiations, bring new features, and introduce new levels of learning. Another limitation to consider is our dual role as work-life researchers and learning interventionists, which has meant balancing between analytical distance and engagement in the development process of the network. Thirdly, the conditions of learning at work are culturally constructed and diverse; our case represents the Nordic tradition of employee-driven work-life development (Alasoini et al., 2011; Gustavsen, 2011). We are aware of these limitations and see that specifying the levels of learning for each network provides a model that mediates the longitudinal analysis, the critical researcher's position, and the culturally situated context of learning. Overall, the findings illuminate the diversity and complexity of the object of work—as well as learning—involved in the digital printing network's activity. This paves the way for further analysis of network collaboration in the digital age.

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Declaration of interest

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References

Alasoini, T., Lahtonen, M., Rouhiainen, N., Sweins, C., Hulkko-Nyman, K., & Spangar, T. (Eds.). (2011). *Linking theory and practice: Learning networks at the service of workplace innovation*. Report 75, TYKES. Helsinki: Tekes. Retrieved from https://issuu.com/gfbertini/docs/linking_theory_and_practice_-_learning_networks_at

Clarke, V., Braun, V., & Hayfield, N. (2015). Thematic analysis. In J. A. Smith (Ed.), *Qualitative psychology: A practical guide to research methods* (pp. 222–248). London: Sage.

Engeström, Y. (2015). *Learning by expanding: An activity-theoretical approach to developmental research* (2nd ed.). Cambridge: Cambridge University Press.

Engeström, Y. (2016). Foreword. In Gedera, D. & Williams, P. J. (Eds.), *Activity theory in education*. Rotterdam: Sense Publishers.

Engeström, Y., & Blackler, F. (2005). On the life of the object. Introduction. *Organization, 12*(3), 307–330.

Engeström, Y., Miettinen, R., & Punamäki, R. L. (Eds.). (1999). *Perspectives on activity theory*. Cambridge: Cambridge University Press.

Engeström, Y., Puonti, A., & Seppänen, L. (2003). Spatial and temporal expansion of the object as a challenge for reorganizing work. In D. Nicolini, S. Gherardi, & D. Yanow (Eds.), *Knowing in organizations: A practice-based approach*, (pp. 151–186). New York: ME Sharpe.

Fenton, H. M., & Romano, F. J. (1997). *On-demand printing: The revolution in digital and customized printing.* Pittsburgh: GATF Press.

Fletcher, K. (2014). *Sustainable fashion and textiles: Design journeys* (2nd ed.). New York: Routledge.

Fragidis, G., Tarabanis, K., Koumpis, A. (2007). Conceptual and business models for customer-centric business ecosystems. In Hussain, F. K. & Chang, E., *Proceedings of Digital EcoSystems and Technologies Conference DEST '07* (pp. 94–99). Cairns: IEEE.

Gebler, M., Uiterkamp, A. J. S., & Visser, C. (2014). A global sustainability perspective on 3D printing technologies. *Energy Policy, 74*, 158–167.

Gold, R., & Bode, E. (2017). *Adult training in the digital age*. Economics Discussion Papers, No. 2017-54. Kiel: Kiel Institute for the World Economy (IfW). Retrieved from http://hdl.handle.net/10419/167687

Gustavsen, B. (2011). The Nordic model of work organization. *Journal of the Knowledge Economy*, *2*(4), 463–480.

Hakkarainen, K., Palonen, T., Paavola, S., & Lehtinen, E. (2004). *Communities of networked expertise: Professional and educational perspectives*. Amsterdam: Elsevier.

Harteis, C. (Ed.). (2017). *The impact of digitalization in the workplace: An educational view*. Cham: Springer.

Hirscher, A.-L., Niinimäki, K., & Armstrong, C. M. J. (2017). Social manufacturing in the fashion sector: New value creation through alternative design strategies? *Journal of Cleaner Production, 172*, 4544–4554.

Jalonen, M., Ristimäki, P., Toiviainen, H., Pulkkis, A., & Lohtander, M. (2016). Between product development and mass production: Tensions as triggers for concept-level learning. *Journal of Workplace Learning*, *28*(1), 33–48.

Knorr Cetina, K. (2016). Objectual practice. In M. Mazzotti (Ed.), *Knowledge as social order: Rethinking the sociology of Barry Barnes,* (pp. 97–112). New York: Routledge.

Leontiev, A. N. (1978). *Activity, consciousness and personality*. Englewood Cliffs: Prentice Hall.

Marx, K. (1986). *Capital: A critique of political economy. The process of production of capital* (Vol. 1). Moscow: Progress Publishers.

Miettinen, R., & Paavola, S. (2018). Beyond the distinction between tool and sign: Objects and artefacts in human activity. In A. Rosa & J. Valsiner (Eds.), *The Cambridge handbook of sociocultural psychology* (pp. 148–162). Cambridge: Cambridge University Press.

Nelson, S. B., Jarrahi, M. H., & Thomson, L. (2017). Mobility of knowledge work and affordances of digital technologies. *International Journal of Information Management*, *37*(2), 54–62.

Nicolini, D., Mengis, J., & Swan, J. (2012). Understanding the role of objects in cross-disciplinary collaboration. *Organization Science*, *23*(3), 612–629.

OECD. (2016). *Automation and independent work in digital economy*. Policy brief on the future of work. Paris: OECD Publishing. Retrieved from https://www.oecd.org/els/emp/Policy%20brief%20-%20Automation%20and%20Independent%20Work%20in%20a%20Digital%20Economy.pdf

Paavola, S., & Miettinen, R. (in press). Dynamics of design collaboration: BIM models as intermediary digital objects. *Computer Supported Cooperative Work (CSCW)*.

Parsons, J. L., & Campbell, J. R. (2004). Digital apparel design process: Placing a new technology into a framework for the creative design process. *Clothing and Textiles Research Journal*, *22*(1–2), 88–98.

Toiviainen, H. (2003). *Learning across levels: Challenges of collaboration in a small-firm network*. Helsinki: Helsinki University Press.

Toiviainen, H. (2007). Interorganizational learning across levels – An object-oriented approach. *Journal of Workplace Learning, 19*(4), 343–358.

Tyler, D. J. (2005). Textile digital printing technologies. *Textile Progress, 37*(4), 1–65.

Welford, R. (2013). *Hijacking environmentalism: Corporate responses to sustainable development*. New York: Routledge.

Whelan, E., Teigland, R., Donnellan, B., & Golden, W. (2010). How Internet technologies impact information flows in R&D: Reconsidering the technological gatekeeper. *R&D Management*, *40*(4), 400–413.

Whitbread, D. (2009). *The design manual*. Sydney: University of New South Wales Press.

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