Ludwig, T., Tolmie, P. and Pipek, V. (2017): From the Internet of Things to an Internet of Practices. In: Proceedings of 15th European Conference on Computer-Supported Cooperative Work - Exploratory Papers, Reports of the European Society for Socially Embedded Technologies (ISSN 2510-2591), DOI: 10.18420/ecscw2017-10

From the Internet of Things to an Internet of Practices

Thomas Ludwig, Peter Tolmie, Volkmar Pipek
University of Siegen
thomas.ludwig@uni-siegen.de

Abstract. In his ground-breaking work on the *habitus* Bourdieu (1977) understands practices as the permanent internalization of the social order in the human body. Others have taken this idea and described practices as 'normatively regulated activities' (Schmidt, 2014). Our own interests here arise from the fact that during the performance of all of these various activities, which may implicate and draw upon the material environment, the surrounding context, their own capabilities, interests and preferences, people often use supportive devices and technologies that help to enable and support their realization. Where these supportive technologies make up a part of the Internet of Things (IoT) they are usually small, interconnected cyber-physical devices and are typically used in social/collaborative settings. As a consequence, the (re-)appropriation of these new devices and technologies is not only a technical, but also a social process. Within this exploratory paper we focus on the potential of IoT technologies for supporting collaborative appropriation within Communities of Practice (CoP) from a practice-oriented perspective. We outline the vision of an Internet of *Practices* (IoP). This vision encompasses and addresses a range of phenomena that has been associated with how CoPs evolve and the resonance activities that can arise as specific bodies of practice adapt, by adding integrated support for the documentation of practices and the sharing of relevant representations such that mutual improvements in practice may take place. Based on our vision of the IoP, we outline some directions CSCW research could take regarding the potential of the IoT and new emerging technologies, thereby expanding the scope of CSCW's areas of interest.

Introduction: Learning Technology Practices

Imagine you are a new photographer within a well-established photographic agency and you've got a new expensive camera for starting your job. The

photographic agency demands that all of its employees use a consistent style for each photo set. You've already used the camera a lot and it has encouraged you to think that you might one day become a more professional photographer. However, having compared your pictures with those of your colleagues who have been in the company for a long time, you've had to acknowledge that their sets of photos always look better than your own. Yet your colleagues and you are both using the same camera, the same tripods, even the same lenses. So you ask yourself: How will I ever be able to take such perfect pictures? This has driven you to search online for lighting conditions, angles for holding the camera and which lenses are best to use in different situations. You've also asked your expert colleagues for help and they have actually described for you how they go about taking pictures. Although you've really appreciated your colleagues' hints, your pictures are still not as good as theirs. The problem is it's just not easy adapting your own activities so they are closer to the established practices of the experts when you only have their explanations to go on, not to mention having to do that alongside of other compounding elements such as the hardware, software and the physical context in which you are using the camera (as well as your own physical abilities). So you continue to struggle to appropriate your camera effectively – or at least the practice of taking good pictures.

But what if the camera was itself able to mediate your colleagues' professional camera-handling practices? What if you were able to perceive expert photographic practices directly when taking your own pictures? What if the cameras were equipped with multiple sensors and were connected through the internet so that they could enable the gathering as well as the sharing of practices of other camera users? Or, to put it another way: What if we could make use of the Internet of Things (IoT) to move beyond just the 'things' and towards an Internet of *Practices* (IoP)?

In this exploratory paper we expand yet further the existing discussion around the potential the IoT as a set of new emerging technologies may have for extending the scope of CSCW's areas of interest (Robertson & Wagner, 2015). We do this by introducing the vision of the IoP as a new theoretical framework that can encompass a variety of complementary interests: 1) the socio-technical (collaborative) concept of appropriation; 2) the technological possibilities of sensors and actuators; and 3) an integrated concept of sociable technologies that can be connected through the IoT to support the mediation as well as implicit learning of technology practices. In doing this we outline a socio-technical perspective on the IoT with regard to CSCW and how the design of IoT technologies could be used to inform appropriation and infrastructuring (Pipek & Wulf, 2009) practices.

Theoretical Framing

Our vision of the Internet of Practice is a conjunction of two discourses. The first of these relates to both the concept of practice itself and communities of practice. The second is on the other discourse relates to IoT-enabled (collaborative) appropriation infrastructures – what we refer to here as ‘sociable technologies’ (Ludwig et al., 2017).

The Concept of Practices

Our entire life encompasses various kinds of variably tool- or technology-based practices: whether preparing dough in a food processor; playing soccer with a ball; or – as discussed above – taking photos with a digital camera using a consistent style for each set of photos. From a ‘practical’ perspective, practices are applied heterogeneously – some people bake tastier bread than others, some people are better at playing soccer than others.

From a theoretical perspective, practice is also often understood heterogeneously (Corradi et al., 2010) and can be described as “routines consisting of a number of interconnected and inseparable elements: physical and mental activities of human bodies, the material environment, artifacts and their use, contexts, human capabilities, affinities and motivation” (Kuutti & Bannon, 2014). This perspective is based on early practice theories that often conceptualize practices as “routinized, oversubjective complexes of bodily movements, of forms of interpreting, knowing how and wanting and of the usage of things” (Reckwitz, 2002). This understanding is itself based on Bourdieu's (1977) Theory of Practices in which he developed the notion of ‘habitus’ to capture

> “the permanent internalization of the social order in the human body”. With this idea, Bourdieu understands practice “as the result of social structures on a particular field (structure; macro) where certain rules apply and also of one’s habitus (agency; micro), i.e. the embodied history that is manifested in our system of thinking, feeling, perceiving and behaving. The habitus assures the collective belief in the rules of the social game (illusio) and that actors act in accordance with their position on the field (doxa), which depends on their relative amount and structure of economic, cultural (and social) capital” (Walther, 2014).

As Kuutti & Bannon (2014) point out, although practice theories differ in many ways, there are also a number of common features. By referring to Nicolini (2013) they list these common features as follows:

1. A process and performative view on social life: structures and institutions are realized through practices; practices are local and timely and they have histories.
2. The critical role of materiality of human bodies and artifacts; there are no practices without them.

3. A different role of agency and actor than in traditional theories: ‘homo practicus’ is both the bearer of practices in his or her mind and body, and the one who produces the practices in action.
4. Seeing knowledge as a capability to act through practices in meaningful and productive ways.
5. The centrality of interests and motivations in all human action and a corresponding focus on power, conflicts and politics.

Schmidt (2014) positions these perspectives in work contexts by saying that a practice is not just any kind of activity, but a regular activity, whereby the regularity is a normative application of general principles. A practice can therefore be understood as a *normatively regulated activity* that differs from some other practice by the body of rules that govern it (Schmidt, 2014). Work is not simply the following of preordained rules, but necessarily involves the local interpretation of these rules in the light of the evolving situation (Kuutti & Bannon, 2014). So, performing the activity of taking pictures by using the photographic agency’s demanding consistent style of for sets of photos is understood as a specific type of practice (for now!).

Kuutti & Bannon (2014) argue that lasting recent years a new ‘practice’ paradigm has emerged in the field of HCI. Instead of simply considering the role of design intervention as changing human actions by introducing novel technology, it needs to be understood that human actions and interactions are just a part of entire practices. Practices emphasize the fabric of action, the knowledge and reasoning that surrounds that action and the context in which it takes place (Castellani et al., 2009). “For some time it has been supposed that context influences what happens in interaction and how it is experienced, resulting in attempts to define richer and richer contexts. But ‘practice’ can be interpreted as the ultimate context: practices are where interactions take place in real life” (Kuutti & Bannon, 2014). So how should we understand the context of practice when taking good, consistent pictures with a new camera?

Internet of Things

In the early 90s, Mark Weiser and his colleagues from Xerox PARC came up with the concept of Ubiquitous Computing, envisioning that “the most profound technologies are those that disappear. They [technologies] weave themselves into the fabric of everyday life until they are indistinguishable from it” (Weiser, 1991). The vision of interconnected small computers, which Weiser described in the early 90s, coupled with the penetration of the internet as well as the miniaturization of computers and electronic assemblies is now commonly known as the Internet of Things (IoT) – a term firstly coined by Kevin Ashton (2009). The “things” are often summarized as cyber-physical systems meaning

> “physical and engineered systems, whose operations are monitored, coordinated, controlled and integrated by a computing and communication core. Just as the internet transformed how

> humans interact with one another, cyber-physical systems will transform how we interact with the physical world around us" (Rajkumar et al., 2010).

Although the 'things' offer new possibilities and functionalities that have come along with (and will continue to come along with) the interest in the IoT (Atzori et al., 2010), they will also increase the complexity of the practices associated with the ecologies of technology they encompass. This will be a result of: (a) increasingly complex devices; (b) an increasing number of less obvious connections and dependencies between IoT devices and things; (c) more and more changes that ensembles of IoT technologies will need to undergo in order to fully integrate the most recent technological options and advances (e.g. depth sensors in cameras); and (d) a new interweaving of the 'digital' and the 'physical' world – such as the one our opening example of the camera sought to illustrate.

By taking the cooperation between cyber-physical things within the IoT seriously, Robertson and Wagner (2015) have already outlined issues from a CSCW perspective with regard to how IoT applications may associate with practices. These arguments in turn are built upon the discussions around the "issues people had with not understanding and/or not trusting the ways in which their sensors worked, as well as the practical realities of location and timing and false alarms that render them less useful" (Stringer et al., 2006). Within this paper we develop a notion of an Internet of Practices that builds upon the IoT and tries to make sense of the IoT from a human-centered perspective to perform practices using IoT.

Infrastructuring and Sociable Technologies

When handling the 'things' or the 'cyber-physical assemblies' do not meet users' intended practices (e.g. the camera during taking pictures), either people with specialized knowledge are needed who know how to make them work again or explain the handling (Crabtree et al., 2006; O'Neill et al., 2005; Robertson & Wagner, 2015) or, as is often the case with sophisticated 'new' technologies, users will discover new ways of handling them by attempting to manage their understanding in the context of their existing (and changing) practices (Dalton et al., 2012; Ludwig et al., 2014; Pipek, 2005; Pipek & Wulf, 2009). The new photographer starts thinking about how to take better pictures and tries new configurations or different positions regarding the angles or lighting conditions. "The recent interest in how people take ownership of artifacts and shape them to their own purposes and practices clearly relates to this practice turn, as it examines the ways in which designed "things" become assimilated into an ongoing set of routines" (Kuutti & Bannon, 2014).

Broadening the focus a little, we want to relate this process of adaptation to the notion of 'intrastructuring'. Star and Ruhleder (1996) consolidated the socio-material aspects of an infrastructure by relating technological infrastructures to the practices they were meaningful to. This approach, which referred back to

previous work in Science and Technology Studies (STS) on 'large technological systems' and infrastructures, was further transformed when Star and Bowker (2002) and later Karasti and Baker (2004) started to widen the design-oriented and product-focused lense of traditional technology development to the concept of infrastructuring.

Infrastructuring can be understood as the reshaping of a work infrastructure and practices of use by "re-conceptualizing one's own work in the context of existing, potential, or envisioned IT tools" (Pipek & Wulf, 2009). Encompassed within the concept of infrastructuring (ibid.) are all (appropriation) activities that lead to discovering and developing the usage of an entire infrastructure and to the successful establishment of a device or system in use.

The relation between an artifact and the practices it supports can be viewed as the trajectory of a artifact when it is confronted with people's practices of 'appropriation' (Dourish, 2003). It can equally be viewed as the trajectory of a practice where breakdowns or innovation lead to the kinds of exploration of technological possibilities and improvements captured by the notion of 'infrastructuring' (Pipek & Wulf, 2009). Pipek (2005) conceptualizes appropriation as the discovery of, and the sense making entailed in, using a device or artifact in practice. This understanding has its roots in established CSCW literature, where appropriation is associated with the process of fitting new technologies to users' practices in situ by both the adoption of, and adaptation to those technologies (Balka & Wagner, 2006; Dourish, 2003; Mackay, 1990; Salovaara et al., 2011; Stevens et al., 2009) and is therefore an important aspect of infrastructuring .

One of the major characteristics of infrastructuring is the "Point of Infrastructur(ing)" (PoI). This is the moment in which a (group of) practitioner(s) understand(s) that the current use of a technological infrastructure needs to be reconsidered (Pipek & Wulf, 2009). The PoI started out as an analytical figure. It sought to capture the moment where people become aware of infrastructure problems or opportunities. This moment can (a) happen at an individual, organizational or even societal level. It is (b) the moment in which the political, social, organizational and technological dimensions of an infrastructure become tangible for the practitioners that depend on it. It (c) initiates a set of activities amongst a variety of stakeholders, which target the infrastructure problem or opportunity. And (d) it may ultimately result in a modified infrastructure and/or a modified (use) practice (Pipek, 2005).

The concept of infrastructuring is usually associated with processes of exchange and interaction in networks of co-users where experiences and stories are shared between actors involved in the appropriation process (Gantt & Nardi, 1992; Mackay, 1990; Pipek, 2005; Pipek & Kahler, 2006). The new photographer starts searching for help, asking professional colleagues or just has some kind of interchange with other camera users who have similar issues. These processes of

exchange and interaction require a variety of communication and cooperation practices, but often come with the burden of being cumbersome and hard to adapt to pre-existing practice (Crabtree et al., 2006).

As Pipek (2005) suggests, appropriation and its encompassing collaborative activities around things defines a Community of Practice (CoP). This is in Wenger's (1998) original sense of a CoP as a social compound in which technological practice can be observed, passed on and further developed. CoPs are viewed by many in business settings as a means of capturing tacit knowledge, or know-how that is not easily articulated (Nonaka & Takeuchi, 1995; Wenger, 1998). Jean Lave and Etienne Wenger's theory of legitimate peripheral participation sees learning within a CoP both related to, and a specific form of, a particular practice (Kuutti & Bannon, 2014). It is therefore obvious that considering the IoT on a purely technological basis misses important points that practitioners (and CoPs) have to consider when developing, re-inventing and 'infrastructuring' their practices (Ludwig et al., 2017; Pipek & Wulf, 2009; Robertson & Wagner, 2015; Star & Bowker, 2002).

In a first test of using improved functional components that are grounded in this way of thinking we turned to 3D printing and argued that new IoT-based technologies are particularly capable of supporting the (collaborative) appropriation activities of their users by making the devices more 'sociable' (Ludwig et al., 2017). In relation to this we coined the term 'sociable technologies' to capture the kinds of hardware-integrated affordances for communicating, documenting and sharing practices of use that can arise through the adoption of new IoT technologies.

Taking network printing technology as a case in point it is worth noting that, in previous work, Castellani et al. (2009) uncovered a number of dislocations between various aspects of technology-based CoPs. Here their focus was on the work of troubleshooting where there was:

> "1) a physical dislocation between the site of the problem and the site of problem resolution; 2) a conceptual dislocation between the users' knowledge and the troubleshooting resources and 3) a logical dislocation between the support resources and the ailing device itself" (Castellani et al., 2009).

For the purposes of our own argument here we would build upon these observations by noting that sociable technologies need to operate on three contextual levels: (1) The *internal context*, where they provide information about their inner workings and current state as well as about their component and behavioral structure; (2) The *socio-material context*; which encompasses things like their location and surroundings, environmental data like room temperature, and maintenance or user/usage data; (3) The *task/process context*: which will relate to things like the purpose and goal of device use (Ludwig et al., 2017, 2014).

Sociable technologies aim to lower the burden of documenting and sharing insights about practices by encompassing the IoT and by gathering as well as

communicating sensor information. With the idea of sociable technologies we follow the idea about the mediation of practices by artifacts (Kuutti & Bannon, 2014). In the case of 3D printing, the printer itself communicates captured sensor information such as print temperature or the movements of the extruder in association with the model and its material characteristics, to give details of use practices (Ludwig et al., 2017).

Resonance Activities

In order to (semi-)automatically sense the actual use practices of a 'thing' in a certain situational context and support the sharing of this information, and its visualization to users with similar practices within a CoP, new design approaches are required that transcend the notion of technology as a product. How might the new camera user experience the practices and infrastructuring activities another experienced camera user has already made? How might a novice learn about new ways of taking pictures with a camera when they've just acquired new lenses?

As we have already pointed out, one of the major characteristics of infrastructuring, understood as a technology development methodology, is the "Point of Infrastructur(ing)" where a (group of) practitioner(s) understand(s) that the current use of a technological infrastructure needs to be reconsidered (Pipek & Wulf, 2009). Now Pipek and Wulf (2009) suggest that points of infrastructuring do not happen arbitrarily during the course of performing a practice. Instead, they argue, there are specific factors which are likely to trigger this reconsideration and that there is a strong dependency between a practice and its supporting infrastructure that, having developed previously, will have become largely invisible to the actors who are engaged in the practice in question.

Here, the concept of infrastructuring suggests that, based on this initial impulse, there is a period of technology (re-)configuration, tailoring and development of conventions, in which the 'last mile of technology development' will be mainly performed by (not necessarily technologically skilled) practitioners. This will continue until the point has been reached at which a new technology usage has been successfully established (Pipek & Wulf, 2009). In terms of infrastructuring, the work infrastructure has been further developed and may "sink into the background" again, re-establishing and strengthening the dependency between the (work) practice and work infrastructure (Pipek & Wulf, 2009).

Infrastructuring occurs in ways that are based upon the nature of the dependency between a practice and its work infrastructure, and as Pipek and Wulf (2009) argue, it is difficult to suggest a general model that would help to describe or suggest details of infrastructuring activities. They adopt the position that activities relating to the 'last mile of technology development' are less about a predefined division of labor and rather more about the development of a network

of cooperation between practitioners (and developers). As Pipek and Wulf (2009) argue, this network of cooperation is inspired and driven by other PoIs that have happened earlier in related practices.

Inspired by this perspective, we can identify processes of infrastructuring that surface to connect 'global' infrastructures to their 'local' usages. Here the appropriation of an infrastructure becomes a part of designing it and putting it to use. As Pipek and Wulf (2009) argue

> "each point of infrastructure does not only provoke in-situ design activities and makes visible prior preparatory activities, but it also creates *resonance activities* of observing and communicating aspects of what has become visible within the work environment or to other work environments."

The concept of resonance activities is understood to be all of those kinds of activities that may become visible to people engaged in other, related practices, or to technology developers who laid the technological foundation of an ongoing practice innovation (initiated by points of infrastructure).

The concept describes the connections between different points of infrastructuring. Through such resonance activities, the changes that emerge around the PoI become accessible to others engaged in practices that have a connection with the one where the PoI occurred. Taking a step back from the IoT as it is currently conceptualized, expertise-sharing platforms like photographer forums cover a lot of the interactions that might count as resonance activities and that might therefore serve to extend infrastructuring around a single PoI. But the limited depth these discussions are able to reach in terms of addressing the relation between infrastructure technologies and a concrete situated practice where a PoI has occurred, show that there is much room for improvement to support these kind of interactions. By examining resonance activities "the social appropriation of certain technology usages can be captured, and the relations between different points of infrastructure become clear" (Pipek & Wulf, 2009).

The Internet of Practices

So, how could a new photographer who is struggling with the practices involved in taking good pictures be supported by professional photographers? How could appropriate bodies of practice pertaining to particular needs mediated through technology?

The purpose of shifting towards the notion of an *Internet of Practices* is to re-consider the IoT and the cooperating cyber-physical systems that characterize it in ways that will allow us to move beyond a limited technological point of view and towards something that recognizes us more strongly the practices and communities that surround its use (Pipek & Wulf, 2009; Star & Bowker, 2002). The position we are arguing for here is that we start to work towards

understanding how the Internet of Things is also an Internet of Practices – or, perhaps more accurately, an evolving Internet of Practices (Figure 1).

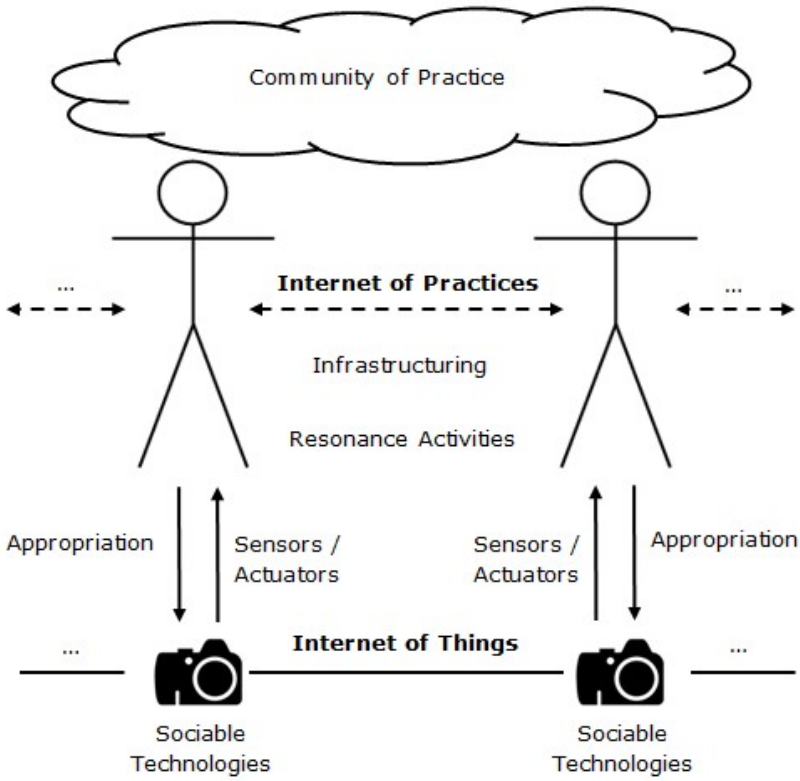

Figure 1: Internet of Practices (IoP)

The IoP encompasses the socio-technical (collaborative) aspects of appropriation and infrastructuring coupled with the technological possibilities of actuators as well as sensors and the integrated concept of sociable technologies connected through the IoT to support the practices of artifact users and therefore (evolving) Communities of Practices by documenting, sharing and communicating their practices.

Adapted to the practice of taking pictures, a camera, when designed as a sociable technology, is also able to gather information about the width of a wide-angle lens or the resolution of a high-contrast display (internal context); the lighting conditions and the position in which the camera is being held (socio-material context); and current interests such as acquiring a sharply focused image of a specific object in a broader landscape (task/process context). All of this documented information can then be shared via the IoT and suggested to another camera user who has similar interests and who is working in a similar socio-material context directly in situ. In these ways the digital cameras of other users can themselves be adapted to meet the shared internal context.

This perspective supports the Practice paradigm by encompassing bodies, artifacts, performances, and routines as a more encompassing frame (Kuutti &

Bannon, 2014). This begins to illustrate how the dependencies of practices on new and complex layers of technologies might be managed by continuous infrastructuring efforts and appropriate methodologies that not only address the development of an IoT product, but the preparation and reflection of how it is used and situated in practice. In relation to the theoretical framework we articulated earlier, documented aspects regarding the practices through which a technology is used are able to create resonance activities to users using the same technology (or where there are similar practices), thereby helping other users to appropriate similar bodies of practice.

So returning to our original example, by making use of the IoP, the new photographer is able to not just acknowledge the expert colleague's *explanations about the practices* best suited to that camera, but also to *directly appropriate these actual practices* in situ. Drawing upon the IoT as a resource, the new photographer's camera is able to give feedback and suggestions to its user, such as when the camera has been positioned at the right angle with regard to the actual lighting conditions; when a specific lens would be much more appropriate with regard to the distance of an object; or when the optimal distance between an object and the camera is reached.

In their own discussion of the future possibilities for the IoT Robertson and Wagner (2015) suggest that "in due course we will have opportunities to study people's practices that include the everyday use of IoT technologies". We argue that in the future we will not only be able to study people's practices and their particular use of IoT technologies, but also, by applying the concept of sociable technologies, users themselves will be able to *harness the IoT to detect, share and mediate these (use) practices* – or, as Schmidt (2014) would have it, they will be able to share the norms of their regulated activities.

Conclusion

Practices are not just any kind of activity. Based on early practice theories, they might be understood as "routines consisting of a number of interconnected and inseparable elements: physical and mental activities of human bodies, the material environment, artifacts and their use, contexts, human capabilities, affinities and motivation" (Kuutti & Bannon, 2014). Within work contexts they could further be described as normatively regulated activities, whereby the notion of 'normative' refers to the application of general principles (Schmidt, 2014).

Schmidt's (2014) argument is that it is possible to observe and determine the normative make-up of a practice, e.g. when people are making excuses for particular actions, when they are asking for guidance, when they are instructing novices, and so on. Within this exploratory paper, we have sought to explore the potential of IoT technologies for mediating the normative character and the collaborative appropriation of the bodies of practice from a practice-oriented

perspective. To accomplish this we have outlined how the Internet of *Practices* might address phenomena relating to evolving Communities of Practice and resonance activities by adding an integrated support for the observation and documentation of practices. This can be further reinforced through the sharing of relevant representations for mutual practice improvements. In our view the concept of an IoP has a great deal of research potential for the CSCW community. Here are just a few avenues that might be explored:

- As Schmidt (2002) has argued awareness is not the product of passively acquired information, but rather a feature of highly active and highly skilled practices. In relation to this Robertson and Wagner (2015) raise the question of how technology-provided and technology-focused awareness could inform, complement and support the people using such applications so that they are aware of relevant issues. With the IoP one could also ask: how could one become aware of other members of a CoP as well as (potentially) interesting activities through the technology? And how to detect similar practices as well as how to compare kinds of practices?
- Devices or cyber-physical systems are often situated within highly collaborative settings and often serve as enablers and mediators for communication (whether co-located or remote). However, if people's practices are connected through IoT technology and they are performing collaborative tasks, the question is how could the activities be aligned or structured at a physical level? This is especially pertinent when almost every tool or device (e.g. a hammer or drill) might count as a cyber-physical system that could be connected through the internet.
- Practice-based research agendas and researchers are usually interested in real-life practices. The practices must therefore be studied where they occur including the natural setting. Suchman (1987) outlined that the aim of research should be an exploration of "the relation of knowledge and action to the particular circumstances in which knowing and acting invariably occur". However, when moving from laboratory studies to in-the-wild studies and understanding the full context (and not just the most immediate one) this becomes challenging and is (right now) all but impossible. So, how to examine the entire practice as the ultimate context?
- As already outlined by Kuutti and Bannon (2014) we are nowadays increasingly faced with digital ecologies and at the same time every practice has a particular set of artifacts that make it possible. We therefore need to broaden the viewpoint on the world about us. How to detect media disruptions and changing artifacts during a practice? How to detect the co-evolution of practices and an entire ecology of artifacts?

- Through the IoT there are increasingly new types of inter-connected devices that are able to further support the mediation of practices such as virtual reality or augmented reality technology. New smart glasses such as Microsoft HoloLens, for instance, could support the mediation of practices between people or the technology (learning) practices within CoPs. However, new technologies require new types of methodology for researchers to examine the distributed practices that are facilitated through those new technologies. A question is if and how qualitative research methods will need to change to cope with studying the use of new types of connected data resources such as sensor data about lightning conditions or information about people's movement patterns.
- Due to the diverse inter-connectedness of infrastructures, their socio-material relations, and the heterogeneous practices associated with the use of technological tools, one question remaining is how to capture related resonance activities across communities? Furthermore, if this can be done, how might one approach designing technological support for them?
- The IoP also requires taking into account the privacy issues that surround CoPs and how they may seek to document and share practices. There is work to be done in that case regarding how best to support the effective negotiation of privacy and security interests within groups of users.

Within this exploratory paper we have introduced an initial vision of an Internet of Practices and how it could evolve from the existing Internet of Things. For this initial foray we have framed our concept theoretically and have related it to existing discourses in CSCW. We have adopted a quite pragmatic view upon how the IoP might serve to support things like CoPs. We are aware there are bleakly portrayed dystopias of a technocratic future, whereby everyone is augmented and adapted to a point of equal competence and capability. In such dystopias differences and the heterogeneity of people are typically devalued and this can also be seen to relate to older debates about de-skilling (Braverman, 1974). However, the position we adopt here is that the IoP may preserve or even enhance the diversity and skills of people, perhaps even cross-culturally.

In future work we expect to work on much finer specifications of the IoP and will be conducting design case studies (Wulf et al., 2015) in different application areas in order to examine the scope, applicability, and potential consequences of using this concept in practical settings. Our primary hope at this stage is that this exploratory paper will inspire researchers to think about other possibilities for the IoT that have not previously been articulated as IoT technology becomes more clearly established as a feature of our everyday lives, thereby expanding – as Robertson and Wagner (2015) requested – the areas of interest to which CSCW research might actively contribute.

References

Ashton, K. (2009). That “Internet of Things” Thing. *RFiD Journal*.

Atzori, L., Lera, A., & Morabito, G. (2010). Internet of Things: A Survey. *Computer Networks2*, *54*(15), 2787–2805.

Balka, E., & Wagner, I. (2006). Making things work: dimensions of configurability as appropriation work. In *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work* (pp. 229–238). ACM. doi:10.1145/1180875.1180912

Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge University Press.

Braverman, H. (1974). *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century*. New York: Monthly Review Press.

Castellani, S., Grasso, A., O’Neill, J., & Roulland, F. (2009). Designing technology as an embedded resource for troubleshooting. *Journal of Computer Supported Cooperative Work*, *18*(2–3), 199–227. doi:10.1007/s10606-008-9088-1

Corradi, G., Gherardi, S., & Verzelloni, L. (2010). Through the practice lens: Where is the bandwagon of practice-based studies heading? *Management Learning*, *41*(3), 265–283. doi:10.1177/1350507609356938

Crabtree, A., O’Neill, J., Tolmie, P., Castellani, S., Colombino, T., & Grasso, A. (2006). The practical indispensability of articulation work to immediate and remote help-giving. In *Proceedings of the 20th anniversary conference on computer supported cooperative work* (pp. 219–228). doi:10.1145/1180875.1180910

Dalton, N., MacKay, G., & Holland, S. (2012). Kolab: Appropriation & Improvisation in Mobile Tangible Collaborative Interaction. In *Proceedings of the Designing Interactive Systems Conference* (pp. 21–24). Newcastle, UK: ACM New York. doi:10.1145/2317956.2317960

Dourish, P. (2003). The Appropriation of Interactive Technologies: Some Lessons from Placeless Documents. *Computer Supported Cooperative Work*, *12*(4), 465–490. doi:10.1023/A:1026149119426

Gantt, M., & Nardi, B. B. A. (1992). Gardeners and gurus: patterns of cooperation among CAD users. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 107–117). Monterey, CA: ACM New York. doi:10.1145/142750.142767

Karasti, H., & Baker, K. S. (2004). Infrastructuring for the long-term: ecological information management. In *Proceedings of the Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the* (pp. 1–10).

Kuutti, K., & Bannon, L. (2014). The turn to practice in HCI: towards a research agenda. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’14)* (pp. 3543–3552). Toronto, Ontario, Canada: ACM New York, NY, USA. doi:10.1145/2556288.2557111

Ludwig, T., Boden, A., & Pipek, V. (2017). 3D Printers as Sociable Technologies: Taking Appropriation Infrastructures to the Internet of Things. *ACM Transactions on Computer-Human Interaction (TOCHI)*,

24(2).

Ludwig, T., Stickel, O., Boden, A., & Pipek, V. (2014). Towards Sociable Technologies: An Empirical Study on Designing Appropriation Infrastructures for 3D Printing. In *Proceedings of DIS14 Designing Interactive Systems* (pp. 835–844). Vancouver, Canada. doi:10.1145/2598510.2598528

Mackay, W. E. (1990). Patterns of sharing customizable software. In *Proceedings of the 1990 ACM conference on Computer-supported cooperative work* (pp. 209–221). Los Angeles, CA: ACM New York. doi:10.1145/99332.99356

Nicolini, D. (2013). *Practice Theory, Work and Organization. An Introduction*. Oxford: Oxford University Press.

Nonaka, I., & Takeuchi, H. (1995). Knowledge-Creating Company. *Knowledge-Creating Company*. doi:10.1016/S0969-4765(04)00066-9

O'Neill, J., Castellani, S., Grasso, A., Roulland, F., & Tolmie, P. (2005). Representations Can be Good Enough. In *Proceedings of the Ninth European Conference on Computer-Supported Cooperative Work (ECSCW)* (pp. 267–286). Paris, France: Srpinger. doi:10.1007/1-4020-4023-7_14

Pipek, V. (2005). *From Tailoring to Appropriation Support: Negotiating Groupware Usage*. University of Oulu. Retrieved from http://herkules.oulu.fi/isbn9514276302/isbn9514276302.pdf

Pipek, V., & Kahler, H. (2006). Supporting Collaborative Tailoring. In *End-User Development* (pp. 315–345). Srpinger.

Pipek, V., & Wulf, V. (2009). Infrastructuring: Toward an Integrated Perspective on the Design and Use of Information Technology. *Journal of the Association for Information Systems (JAIS), 10*(5), 447–473.

Rajkumar, R., Lee, I. L. I., Sha, L. S. L., & Stankovic, J. (2010). Cyber-physical systems: The next computing revolution. In *47th ACM/IEEE Design Automation Conference (DAC)* (pp. 731–736). doi:10.1145/1837274.1837461

Reckwitz, A. (2002). Toward a theory of social practices. *European Journal of Social Theory*, *5*(2), 243–263. Retrieved from http://est.sagepub.com/content/5/2/243.short%5Cnpapers3://publication/uuid/C2907815-3C48-4044-A729-DCFE2FCBE630

Robertson, T., & Wagner, I. (2015). CSCW and the Internet of Things. In N. Boulus-Rødje, G. Ellingsen, T. Bratteteig, M. Aanestad, & P. Bjorn (Eds.), *Proceedings of the 14th European Conference on Computer Supported Cooperative Work (ECSCW)* (pp. 19–23). Oslo, Norway: Springer International Publishing. doi:10.1007/978-3-319-20499-4

Salovaara, A., Höök, K., Cheverst, K., Twidale, M., Chalmers, M., & Sas, C. (2011). Appropriation and creative use: linking user studies and design. *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems*. doi:http://doi.acm.org/10.1145/1979482.1979585

Schmidt, K. (2002). The problem with "awareness": Introductory remarks on "awareness in CSCW." *Journal of Computer Supported Cooperative Work*, *11*(3–4), 285–298. doi:10.1023/A:1021272909573

Schmidt, K. (2014). The Concept of “Practice”: What’s the Point? In C. Rossitto, L. Ciolfi, D. Martin, & B. Conein (Eds.), *Proceedings of the International Conference on the Design of Cooperative Systems (COOP)* (pp. 427–444). Nice, France: Springer.

Star, S. L., & Bowker, G. C. (2002). How to infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), *Handbook of New Media - Social Shaping and Consequences of ICTs* (pp. 151–162). London, UK: SAGE Pub.

Star, S. L., & Ruhleder, K. (1996). Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research*, *7*(1), 111–134. doi:10.1287/isre.7.1.111

Stevens, G., Pipek, V., & Wulf, V. (2009). Appropriation Infrastructure: Supporting the Design of Usages. In B. De Ruyter, V. Pipek, M. B. Rosson, & V. Wulf (Eds.), *Proceedings of the 2nd International Symposium on End-User Development* (Vol. 5435/2009, pp. 50–69). Heidelberg, Germany: Springer. doi:10.1007/978-3-642-00427-8

Stringer, M., Fitzpatrick, G., & Harris, E. (2006). Lessons for the future: Experiences with the installation and use of today’s domestic sensors and technologies. In *Proceedings of the 4th International Conference on Pervasive Computing* (pp. 383–399). Srpinger Berlin Heidelberg.

Walther, M. (2014). *Repatriation to France and Germany*. doi:10.1007/978-3-658-05700-8

Weiser, M. (1991). The Computer for the 21st Century. *Scientific American*, 1–9.

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press.

Wulf, V., Müller, C., Pipek, V., Randall, D., Rohde, M., & Stevens, G. (2015). Practice-Based Computing: Empirically Grounded Conceptualizations Derived from Design Case Studies. In V. Wulf, K. Schmidt, & D. Randall (Eds.), *Designing Socially Embedded Technologies in the Real-World* (pp. 111–150). London: Springer London. doi:10.1007/978-1-4471-6720-4_7