

Collectives and Their Artifact Ecologies

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Computing today happens across multiple devices, applications, users, organizational units, and in the rest of the world outside. Groups and communities come together for different reasons and operate within contexts that may differ from dominant modes of production and consumption. With a foundation in activity theoretical HCI, we develop the concept of *collective artifact ecologies*. This concept enables us to identify struggles of collective use of computational devices today, delimiting collective artifact ecologies in order to study and explain how they develop and overlap. Through an analysis of three empirical cases, we illustrate the notion of collectives and how they face challenges in establishing, maintaining and negotiating their artifact ecologies. This paper, therefore, contributes a theoretical foundation for analyzing groups and communities as collectives, with a particular emphasis on the multiple tools and artifacts they use. To serve as a starting point for further engagement with these concepts, we provide guiding questions to support the understanding of collective artifact ecologies.

CCS Concepts: • **Human-centered computing** → **HCI theory, concepts and models**; **Collaborative and social computing theory, concepts and paradigms**.

Additional Key Words and Phrases: Collectives, Artifact Ecologies, HCI Theory

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1 INTRODUCTION

For over a decade we have, collectively, shared an epistemic interest in understanding how multiple people in various constellations and contexts appropriate a wide range of interactive technologies, devices, services, and platforms to cooperate and collaborate toward shared commitments. From 2014 to 2016 we studied how a local volunteer-based organic food association appropriated and used various technologies in their community activities and the role these played in forming and growing the community. In 2010 and 2011 and again in 2016 and 2017 we interviewed households

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on how they approach smartphones and other technologies, how these are used, where, by whom, and how sharing and access is negotiated among the household members. From 2017 to 2019 we studied how a biomolecular research group works with complex macro-molecules and the role of devices, computers, software and custom tools play in their scientific practice. Prior work in this area has developed *artifact ecologies* as a theoretical concept for discussing the multiple technologies that people use [20, 92], how these technologies change [19], what their dynamics are [15, 16] and their role in a organic food association [20], households [10, 92], and a research lab [70], including a survey of similar concepts [61]. Initially, the definition was scaled from Jung et al. [45] to the community level with the ‘community artifact ecology’ [20]. However, as we have applied artifact ecologies in additional cases and our thinking developed, the focus on communities stand conceptually underdeveloped and increasingly insufficient to analyze the additional cases.

In this paper we turn our attention to the conceptual counterpart of artifact ecologies: the social constellation of people who pick up, learn, use, share, recommend, reject, modify and appropriate the many tools that come to play in and around their activities. The main concern addressed here is the lack of understanding of collectivity in CSCW and consequently how we can use the concept of *collective* as a complementary theoretical construct to artifact ecologies. Together, the two constructs allow us to analyze and articulate how multiple people appropriate and collaborate with and across multiple technologies.

Why ‘collectives’? Historically, CSCW discusses related perspectives under the common terms of ‘group’ and ‘community’. Groups as a concept has been discussed from the early days of CSCW in close connection with Groupware systems [36] and an interest in micro-collaboration where few individuals collaborate around a specific task with a single groupware system (“group user-interfaces” [29]). The primary goal of this work is the design of new systems for use and coordination in smaller groups closely related tasks and responsibilities. This focus has continued to this day under new headings inside and outside CSCW, e.g. in relation to workspace awareness [e.g. 37, 69], spatial organization of people in instanced collaboration [e.g. 68], various cross-device and mixed-focus collaboration studies [e.g. 42, 76] and the present upsurge in remote collaboration [e.g. 43, 100]. Lee et al. [57] share this observation and note that the notion of teams in CSCW does not adequately reflect their empirical case. They propose *human infrastructure* as a useful concept for comparing human and organizational arrangements and technological infrastructure.

‘Community’ represents a more recent interest in CSCW. Though some work has looked at and still shows interest in the online presence of physical communities [e.g. 27, 38, 44], the majority of contemporary work in CSCW focuses on communities that are defined by their online existence [77]. This orientation toward *online communities* is evident when reviewing recent CSCW works, with an extensive focuses on studying communities on social media and their usage [e.g. 26, 65, 87], sentiments and language of particular communities [e.g. 63, 91], response to major events [e.g. 95, 96] and (computational) analysis of platform-specific communities [e.g. 25, 60, 64], and more.

Both ‘group’ and ‘community’ are unfit as a theoretical starting points for our purposes. Perhaps obviously, it is exceedingly difficult to attach special meaning to commonplace terms that appear with a large variety of conceptual meanings and empirical connotations across CSCW literature. The existing terms are associated with particular empirical interest in understanding how people use specific, and often singular, technologies – a groupware system or a community platform. They configure ‘the group’ or ‘the community’ through the lens of the technology and the short-term interest in studying, designing, developing and evaluating group or community technologies. In other instances, orientation toward particular ideals, groups and communities reflect ideals within the researchers themselves, e.g. the ‘small group ideal’ [13] or community research as universally ‘good’ [9].

In contrast, our interest in collectives focuses on aspects of multiple people and multiple technologies that neither ‘group’ nor ‘community’ can account for. We want to understand what holds a collective together when people come and go, the history and developments, roles, values and division of labor, negotiation and strategies, patterns of appropriation, and how all this resonates through their artifact ecology and back. The ambition is to develop a generative meso-level concept of collective artifact ecologies that has both analytical, critical and constructive power [7, 61]. Analytically, the concept offers a perspective that goes beyond looking at individuals, tasks, objectives, and technologies in isolation and allows us to examine how groups and communities develop activities and routines in and across multiple artifacts [e.g. 5, 18, 20, 70]. Critically, the concept allows us to examine and question the tensions arising between the collective and its (organizational) context, common conceptions of technology, dominant models of ownership, design patterns, and individual appropriation of, often, mono-application software [e.g. 19, 71, 72]. And finally, constructively the concept suggests to consider collectivity and artifact ecologies as an underdeveloped position when appropriating and developing technologies for communities as also discussed by Bødker et al. [21]. In this paper we focus on the analytical application, but will return to the critical and constructive perspectives in the discussion.

The paper is organized as follows. First, we describe the methodology of *theorizing* collectives and the theoretical inspirations and empirical background. This is followed by an analysis of the three cases presented using the two concepts ‘collectives’ and ‘artifact ecologies’. Finally, we discuss important open analytical and methodological considerations in relation to working with the concept of collectives and artifact ecologies, and speculate on what the concept of *collective artifact ecologies* mean when constructing software for collectives.

2 THEORIZING COLLECTIVES AND ARTIFACT ECOLOGIES

In this section, we explain our position on theorizing for CSCW: First more broadly on how to do it and what contributions it provides, and later more specifically on our process of theorizing *collectives* and their artifact ecologies.

What is theory? Halverson [39] proposed that for CSCW, theories are like “a pair of dark glasses” [39, p.245] that we put on to bring “some objects into sharper contrast, while others fade into obscurity” [39, p.245]. This metaphorical definition of theory [53] is helpful when we want to use theory in analysis and reflection — it positions theory as an easily swapped lens through which we can look at an object of study — but does not provide much guidance on what constitutes a theory or the act of theorizing. Kerlinger and Lee [51] suggested a more descriptive definition of theory, with a concrete list of what should be included: “A theory is a set of interrelated constructs (concepts), definitions, and propositions that present a systematic view of phenomena by specifying relations among variables, with the purpose of explaining and predicting the phenomena.” [51, p.9]. This is the understanding of a theory that we have used to guide our work in this paper.

How can we theorize? A concrete definition of theory provides an end-goal, but not a road map of how to get there. Leveraging metaphor again, van Rooij and Blokpoel [94] suggested that developing theory is similar to sculpting: “While a sculptor may have a general idea of what type of sculpture they want to make, it is by looking at intermediate states that they decide how to proceed; e.g., chisel away a piece of rock, add some more clay, or start anew.” [94, p.285]. Following this metaphor, the ‘general idea’ for our sculpture is a concept of collectives that can be used to study the interrelation between groups of people and their use of technology. The ‘rock’ and ‘clay’ from which we develop this theoretical construct are primarily data from empirical case studies that span ten years (see Section 2.1), as well as an analysis of existing theories of collectives and artifact ecologies (see Section 2.2). In theorizing collective artifact ecologies, this paper should be seen as a proposition and place from which we can see how to proceed.

To theorize collectives from this rock and clay, we first identify similarities between the cases and then conceptualize these similarities as “interrelated constructs” that can be used to describe and analyze collectives more generally. This approach follows *analogical modeling*—an imaginative method to theory construction that suggests new knowledge can be constructed by analogy, i.e., by extrapolating from what is already known and understood (see Hesse [40, 41]). Methodologically, we do this in two steps. First, we focus on the similarities and differences between the empirical cases, and consider if observations and insights from one can predict¹ observations and analyses in the other cases. This transfer of knowledge from one case to another is predicated on the cases being *analogous*; i.e., they share enough *positive* analogies and there are limited *negative* analogies. *Positive* analogies are characteristics of one case that we know are also present in another. *Negative* analogies are characteristics that are unique to a case, that have an impact on what is being studied, and which cannot be reconciled across the cases. There are also *neutral* analogies, which are those properties of which we do not (yet) know whether they are positive or negative. These neutral properties are where knowledge from one case can be used to extend knowledge about another by making predictions, which can then be evaluated through new studies [79, p.382].

To illustrate this process with an example, we know from prior work that when people engage in collaborative activities, they will likely need to negotiate which technologies they choose to use (see Larsen-Ledet et al. [54], Nouwens and Klokmoose [71], Rossitto et al. [80]). The positive analogy between these cases is that they all focus on people who use multiple technological tools while collaborating on specific tasks, and those digital tools are chosen based on an ongoing process of explicit (verbal) and implicit (behavioral) negotiations. The neutral analogies, of which we do not know whether they are relevant to consider or not, can be things such as the nature of the activity (nomadic work [80], collaborative writing [54], and non-standard knowledge work [71]), or the specific technologies used (e.g., Basecamp [80], Google Docs [54], and Microsoft Word [71]). If these cases are considered analogous, then we could, for example, use the observations on the process of negotiation in nomadic group work and collaborative writing to “predict” that similar patterns are present for non-standard knowledge workers (and other analogous cases).

In the second step of developing our theoretical model, we move from case-to-case analogical reasoning to synthesizing the relevant analogies into theoretical concepts. These concepts are based on the positive and neutral analogies between the cases, but abstracted away from their empirical particularities. This process of abstraction is not a straight-forward or delimited activity, but something which we have engaged in messily, with fits and starts, over the decade of data gathering, analysis, reflection, and discussion. As noted by others, theorizing can be a messy and complex process [see e.g. 93, 98].

For example, if we return to the studies above, the positive analogies between the cases could be extrapolated into two concepts: 1) *technology-mediated collaboration*, which could refer to the use of digital technologies in order to work together on a set of tasks (synchronously and asynchronously) to achieve a particular goal, and; 2) *software negotiation*, which could refer to the (implicit and explicit) process between multiple people of choosing which digital tools to use and how to use it. The interrelation of these constructs can then be articulated independently from the three cases as follows: if people engage in collaboration mediated by multiple technologies, then they will need to negotiate which subset of available technologies to use to carry out their particular activity.

2.1 Empirical cases

We develop our theoretical concept of collectives from a base of three empirical cases, spanning a decade of work (see Table 1). This data has been collected and analyzed using different frameworks

¹We use ‘prediction’ cautiously as suggesting what to give empirical attention to.

and published for different purposes. We reengage with them here because they all focus on groups of people that use complex constellations of technologies which mediate their daily activities.

Setting	Year	Focus	Publications
Organic food community	2014-2016	Community technologies, infrastructure and appropriation over time	[19, 20, 22]
Academic research lab	2017-2019	Biomolecular nanoscience, distributed, multi-device interaction with multimedia data	[70]
Households	2010-2011	Smartphones and appropriation	[10, 11, 17]
	2016-2017	Smartphones – artifact ecologies	[22, 92]

Table 1. Overview of the three cases. Time span, focus and related publications.

2.1.1 Case 1: Volunteer-based organic food initiative. The “Aarhus Organic Food Community” (AOFF) is a group of people brought together by the desire to have inexpensive access to local and organic food and who engage in a joint activity around this shared goal. The initiative was started in 2010 based on a similar group in Copenhagen, Denmark, and has over the years significantly expanded its membership numbers (to over 900 in 2016). Volunteer-based initiatives are characterized by a high degree of self-organization [90], with members joining and leaving over time. Often, they rely on mundane [see 28] and freely available technologies, provided by global commercial tech giants such as Facebook or Google; they may attempt to find the necessary funding and/or expertise required to set-up their own solutions or typically some combination of the two [e.g. 20, 24]. In previous studies of AOFF, we have observed: the emergence and formation of an artifact ecology from the beginning has contributed to the development of interpersonal relations, identity, and activity [20]; the development of this artifact ecology over time, and the way in which members have taken on more responsibility and guided decisions around the AE has also contributed to development of interpersonal relations, identity and activity [19]; as well as how the artifact ecology of the initiative overlaps with other artifact ecologies associated with the members [22].

2.1.2 Case 2: Academic research lab. The Andersen lab [70] is a research laboratory at the Interdisciplinary Nanoscience Center at Aarhus University. The lab specializes in using biomolecules to create nano-devices that can fold and unfold in particular ways to, for example, deliver drugs in specific areas of the body. The lab has a mix of temporary and permanent staff; at the time of the study, the lab consisted of one principle investigator (PI), eight postdoctoral researchers (one remote), and four PhD students. The formal research mission of the lab is not necessarily the (only) reason each of these individuals joined the group. The research lab is part of a research university, which itself is part of Danish normative educational structure, so the lab often has master students that join as part of their mandatory thesis project. The research lab is renowned within its field of research, so researchers might join to accrue occupational capital before (willingly or not) moving on to another group. For them, creating new knowledge might be subordinate to other goals. The lab has a great deal of autonomy and (some) control over the equipment, tools and software used. Yet, some of their tools and software were governed or dictated by the hosting institution, while others were personal to members of the lab. In the lab many social values of scientific research such as, e.g., ownership of results meet and collide with educational licensing of software (contrasting for instance, open source software and data formats and cheaply priced closed software), role of specialized, scarce artifacts and more [70].

2.1.3 Case 3: Households. Households consist of people who live together on a somewhat permanent basis, and exist in many different constellations, whether through voluntary cohabitation or family relations. These different arrangements and the relationships between the members matter for how they see and interact with technology. A number of interview studies have looked at the introduction and use of technology in households [10, 11, 17, 22, 92]. The families that consisted of parents and children all had deeply embedded and unspoken values about how children should be cared and provided for, which also affected the accepted use of technology in the household. In other households, such as platonically or romantically co-habiting adults, the motives and interpersonal relations seemed sometimes more negotiated, and often of a more practical nature [11]. It is characteristic to many households that many technologies and much of their artifact ecology is brought home from somebody's work or school. Adults typically have at least one smartphone that is often used for both work and personal stuff. Some adults have several smart phones, e.g. one for work, another for private use. Printers and wifi are shared and their placement often negotiated in the family [92]. Maintenance of both these shared devices, and e.g. family photos is often done by one adult. Parents are often also negotiating both their own use of technology in front of their children and their children's access to technology, and these negotiations include both place and time (e.g. no phones at dinner). The recent abundance of streaming services and the sharing of devices for watching TV or movies together has, e.g., introduced a new 'space' for negotiating what to watch and with whom [10]. Are older siblings for instance (considered) able to facilitate and control the TV watching of their younger siblings? How do (even) adults in a household decide what to watch together?

With this overview of our empirical cases we now turn to a discussion of the theoretical influences of the analyses.

2.2 Theoretical influences

Our theoretical influences are primarily rooted in activity theory. Activity theory is a framework which tries to understand people and the social structures they create by looking at their *activities*, see Bannon and Bødker [3], Bardram [4] and Kaptelinin et al. [48] for an introduction. An activity is purposeful and carried out by human beings together through the actions of each of them. The object of the activity is both manifest and ideal in that people act with purpose to change the object from material to outcome, as this outcome is also anticipated in the activity. The actions performed to realize activities transform both subjects and objects. Because of this transformation, activity theory takes the position that trying to understand the object and subject separately is not constructive; instead, they should be analyzed through the activity that shapes them into what they are in that moment.

In Human-Computer Interaction, activity theory has often been used to address the individual human use of technology, with a focus on how technological artifacts mediate the relation between the human users and their object of activity. CSCW [e.g. 4, 23, 52] has in addition used activity theory to consider groups of people, communities and collectives while retaining an understanding of the dualism between collectives and individuals (i.e., a collective is more than the sum of its individuals). It is however this element that we address further here.

Collectivity is introduced in activity theory as collective activity by Leontiev and others [see 59, 83] and later developed as a constituting component in Engeström's [31] triangle model of the structure of human activity. To understand a *collective* subject, then, activity theory starts from the activities the collective engages in [see 59, 83], because a collective subject becomes what it is through its activities.

Collective activities can be scoped at different levels. For example, a collective activity can be any activity where people are gathered around a shared object to achieve the same outcome (which

Meshcheraykov calls a “shared object activity” [31, p.87]), such as carrying a table. A collective activity can also be more distributed, where people engage in individual actions that all have their own outcomes, but whose purpose only becomes meaningful when seen all together, such as can be seen in Leontiev’s analysis of the division of labor in a primeval collective hunt that involves people doing different actions towards the same motive (getting food) and objects (animals) with different mediating artifacts (of which some are arms) (see Leontiev and Cole [59, p.186ff] and discussion in Engeström [31, p.83ff]).

Depending on which analytical perspective is chosen, the collective is constructed in different ways. In the “shared object activity” perspective, the people in the collective together make up the subject that acts on an object (subject → object). Here, the collective is an “active agent”. In the distributed activity perspective, the individual people are the subject and the collective plays a mediating role between the subject and the object (subject → collective → object). The choice between these different perspective depends on the empirical concerns of the researcher(s).

Because of the primacy of activity, Davydov [see 58] and Rubtsov [83] argue that activity theory has struggled to understand aspects of collectives that are not activity-centric. In other words, from the perspective of Leontiev, there is only a collective when there is a concrete activity, which leads Davydov [cited in 58] and Rubtsov [83] on to a discussion of collective subjects. The collective subject (and later community) can be considered in two ways in the analysis of the activity. Just as individuals can be seen as the subject in the subject → object relation, so can people engaged in collective activity be considered as acting in this relation.

Lektorsky [58] summarizes how collective subjects can be different and include social institutions or more or less constant social groups. They may be temporary, have definite goals and disappear when these goals are achieved. Relations between participants in collective activity can differ, including adherence to rules and replication of patterns of activity [58, p.82]. Regardless, the collective (subject) play an important role in human activity. According to Lektorsky, it is active and has its own aims, interests, memory, and norms: “*Individual subjects, participating in collective activity, feel that they belong to a collective entity with which they identify themselves. Thus, collective responsibility becomes possible. Specific “we” feelings arise.*” [58, p.81].

We generally subscribe to the activity theoretical understanding of activity and how it affects being and becoming, however, we also need a way of talking about collectives that can consider the objectives, tools, values, and motivations as more than a sum of its activities.

We are not alone with using activity theory in CSCW. With a primary focus on organized work activity more than collectives, Bardram [4] and Borchorst and Bødker [23] have previously made use of analytical distinctions between three levels of collaboration that relate to how participants share motive, object, and orientation toward one another: co-ordinated, co-operative, and co-constructive activity [4, 31, 34, 78], that further point to the different manners in which human beings organize towards collective activity.

In more recent discussions, Engeström [32] has moved towards a theoretical discussion of more dynamic collectives. He analyzes amoeba-like collective activities that do not pursue short-term goals, using birding and skateboarding as examples [32, p.7]. Engeström introduces the notion of knotworking ([33, p.194], see also Spinuzzi [88] and Abou Amsha et al. [1]) to refer to “*rapidly pulsating, distributed, and partially improvised orchestration of collaborative performance between otherwise loosely connected actors and activity systems.* Through the notion of knotworking, Engeström study more temporary collectives that come and go and talks about a mycorrhizae-like formation that does not have strictly defined criteria of membership: “*A mycorrhizae formation is simultaneously a living, expanding process (or bundle of developing connections) and a relatively durable, stabilized structure; both a mental landscape and a material infrastructure.*” [32, p.7].

These elements point to a conception of collectives as a unit of analysis to supplement the community-through-activity and activity-systems perspective in activity theory. Collectives are not, they become through the contributions of people. The boundaries of collectives, the core of the activities that hold the collective together, and the people who participate may change, but somehow there is a shared concern or interest among the participants.

In order to further conceptualize the relationships between people in collectives, we turn to the work of Petrovsky that is using the term collectives as a conceptual alternative to notions of groups and communities. Kaptelinin and colleagues [46–49] briefly mentioned the work of Petrovsky in their various discussions of activity theory, collective subjects, CSCW and groups, but do not develop the discussion further, which we have been quite curious about.

Petrovsky's work was developed from a school of Russian social psychology that developed differently than Western social psychology [see 2]. Petrovsky maintained a focus on how social activity allows particular connections and relations to arise, seeing the group as the subject of activity and studying social groups engaged in concrete activities.

The works of Petrovsky and Engeström have been compared, and a difference in the approaches has been pointed out: Where Engeström included community (or group) as a mediating factor in his well-known expanded triangle, Petrovsky was seeking the collective as the subject that engages in subject-object interactions in the world [47, p.305], similar to the 'collective subject' discussed above.

Petrovsky's maintained a distinction between the collective and other types of group: "*the collective is a group in which interpersonal relations are mediated by the socially valuable and personally significant content of joint activity*" [75, p.78]. At the core of collectives is the understanding of the identity and values of a collective, their shared activity, how these two aspects mediate interpersonal relations, and how it all develops over time. Petrovsky proposed a way of understanding how meaningful intra-group activities mediate and reify (i) the shared understanding of the central activities and their goals, (ii) the social norms and values of the collective, and (iii) interpersonal relations (attitude, emotions, empathy, competence etc.) and solidarity.

Petrovsky's understanding of mediation emphasized social norms, moral values, and interpersonal relationships, e.g., trusting people's judgment and competences, forming broader social bonds through shared experiences, developing empathy. He refers to this process as *active group emotional identification* [74] which may be less explicit in many activity theoretical accounts. It must be noted here that we do not read this as or subscribe to the notion of 'collective beliefs' as a collectively held belief or values, but rather learning and accepting certain perspectives as part of and means to realizing the collective goals. Members of a collective can reach conclusions that are irreducible to the view of the collective (and not necessarily that of individual members) [see 99].

When considering who is who in the collective, Petrovsky talked about how members look to their group as a source of orientation in the surrounding reality. He understood these connections as *referentiality*, where any given member of the collective can mediate the subject-object relationship of another, towards the shared goal, essentially as "*a form of special subject-subject-object relations*" [75, p.115]. The notion of referentiality provides a way to identify and articulate the roles that members develop and take on in order to do something with regard to the collective's joint activity. This could be individuals who are recognized by the collective as competent or adept in particular aspects of the joint activity, the purpose of the activity or collective values and history. With a focus on learning and development, these individuals are often referred to as the *more capable peers* in the original work of Vygotsky [97].

This learning perspective is not limited to learning in isolated learning activities, to the contrary, it is often seen as a perspective of learning and development as it is happening situated everywhere in human activity [31, 32, 55]. Hence, an important element in the connection between the more

capable peers and the newcomers, and learners [25] is the routines, means and perhaps even rituals that help peers support newcomers in joining and developing the collective. Without fully developing the connection here, referentiality is the mechanism within the collective through which more capable peers are recognized. Hence, the “tech person” does not necessarily assume the role of the technology-adept member by education or through a formally appointed position, but by showing or by being recognized as having an affinity for using or appropriating technology in the joint activities, that they therefore become a more referential person for the collective. Based on these theoretical influences we move on to summarize the framing of collectives.

2.3 Operationalizing Collectives

We arrive at a conceptualization of a collective that puts emphasis on collective activities as joint activities and/or distributed activities that mediate both the goals and meaning of particular activities (joint), put them together in meaningful relations (distributed) and, in total, mediates the various aspects of collectivity – ‘we-feelings’, solidarity, values and high-level objectives. Collectives are more than the sum of its activities, members, tools and objectives. As such, collectives are emergent and just as with activities, often unconscious to those participating in collective activities. When articulating collectives, we often refer to concrete and familiar entities and various aspects of grouping in activities and/or formal organizations. Work in activities happen with different levels of grouping (one or more individuals acting as a collective subject) and with reference to the collective (community in Engeström [31]). We often participate in multiple distinct collectives (families, associations, work etc.), however, there does not have to be full agreement with the values and ideals with each individual collective, e.g. going to work to make a living and participating in a local practice does not mean one believes or adopts the goals and ideals of the entire organization.

When wanting to understand a group of people as a collective, and to analyze the collective artifact ecology, we suggest investigating the three aspects central to collectives: collective activity, identity, and development.

1. *The joint and distributed **collective activities** that mediate collective understandings and solidarity.*

- What are the formative joint and distributed activities and what are their objectives?
- How do the activities relate to the social environment and social values in which the collective exists?
- How do the activities serve to mediate interpersonal relationships between members of the collective?
- What are the roles of referentiality and more capable peers in these activities?

2. *The **identity** of the collective as articulated by the collective, in relation to both within-collective (internal) practices, and other (external) social influences.*

- How present (tacit/articulated) is the identity and values of the collective in the collective activities?
- How is the identity of the collective understood within the collective?
- How is the identity and goals of the collective related to those of the social environment and social values?

3. *The collective can be understood in terms of having a history, and being oriented towards future **development** (or degradation), both towards fulfilling the goals of the collective and towards a higher degree of interpersonal relations.*

- How do the goals reflect the society in which the collective is situated?
- To what degree are the interpersonal relations mediated by the collective activity?
- What is the history of the collective?

- How do the goals of the collective direct future development?

In comparing loosely with groups and communities, collectives are characterized by being more than the sum of their members, activities and tools. All of these come and go, yet the collective is maintained through particular activities, members and tools, that are recognized and maintained within the collective.

2.4 Artifact Ecologies

Activity theoretical HCI has long offered a well-developed understanding of artifacts and their role in human activity. Artifacts mediate human relationships with objects of their activity. Artifacts are mediators that help users act on objects, in ways they could not without using the mediator [6–8]. Like with activities, it often makes most sense to not look at one artifact at a time but to focus on the plurality of objects and artifacts and talk about *artifact ecologies* [15, 16]. Bødker & Klokmoose address the development of artifact ecologies beyond singular artifacts in use by communities. This perspective is further developed by Bødker et al. [20, 22].

In the attempt to understand the relationship between collectives and their technologies, multiplicity is important practically and conceptually. Bødker et al. [21] surveyed platforms for communities and the sharing economy and pointed out that “[i]t is, however, often larger, ‘monotechnological’ platforms that are studied in the wider literature, rather than smaller, local platforms that do perhaps lend components from other technologies and infrastructures.” [21, p.2] They pointed to the different roles that technology may have for communities of various kinds: “For some, the community comes first and one or several technologies are meshed together to support the joint activities of the community. This is true when particular communities organize themselves through e.g. Facebook (groups). Or when others combine Facebook with Google docs and email distribution lists [...]. Other forms of communities are entirely bound to a particular technological platform” [21, p.3]. In their analyses of existing platforms of sharing and caring, they found in particular a lack of mechanisms for facilitating collectivity or community building: “Social capital plays an important role here, as well as connections with social movements and providing a feeling of collective action among the participants” [21, p.7]. Multiplicity shows up in literature on artifact ecologies [45, 67], constellations of technologies [80], digital assemblies [85] and related concepts as surveyed by [61].

In an attempt to articulate artifact ecologies at play in voluntary collaborative work over time, Bødker et al. [20] proposed the concept of a community artifact ecology as the “*particular constellation of artifacts that a community owns, has access to and uses in its activities*” [20, p.1144]. Here, groups of individuals interact with one another and with others in activities supporting the community, through a series of artifacts chosen by them. The agency of groups in the shaping of their shared artifact ecologies allows for taking a more design-based perspective rather than limiting their interaction to use only. They pointed out how artifact ecologies are dynamic and change over time and how individuals learn new tools through peers and practices. Artifacts in an artifact ecology, therefore, are inclusive of the digital and non-digital, e.g. anything from devices, software applications, service touch points, platforms, to scripts and code libraries, and yes, even whiteboards and keyboards and documents [19, 20, 22].

Rossitto et al. [80] worked on constellations of technologies: How student groups negotiate artifacts in group work suggests that the short term (a semester) grouping around a common goal (learning a subject, writing assignments and passing the exam) will make negotiation a bit casual (between task, location and personal familiarity) and less committed. Larsen-Ledet et al. [54] integrated multiple perspectives of artifact ecologies in a study of collaborative writing and the tools used therein. They discuss the group of author’s artifact ecology as a negotiated ‘whole’ made

up of a subset of the individual's artifact ecologies and how activities transition across different tools and individual's ecologies.

In the next section we summarize the theoretical background in a definition of collective artifact ecologies and highlight a series of analytical perspectives and questions in order to look at examples from our empirical cases and strengthen the perspective.

3 COLLECTIVE ARTIFACT ECOLOGIES – WHAT TO LOOK FOR?

Based on the above analysis of the influential theoretical positions and concepts, we define and use the framing of artifact ecologies consistent with the position synthesized by Lyle et al. [61]: *The collective artifact ecology can be identified as the particular constellation of artifacts that a collective has made its own and uses; and which contributes to the development of the identity of the collective, its joint activities, values and ideals, and the respective interpersonal relations.* By reintroducing the concerns for what makes a collective, we emphasize the role of the artifact ecology. It support the joint and distributed collective activity and mediating interpersonal relations, including the roles of more capable peers. In addition, they also mediate, expose and support the identity of the collective and its context within society. Mediation and support are not static and hence, we have a particular focus on artifacts in the collective artifact ecology that support or, for that matter, hinder the development of the collective.

When applying collective artifact ecology as a theoretical perspective, it is important to consider the collective from three perspectives. First, the joint and collective activities that mediate interpersonal relations: we come to know each other through participating in joint activities. Second, the identity of the collective and its role within society provides meaning to the collective, which in turn is mediated to individual members through the identity and activities of the collective. Third, considering the development of the collective – is it an “institutionalized” or familiar collective or an emerging or grass-root collective from an outside perspective?

The starting point for analyzing a collective artifact ecology hence lies in the collective as much as in the technological artifacts, in particular:

- What are the formative joint and distributed activities and what are their objectives?
- How do the activities relate to the social environment and social values in which the collective exists?
- How do the activities serve to mediate interpersonal relationships between members of the collective?
- What are the roles of referentiality and more capable peers in these activities?
- How present (tacit/articulated) is the identity and values of the collective in the collective activities?
- How is the identity of the collective understood within the collective?
- How is the identity and goals of the collective related to those of the social environment and social values?
- How do the goals reflect the society in which the collective is situated?
- To what degree are the interpersonal relations mediated by the collective activity?
- What is the history of the collective?
- How do the goals of the collective direct future development?

When analyzing artifacts in the collective artifact ecology, it is important to consider how they support the joint and distributed collective activity *and* mediate interpersonal relations. We know that technologies help realize concrete tasks and carry out activities, while also serving as means for coordination, articulation work and caring work within collectives [see 81, 86]. Particular artifacts mediate the identity of the collective from within—e.g. in how they are used to organize

events, share material or as an object of collective activities—and externally through identification, communication and as potential entry-point for membership and participation. Finally, as the artifact ecology is important to the functioning of the collective, they also mediate interpersonal relationships, including the roles of more capable peers and members who are expert users.

Following the above, **the artifacts, and artifact ecology of the collective** can be considered through the following questions:

- How does the artifact ecology of a collective serve its joint and distributed activity (and in turn contributes to the interpersonal relations of its members)? More generally, what are different ways in which an artifact mediates communication and how is it documented and used towards a particular goal?
- How do the artifacts used by the collective contribute to the identity of the collective, in terms of shaping their practices and how does the collective interact and present itself to the wider society?
- Finally, in terms of the development of the collective, how does the change in artifacts and their arrangement reflect or contribute towards the joint goals and a higher degree of interpersonal relations?

These questions and considerations have proven useful for us in thinking about and applying the concepts in collective artifact ecologies, as we do in the following section. They are not the only relevant questions to ask, but can act as an entry-point into the analysis. Depending on the particularities of the case, additional questions will become relevant. This could be on the prominence of interpersonal relations and the dynamics of referentiality (e.g. formal / informal roles), are mediated by the artifacts or how key members influence decision-making around the artifacts. There are examples where tech-savvy members play a decisive role in appropriating new artifacts due to their recognized competences and knowledge within the collective. Or it could be that understanding the historical and dynamic developments of a collective and its artifact ecology indicates the importance of considering the different timescales at which development and change occurs. There is a possible mismatch of timescales between the collective (e.g. families: generations, communities: decades, labs: decades/funding-rounds), and that of technological development (considering social media, mobile, wiki's, sharing platforms etc. are new and volatile concepts).

4 ANALYZING COLLECTIVES AND THEIR ARTIFACT ECOLOGIES

In this section we use the cases introduced earlier to activate and illustrate the theoretical concepts. We will first analyse the organic food initiative and the research lab, and then compare with households, which we already indicated are outliers in our conceptual landscape. We will not present the systematic analysis of all three cases but rather bring out the insights that are new within the present context.

4.1 Collective Activities

Volunteer associations typically have a defining activity driven by a cause and in the case of AOFF, this joint activity was initially determined by the founding members with inspiration from a similar community in another city. They were inspired by this similar community in their choice of activities as well as artifacts, which started with a Facebook page to recruit interested people and a wiki for public presence and organizing work [20]. With the influx of new members, this initial artifact ecology became less useful. The group changed from being a small group of key active actors to a combination of a small group of active members and an ever increasing number of passive members. In some ways the AOFF went from being one joint activity involving all members who were also also concerned with the overall idea of providing local, organic produce, to a more

distributed set of activities involving some members of which only some were more generally concerned with the overall cause, while others were doing what was required to bring home their produce bags.

Bødker et al. [20] discuss several community activities set up to hold AOFF together, e.g. the Thursday activities in a local community building. It also discusses how the emergent idea of a website went on to drive much activity in the AOFF, as a vision that would solve all their technological problems, more actually than something that eventually did so.

In expanding the volunteer association, the artifact ecology nonetheless went through several iterations [20] reflecting the changes taking place in practices supporting the overall activity (e.g. change in payment methods). At the same time, the change in the artifact ecology triggered new specialized activities for specific members (e.g. the emergence of the “web support” role).

The lab’s joint activities were overall related to laboratory research including research education. The collective artifact ecology resulted from the mixture of different personal practices, organizational governance, and regulatory requirements (such as safety regulations).

Graduate students, postdocs, and research assistants were on temporary contracts and hereby change in the collective was inherent to the dynamics of a research group. Typically, however, one (or more) senior researcher or professor would be on a permanent contract, and played the defining role to the purpose of the collective. This person or persons could retire, quit or be fired, which potentially could result in a major disruption of the collective. When people were leaving a research group (e.g. by graduating) they were still part of an extended collective and would continue their collaboration with the group.

This lab was part of multiple, hierarchically positioned and overlapping structures (department, school, building, university, country-wide university supergroup) that shaped their joint activities and there were a number of resources they had a connection to, but whose integration into their collective’s ecology required negotiation outside the collective.

Devices that entered certain parts of the laboratory were not supposed to leave again as they can become contaminated. Some were bought at a university level (office software licenses), some bought at the department level (e.g., large equipment, furniture and (some) computers), some through the grants of the lab (equipment, software, computers), and finally some were personally owned by the lab members (e.g., phones and laptops).

The cases demonstrate how both joint activities and the connected artifacts are important for sustaining and developing the collective. The joint activities in various ways borrow from and are shaped by activities outside the collective, yet the joint activities are certainly also shaped in the meeting with coming and going members of the collective. Whereas the joint activities are the ‘bread and butter’ of the collective, the collectives and their technologies need to also look at in terms of their shared values and referentiality.

4.2 Referentiality, internal values and external roles

Regarding AOFF, seasoned members took on particular responsibilities towards the collective values, without necessarily being experts or more skillful, but rather they either themselves took on a responsibility or were slowly given the responsibility through recognition. This meant that other members of the collective increasingly depended on this person, but also that this person was more likely to burn out. The effectiveness of these kinds of role or action that a member took on is likely to be depending on their degree of referentiality within the group.

In the case of AOFF, but also observed in other similar volunteer-based groups [e.g. 24], the Facebook platform often served as the *de facto* technology around which to organize due to its recognizability and accessibility for members. Its dominant market position meant that most members and potential future members already had a profile there, lowering the threshold for

adoption and outreach. Currently, it seems to be a norm for volunteer-based initiatives, movements, and communities to have a private Facebook group to support members to self-organize, and a public Facebook page to advertise the group and its activities and gain followers [24, 84]. The (vision of) the website discussed above was supplementing this referentiality in various ways.

The AOFF collective artifact ecology was closely entangled with the members' own artifact ecologies and practices developed elsewhere, e.g. at home or work. Familiar tools from other contexts were brought in by individual members and integrated into the group's practices reflecting to a certain degree the collective's values regarding sustainability, volunteering as well as keeping costs low [19, 20]. The desire of AOFF to only operate locally meant that they worked with a small number of local farmers. This limited membership both in size and geographical distance. Furthermore, the struggle of AOFF when it came to finding the right forms of payment illustrates that decisions of the collective were tied with practical and commercial challenges introduced to them by the banking system at large, where values of sustainability are often unclear.

The research labs used conventional laptops, tablets, smartphones in their daily work together with ordinary productivity software. However, they also used specialized scientific equipment and software such as vortex centrifuges, some share with other labs. Their scientific software was a collection of self-developed scripts and tools developed by other scientific laboratories. A digital lab notebook was used to plan and execute study protocols, record results, and document analyses.

These devices being volunteered into the collective artifact ecology is connected to the topic of referentiality. While the strength of the development of the collective (and the member to that collective) shape whether what is volunteered, the collective's willingness to integrate it into the joint activities, is shaped by the referentiality among members.

A research lab like the lab had certain infrastructure provided by their host institution, but they were also dependent on grants to fund the purchase of experimental equipment. Part of the success of the lab was their use of computational methods and tools, and a significant challenge for them was to secure funding for maintaining and developing their more immaterial artifacts such as scripts and software tools. This also means that the PI of the lab had to consider the future perspectives when a researcher on a temporary contract introduces or proposes to introduce a new software or equipment. What would happen when the contract of this researcher ended, would the expertise with the new artifact disappear?

The degree to which members incorporated collective artifacts into personal ecologies depend on the referentiality of the member. For example, when the PI 'suggested' the use of a particular tool in the lab, this carried enough weight that subversion was done quietly. Other difficulties with negotiating between collective artifacts within personal ecologies stemmed from having to deal with leftovers of appropriations of that artifact by other members of the collective; or not trusting the other members of the collective to use the artifacts appropriately.

Largely, collectives are open for members to maintain and develop the collective; to look to the group as a source of orientation. In our cases, however, tensions exist between the collective's choice of shared technology and the values of members around e.g. privacy. For instance, some members of AOFF have started to boycott Facebook over its repeated abuse of data collection and dissemination practices. For others, Facebook is a 'necessary evil', because it has merits when it comes to communicating with members and the general public. For members who had deleted their account or decided never to open one, their desire to share the identity and be part of the collective meant having to either override their personal preferences and get an account or accept being left out of an important communication channel. The tensions around the values of the collective contrast here with the needs for accessibility (e.g. greater public visibility) and control.

We have seen examples where choices to introduce a new technological artifact were negotiated vis-a-vis other artifacts, examples where new technological artifacts inadvertently lead to

obsolescence for others, or to stronger ramifications in the entire ecology: In the research lab, the introduction of an Electronic Laboratory Notebook (ELN) (mostly) replaced the paper notebooks that had been the linchpin of natural sciences for hundreds of years. This change to the ecology – the digitization of the process – had far-reaching consequences for the artifact ecologies the researchers had been using (and teaching to the new generation) until then. This tension and process of negotiation reflects the transitions between unsatisfactory, excited and stable artifact ecology states described by Bødker and Klokmose [16].

4.3 Founders, champions and more capable peers

In the case of AOFF, the founding members and more capable peers were key in shaping the collective artifact ecology as we saw above [19, 20].

Whereas the founding members introduced familiar tools, such as Facebook groups or later Google documents, it has been other volunteers, and more capable peers who have, for example, hosted the website on their own server, or pushed for the building of a new website using their own preferred content management system. This also created tensions between members regarding expectations for what could and should be delivered, and in terms of workload. While it is often the case that some members are more active than others in the joint activity of the collective, the collectives are not only the sum of its members. In the AOFF case, the founding members played an important role in shaping all parts of the collective and its artifact ecology, both from the start, and later in the more established/routinized/delegated stages of the collective. AOFF, with a limited infrastructure of their own and dependent on volunteer time, members' own resources, membership fees, donations of equipment, opportunities to apply for community funding grants from municipal councils, ongoing commitments from domain experts, existed in an inherently precarious situation and as such were influenced by internal and external changes regarding their identity and activity.

In the research lab, “[b]iomolecular nanoscientists with the computational literacy to produce or modify scripts were ‘pretty rare’ (P10) and learning how to program was considered ‘a whole other career’ (P11) rather than an integral part of their job. As a result, the development and maintenance of the computational tools vital to the participants’ research rested on the very precarious foundation of a once-in-a-blue-moon computationally literate graduate student, postdoc, or research assistant.” [70, p.6]

Changes in the collective artifact ecology are, hence, often due to the work of somebody who would champion this. This member would initiate and maintain a new artifacts' existence and integration with all other members' individual ecologies by serving as a more capable peer, championing their use, helping other members with integrating it into their workflows, and taking care of their maintenance. This role would be appointed based on specific expertise, or volunteering. A champion would not always be successful in their promotion either, due to underground resistance to the collective artifact (e.g., collective spreadsheet of buffers and samples). When however, the artifact was important to the collective's ability to work towards their goals, the departure of a champion had significant consequences, such as when the postdoc who developed the widely used (but not widely understood) scripts for generating 3D models of molecular structures moved on, this caused serious challenges.

In collectives, where members come and go at somewhat timescales, certain members play particular roles, some are simply more steady or long-term members with or without some form of formal responsibilities, both internally towards the collective and externally towards the world outside. Others take on roles of shaping, introducing, promoting, maintaining, in particular as we have addressed in the cases, the technologies shared in the collective. Tasks include teaching other members of the collective, and their departure often becomes particularly painful, because the collective is left without their skills and also sometimes without the actual technology they

introduced. Part of the reason for this problem is the general scarcity of members with these kinds of skills, which make it challenging for collectives to introduce training and redundancy for these duties.

4.4 Tensions and development of Artifact Ecologies in a Household Collective

As indicated we have been considering it an open question if, and in what ways, it would make sense to consider households as collectives, and hence what an analysis of their collective artifact ecologies would add.

First of all, households are less than the two other cases held together by a joint activity, and more so by commitments (that are not necessarily reciprocal) between members of the household. The studied families of parents and children all expose values with respect to social reproduction and caring and providing for the children in particular. To a large extent, these values are so deeply embedded in the family structure that they are not even talked about when relating to e.g. child upbringing and the use of technology in the family. In other households, be these adult pairs living together or adult co-housing, the motives and interpersonal relations seem sometimes more negotiated, and often of a more practical nature. For all of the households, it seems however that they are investments of, and over time and that the relationships is a matter of getting a later return of this investment.

Households have connections to work, school systems, and even NGOs such as volunteer food and other organizations, etc. [11, 22]. The time scale of a household is often long, and change may happen in connection with children growing up, or adults growing old. There is however a difference between households consisting of children and adults as a family unit, and households of co-habiting adults, which are often more practical arrangements with fewer shared values, even if some members live together for a longer time. Changes in households are often connected to life circumstances (new job, family addition, divorce, death etc.) whether everybody in the household are close relatives or not.

Adults in particular have experience with and bring home technological artifacts, it is however, further evident that e.g. strategic decisions in the local or national school system to give school children tablets, or to require that they buy them, could shift the household' joint possibility of deciding who have access to technology in the home, where and when, to respect the social values of the household [10].

It does not seem that technology is used very much in households to support identity and referentiality. It is however the case that several households have various forms of shared calendars, either on paper or in some electronic form. These help members orient towards each other and their activities (see also [14]).

The technologies of the households studied were for the most part familiar consumer technologies, including entertainment systems, gaming consoles, printers and PCs, laptops, tablets and smartphones. Few households had "smart" infrastructures or appliances, e.g. smart utility meters, alarms systems and light systems. Some of the technologies were fixed in particular locations, e.g. entertainment systems in living rooms, printers, and PCs in home-office setups, whereas others follow individuals and their routines [10, 92]. On top of work stuff, households engaged with various communities and activities – schools, daycare, sports clubs and NGOs – through designated applications, social media or webpages. Households combined technological artifacts that members brought home from work (laptops and smartphones) with similarly mobile technologies owned and purchased by members [22]. Many households had social rules for when technologies could not be used (no phones while dining, never phones in the bedroom, or no gaming outside the teenager's own room) [10]. In some households these rules were important and under negotiation among members, and in others they are more implicit. The interviewed households have developed new

sets of routines such as with ‘TV watching’ where multiple devices and apps, even with overlapping functionality, have been appropriated for particular joint activities.

Bødker and Christiansen [11] discussed how users of smartphones, such as some of the household members, shared the recent news regarding apps with circles of friends or relatives. In one case mentioned it was a circle of family members who stepped away from family dinners to discuss what apps they used, and in another, it was a circle of young female friends who used their joint dinners to talk. This was one way that makes users of everyday technologies build up their technical competencies, and use this also with their own households, as champions and more capable peers, as it is also illustrated in Bødker and Christiansen’s study. In households, we often found that such a more capable peer (in terms of technical competence) became the main person responsible for setting-up and maintaining the technology shared with the collective [10]. It was often a parent but in one case also a teenage son taking on this role. Sometimes those technologies were specifically purchased for this kind of shared use, such as iPads, set-up for use by the children in the living room or family activities in the kitchen. In this kind of arrangement, a fundamental tension existed between the personal computing paradigm that underlies how access to these devices needed to be managed, and the actual, much more fluid ownership in collective households. The vast majority of cross-device interactions and data management was designed to happen through a single user account. As a result, children playing on an iPad might get notifications and messages sent to a parent’s smartphone and such. [10, 17].

The tension between the individuals’ preferences and the software enforced by the collective’s agenda in many ways mirrors that of the households where there was a much greater tendency to make do with what is available for the time that it worked. Both the notion of personal accounts and organizational ditto broke down when members of the collectives organized and shared through e.g. App store accounts).

4.5 Summary

The collective activities – carried out jointly or distributed – played a significant role in maintaining the collectives, but were less prevalent among households, at least regarding such that were technology-supported one way or another. Both joint and distributed activities were nonetheless important in maintaining and developing collectives and the values of the collective were reflected in, and also built up through the activity. Looking at the technologies used, Facebook, shared calendars and some amount of bespoke technologies (in the case of the lab) were important in supporting both activities and values among members. Externally, we see examples like the AOFF website that was also about showing the collective to the world.

There was a difference between the lab and AOFF in how they fostered and maintained referentiality. These differences were somewhat connected to both resources available to make it possible to shape a collective artifact ecology to support the collective. AOFF was more dependent on in particular Facebook, and ad hoc components of members’ personal ecologies as regards referentiality. The households had very little technology mediated referentiality except for shared calendars and they were equally as AOFF depending on members’ technologies from e.g. work to support this.

In all cases there were tensions between collective and personal artifact ecologies. Both the lab and AOFF showed examples of collective artifacts that were planned and introduced, but also of artifacts that were more hap-hazardously brought in into the collective artifact ecology by members, and sometimes left there for longer, and sometimes not [see 19]. This was true in the case of households as well even though the resources for planning were fewer (households did however plan and make decisions regarding e.g Internet and Wi-fi setup).

The analyses illustrate different roles for champions, founding members and more capable peers. There were somewhat different starting points in the cases, but parallel ways in which members with particular skills and interests contributed to and with the introduction and maintenance of particular artifacts in the collective artifact ecology. This was mainly done as volunteering and there is a slight difference to household where this was perhaps less of a volunteer role, by virtue of there being fewer to choose between and of the more direct needs of maintaining the household.

Tensions in and development of the collective artifact ecology is also a matter of timescale and the different timescales at which development and change occurs. There is a possible mismatch of timescales between the collective (e.g. families: generations; communities: decades; labs: decades/funding-rounds), and that of technological development, considering that many technologies we have discussed, such as social media, mobile technologies, wikis, sharing platforms etc., are new and volatile concepts. The most immediate examples where tensions happened and also were resolved in the three cases were when the challenges of payment in AOFF got solved as a mobile payment scheme was introduced by the banks, making both cash and card payment redundant. In families there were some instances where children's needs and wishes developed as they grew older, with increasing pressure on the one hand to acquire new technologies, and on the other to set former rules for when and where these technologies could be used.

5 DISCUSSION

In the introduction we opened up the space for thinking about collectives with a theoretical proposition potentially having analytical, critical and constructive power [7]. In this section we reflect on some main points regarding the theoretical foundation, and a concern regarding how to work methodologically. The reflections are primarily focused on the analytical prospects of *collective artifact ecologies*. First, what holds a collective together? We return to referentiality and its role in helping to analyze and understand how certain members within a collective take on leadership or other roles. Second, when is a group a collective? Here we draw parallels to the discussion of the scale and scope of boundary object analysis in an effort to address the issue of boundaries of a collective. Third, we bring collectives as a conceptual frame for analysis of groups and their artifact ecologies in the context of other work within CSCW, which we would encourage as the focus of future work exploring these concepts. Finally, we turn to more open speculations about the critical and constructive merits of the theoretical constructs presented in this paper.

5.1 What holds a collective together?

We have focused on the activity, identity and developmental aspects of a collective, as these have been of interest for systematically analyzing the example collectives above, but we also recognize that there is an additional layer of the interpersonal relations of a collective which is not informed by activity nor values. For the volunteer case example, the founding members knew each other before they began their endeavor, and it is likely that in many cases of collectives that people may join together, already having developed interpersonal relations with others outside the activity (and sometimes also without shared values). What prior relations mean in the formation of new collectives is open for consideration.

With the concept of referentiality, we have a way to talk about the actions people take within a collective, without deferring to the technical proficiency of individual members. What holds a collective and their artifact ecology together is reflected in the interpersonal relations. While descriptively this offers a way through which to understand why the relationships are the way they are, there may be a normative aspect to this with which to direct efforts in changes to the artifact ecology: How can changes to the artifact ecology, in service of the shared activity and reflecting the values of the collective, build the referentiality of those within the collective?

For the newcomers into the collectives it may make sense to see them as legitimate peripheral participants (as in Lave and Wenger's communities of practices [56]); and they do not necessarily end up ever moving to 'the center' even if they get to share more of the routines and artifacts of the collective artifact ecology. This is true for the AOFF as well as the lab, such as when some new members of AOFF do not closely engage with the community or when lab members come in only to do their project and then leave again [35]. Looking instead at where members are in relation to this 'center' with the concept of referentiality shifts the focus to the interpersonal relations with other members in relation to both identity and values, as well as the shared activity. Development is, therefore, not a journey towards the center in terms of skills or expertise. Some collectives have a fairly stable motive or mission, such as the distribution of organic food, or sustaining a family for that matter. This does not mean that the motive does not change. It may change either in tension with external changes or in the ongoing negotiation of the motive among members. The motive is, however, also not necessarily the primary reason for all members: Some members of the AOFF might see their own wish to get cheap, organic food as most important, and do not necessarily care how this is brought about. Rositto et al. [81] discussed the case of a food bank that points in this direction. It is quite clear in that case that the overall motivation of the Foodbank, of combating food waste, is different from the motivation of many of its volunteers, of helping people in need.

5.2 When is a collective?

We apply collective artifact ecologies as a concept in our analysis but recognize it requires further work. This is similar to other concepts that have also needed delimitation, such as 'boundary objects', which spurred the 2010 reflections by Star on more clearly identifying her thoughts about what is not a boundary object. Star [89] spoke of two aspects to consider when the concept of 'boundary objects' should apply: scale and scope. For boundary objects, Star considered it most useful at the organizational level, while recognizing that given the right circumstances, it could apply to, for example, a single word. For collective artifact ecologies, we would consider it most useful at the level of group of greater or equal size than a family or household and with a mixture of artifacts (to reflect the multiplicity of people and artifacts of our intended analysis), while also recognizing that there are situations where this does not hold. Similarly, the grander the scale, the more difficult it may become to analyze the group, their artifacts and activities as a single collective artifact ecology, while it would still remain useful to look at sub-groups within the larger group as smaller collectives (such as our example of a research lab within the larger context of the university). As an edge case, trying to apply a collective artifact ecologies understanding to a small diffuse group using a single artifact might result in an expanded scope and understanding of the group as a formation of people and their relationship to the technology used, for example by allowing to bring forward any potential shared history between the group members (how they came together, what goals that might develop), and how the single artifact focus might actually hide other infrastructure or artifacts on which it depends.

When we analyze groups as collectives, it forces us to recognize the developmental aspect and as such it is necessary to look beyond understanding the specifics of the group as they are in the moment. This includes the ways in which the artifact ecology is configured, the role different artifacts play in the joint activity, not only with a concern for efficiency or just what happens to be available at the time, but as a result of the development of joint activity and the identity of the collective, the interpersonal relations, in a wider societal context. For collectives and their artifact ecologies, such an analysis provides a rich understanding of how and why it has developed the way it has, and it exposes the glue of what keeps a collective together. Looking back on the parallels drawn with Star's reflections on boundary objects above as "*useful to some and not to others, is subject to partial usage and analysis*" [89, p.612], we can similarly emphasize the issue of scale as it

applies to a collective. The upper bound of a collective is ultimately not addressed in our current work.

5.3 How to work with collective artifact ecologies?

We deliberately chose cases that involve multiple technological artifacts that were not specifically developed for the activities in question. This is certainly different from studying e.g. the classical development and deployment of technologies in organizational units, where decisions are often made top-down, and the new artifact seen as replacing specific technologies or built to fit into an existing artifact ecology. It is hence also an open question if our concepts and analyses would work, and even be strengthened from such cases.

We also deliberately chose to look at collectives that were not driven by one or more shared artifacts, or single platforms as such. We started the paper with Bødker et al. [21]'s call for a focus on lacking collectivity mechanisms in such communities. With our collective artifact ecologies concepts these mechanisms may more specifically be understood as support for e.g. referentiality, but it is up to future work to actually address such cases.

Whereas this paper takes a theoretical take on collective artifact ecologies, section 3 has already provided the reader with step by step suggestions on what to look for when taking a collective artifact ecology approach to studying complex formations of multiple people and their multiple technologies. Empirically, we can so far only rely on our own scattered attempts at studying artifact ecologies and further attempts should be taken in future research. Mapping artifact ecologies is one approach we have followed, taking inspiration from Jung et al. [45] and Bødker et al. [12].

Mapping of artifact ecologies refers to a process that produces a static snapshot of the artifact ecologies structure, from which further complexity can be understood. The process of mapping can begin with an inventory of different artifacts that someone (or in this case, the collective) would interact with as part of their shared activity and goal driven actions that contribute to the ongoing development of the collective. The description (visual or written) should highlight contextual aspects of the shared activity and the different artifacts that are involved. We have also been inspired by the approach used by Bødker et al. [19] and Lyle et al. [62] that maps the different strategic and tactical, internal and external actions taken over a longer time period, and by the analysis of artifacts in use suggested by Bødker & Klokmoose [15] in their Human-Artifact Model. There could be many, other more or less prescriptive approaches to analyzing collective artifact ecologies. At the same time, the notion of collectives and collective artifact ecologies also showcase entities that are not fixed but rather are continuously in-the-making, rendering certain visualizations difficult and sometimes maybe misleading [50]. We have ourselves chosen not to be very prescriptive, and in our approach we see the collectives on the one hand, and technologies in use on the other, as natural starting points, that can be applied for various kinds of qualitative studies and analyses. However, we are not very interested in collectives as such without the focus on shared technologies, and we have deliberately limited the focus on collectives, in the same way as we also do not believe in endless analyses of artifacts as such.

We believe that systematic analyses of particular cases would be useful and we see it as possible future work to extend on some of the mapping methods that we and others have worked with in the past. We are however cautious when it comes to the complexity of such mapping exercises, which is one reason why they have not been brought further for this paper.

5.4 Thinking critically and constructively with collective artifact ecologies?

Recent contributions invite us to think about the generative aspects of theory. Beaudouin-Lafon et al. [7] propose generative theories of interaction that, as conceptual tools, can help researchers explore the analytical, critical and constructive power of new theories grounded in existing ones.

Oulasvirta & Hornbæk [73] discuss how theories can support counter-factual thinking and theories as ‘speculation pumps’. Here, theory can generate propositions that support reflection on the consequences of a design and help identify design choices. While we do not have designers in mind with our present contribution, we see potential in using collective artifact ecologies to think critically about how collective activities, identity and development challenge dominant designs and applications (and the other way around). Plenty of recent contributions have illustrated the multiple tensions arising when collectives appropriate and negotiate technologies, e.g. the struggles of running a community on freely available services and applications [20, 82], the mismatch between caring aspects of a community and appropriated technologies [81], the implications of commitment to mono-technologies/platforms/monoliths [21] etc. We see a potential in employing the framing of collective artifact ecologies as a critical lens into understanding these tensions from a collective perspective.

When ‘groupware’ emerged, it filled a clear technical and conceptual gap in how we understand and develop technology. It was defined by Ellis et al. [30] as “*computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment.*” [30, p.40]. Back then the urgent topics were real-time collaboration, group interfaces and processes, concurrency, control and many other issues arising when groupware met group work. Today, computing happens across multiple devices and multiple social constellations. It is worth considering if the ‘group’ perspective is a useful analytical and constructive framing today (or even at the time [see 66]) as activities and technologies quickly transcend this level of groups. From a constructive perspective, an obvious question would be, what would define *collectiveware*?

The problem with groupware in relation to collectives lies in its definition. Groupware is defined based on a consciously decided common task with common goals. The collective is defined through collective activities that are not always fully conscious to the subjects.

The very state of computing as happening across multiple artifacts in artifact ecologies seems to challenge – not only the analytical and critical perspectives – but contemporary technologies and constructive approaches. Software development still has not come up with a good reply to the space between organizational IT and personal computing. The space that we theorize as a collective level.

6 CONCLUSION

The paper has defined and discussed collective artifact ecologies, and motivated their usefulness for CSCW. Collectives are driven by their collective activity, their identity in relation to their practices and the wider society, and their development, both historical, and future oriented towards fulfilling the joint goals of the collective and towards a higher degree of interpersonal relations (which in turn are mediated by the joint activity). Built on this understanding of collective, and prior work on artifact ecologies, we have constructed the definition of the collective artifact ecology as the particular constellation of artifacts that a collective has made its own and uses; that contributes to the development of the identity of the collective, its activities, values and ideals, and the respective interpersonal relations. To serve as a starting point for further engagement with these concepts, we have provided a number of guiding questions and suggestions to support the understanding of both collectives as a means to analyze groups. These questions have been supplemented with discussions about the limits, bounds and when to utilize these theoretical concepts. The ways in which individuals mediate the introduction and use of technology have been analyzed, including the concept of referentiality within a collective which has served to help explain the exercised ability of members to act in different capacities. Artifacts in collective artifact ecologies include some that are introduced deliberately to support the joint activities and the identity of the collective and some that more hap-hazardously are used by members based on their experience and availability from other artifact ecologies. The concerns for what makes a collective

in addition to joint and distributed collective activity, helps focus on mediating interpersonal relations, artifacts that mediate and support the identity of the collective and its context within society, artifacts that mediate interpersonal relationships, including the roles of more capable peers. Mediation and support develop in tensions that support or hinder the development of the collective. In developing the concepts, we have tried to be as transparent and reflective about the process of theorizing as a messy collective effort that mixes analogical reasoning and family resemblance. Developing theory is a collective activity and our proposition, a theory of *collective artifact ecologies*, is an open invitation to the broader CSCW community to participate in the collective activity of theorizing.

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