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Theorising effective uses of digital technology with activity theory

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ABSTRACT
Effective uses of digital technologies are vital to full inclusion in a network society. Digital-abilities researchers have produced several major frameworks, but these have generally not incorporated socio-contextual perspectives. To explore this lacuna, and engage in a reflective act of theorisation, activity theory is used to conceptualise four sub-systems of digitally mediated action. Eschewing technological determinism, humans are positioned as active agents capable of identifying, taking up, modifying and even subverting established technology uses in pursuit of meaningful objectives. At the same time, attention is given to contextual conditions shaping diverse activity systems supported by assemblages of humans and machines. Having theorised effective digital-technology uses through the lens of activity theory, the author reflects on this conceptual apparatus itself. In so doing, activity theory is characterised as a fertile, if complex and contested, future-oriented tradition that challenges individual-social dichotomies and addresses both humans and machines as mediators of activity, development and learning.

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Problem statement

Variously cast as literacies, competences and skills, effective use of digital technology is a prominent international research theme. Ferrari (2012) identified numerous digital-abilities models, but few have developed into fully theorised and operationalised frameworks (Desjardins, 2005; Eshet, 2012; Ferrari, 2013; van Deursen, Helsper, & Eynon, 2014). Even among the most developed frameworks, socio-cultural perspectives (e.g. activity theory, distributed cognition and situated action) have not gained attention. This 'theory gap' appears significant because such approaches have deeply influenced the cognate domains of human–computer interaction (HCI) (Clemmensen, Kaptelinin, & Nardi, 2016; Kaptelinin & Nardi, 2012; Kuuti, 1995) and digital learning (DeVane & Squire, 2012; Jones, 2015). To address this gap, this study (re)theorises effective digital-technology use on the base of activity theory. It begins with a brief overview of activity theory. Next, a compact conceptual grammar is constructed, and four sub-systems of digitally mediated action are systematically explored. Finally, key findings are organised, and activity theory is assessed as a tool for theorising. This exercise deepens an established body of research and offers a case study for theorising the educational use of digital technology.

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Enter activity theory

Activity theory has been called 'an agenda for a research program' (Kuuti, 1992, p. 234), a 'conceptual framework and vocabulary' (Turner, 2016, p. 27) and an 'intellectual tradition' (DeVane & Squire, 2012, p. 242). Leontiev, one of activity theory's founding thinkers, spoke of an 'activity approach' (*dejatel'nostnyj podhod*) (Leontiev, 1977b). This approach originated in a 1920s post-revolutionary context and is associated with the 'troika' of Vygotsky, Leontiev and Luria (Kozulin, 1986). Building directly on Marx and countering the classical-conditioning paradigm of Pavlov, they launched a cultural-historical perspective open to radical psychological and social restructuring (Daniels, 2017; Kozulin & Presseisen, 1995; Rückriem, 2014). After completing a body of seminal psychological research in Moscow led by Vygotsky, with Stalin tightening party control over science in 1929, Leontiev assembled his own research group in Kharkov, Ukraine (Leontiev, 2005b; Yasnitsky, 2008) where *activity* become a major facet of study. Although Vygotsky died in 1934 of tuberculosis, he bequeathed to Leontiev a key conceptual cornerstone: *mediated action* as a unit of analysis (Wertsch, 1994; Yamagata-Lynch, 2010).

Vygotsky's mediated action

Rejecting behaviourist perspectives, Vygotsky brought humans, as active agents, together with their social environment as a single functional unit in several laboratory studies. Findings demonstrated that language and artefacts restructured cognition, thus transforming a stimulus-response process into a culturally mediated act (Wertsch & Tulviste, 1992). In addition to exploring ways in which humans mediate the cognitive processes of others as carriers of signs, symbols and meanings (Kozulin & Presseisen, 1995), Vygotsky also emphasised tool mediation. He distinguished between (a) technical tools, which are directed towards the mastery of natural processes; and (b) psychological tools – including both material artefacts (e.g. maps, works of art and blueprints) and symbolic systems (e.g. language, different forms of numeration and counting, algebraic notations, mnemonic aids and all sorts of conventional signs) – which are directed towards mental processes (Vygotsky, 1997). Because tools of all types are cultural products, Vygotsky construed individual mental functioning as determined 'from the outside', and formed fully through the gradual internalisation of external models and processes (Kaptelinin & Nardi, 2012).

Mediated action to collective activity

Leontiev (1977a) 'zoomed out' on Vygotsky's mediated action to explore *activity* – still primarily from the perspective of an individual actor – as a fuller link between the environment and human consciousness. His theorisation introduced several constituent elements and a dynamic hierarchical structure (e.g. Leontiev, 1977a, 2005a, 2006). With respect to constituent elements, activity is centred on an active *human agent* pursuing an *object* (Leontiev, 1977a). This object anchors subjective human experiences by focusing attention and providing motivation for an activity (Kaptelinin, 2005). The human pursuit of objects is mediated by *tools/instruments*. Leontiev elaborated the concept of 'functional organs' to speak about human–tool partnerships that extend natural capacities (Kaptelinin & Nardi, 2012). He derived another element from the inherently social nature of activity. Through activity, humans not only enter a relationship with nature, they also enter a relationship with a *community* to pursue social objects facilitated by coordinated action and purposeful communication. Even in ancient times, collective activity produced a technical *division of labour* and corresponding *rules* of participation. In the end, six items – *human agent, object, tools/ instruments, community, division of labour* and *rules* – were introduced as the constituent elements (and mediators) of human activity.

Leontiev also theorised a dynamic hierarchical sub-structure for activity (Leontiev, 2006), which functioned through psychological processes such as internalisation, externalisation, automatisation, de-automatisation and object transformation. Within this hierarchy, activity is driven by motive, actions by goals, and operations by contextual conditions (Kaptelinin & Nardi, 2012). Positioned on a vertical axis, an activity can transform downward into an action, and an action into an operation. In the upward direction, an operation can transform into an action, and an action into activity. Because goals and motives can change in the minds of human agents, these downward and upward transitions can happen without being immediately perceptible to others. Indeed, in contexts of collective labour, conditions, goals and motives typically transform over time as needs and circumstances change. However, activity systems achieve stability through a community's communication about objects, the use of mediating tools, participant roles, and both explicit and implicit rules of conduct.

Modelling collective activity

The Finnish educationalist Engeström (2015) expanded activity theory in the 1980s as a basis for exploring transformative work activity. One of his most significant early contributions was to reduce Leontiev's complex written theorisations to a visual tool for applied research. As shown in Figure 1, this multi-triangle model of an activity system consists of four sub-triangles (Engeström, 1987). Triangle 1 (labelled in the explanatory key) is Vygotsky's mediated-action model. Triangle 2, a vertical flip of Triangle 1, introduces the community, thus extending the model to collective activity. Triangle 3 positions rules (including traditions, rituals, guiding values etc.) as a mediator between the person and community. Similarly, Triangle 4 situates division of labour (social or organisational roles) as a mediator between the community and object. The object itself is depicted with an oval highlight, suggesting that 'object-oriented actions are always, explicitly or implicitly, characterised by ambiguity, surprise, interpretation, sense making and potential for change' (Engeström, 2001, p. 134). Finally, an activity outcome is added, which could form the basis for a new activity. Engeström also modelled complex work environments using multiple interacting systems, which he called a 'third generation' approach (Engeström, 2001, 2009, 2011, 2015; Engeström & Sannino, 2010).

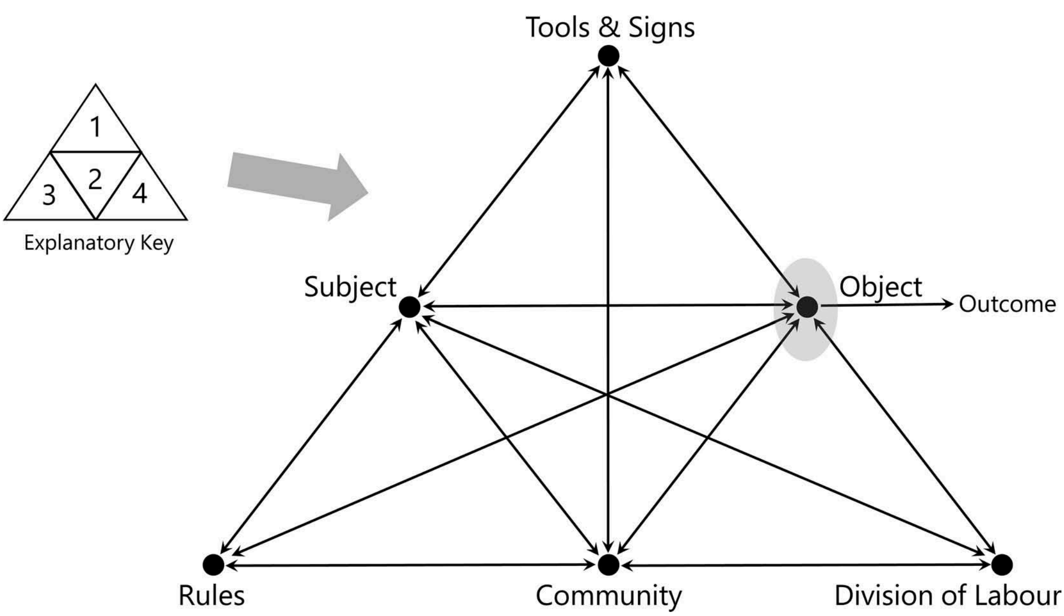

Figure 1. An activity system, as modelled by Engeström (right), with author's explanatory key (left).

This model is well rooted in the work of Vygotsky and Leontiev, and it has been applied fruitfully by interventionist researchers in a variety of domains (Ellis, 2008; Engeström, Kajamaa, Lahtinen, & Sannino, 2015; Fitzsimons, 2003; Hasu, 2000; Rasmussen & Ludvigsen, 2009; Seppanen, 2002; Virtaluoto, Sannino, & Engeström, 2016; Yamazumi, 2008). However, it is noteworthy that Engeström largely ignored ICTs as cognitive tools and mediating means in his development and application of activity theory (Rückriem, 2009). This disposition can be contrasted with that of Leontiev, who already in the 1970s highlighted the potential for extending human capacities through smart machines (Leontiev, 1977b). Thus, Rückriem (2009) urges activity theorists to follow Leontiev and incorporate digital-media and -system theories in their work. Recognising the merits of this suggestion, Engeström (2009) nevertheless cautions us to avoid technological determinism and recognise object-oriented humans as the primary drivers of activity.

Theorising with activity theory

Theorising with activity theory requires both familiarity with foundational cultural-historical concepts and an aptitude for improvisation. Among activity-theoretical researchers, improvisation has taken several forms. To align activity theory with today's complex human–computer environments, some are augmenting activity theory with forms of distributed cognition (Shaffer & Clinton, 2006), Peircean theory and ecofunctionalism (Norros, 2017). Others are using pieces of activity theory as grist for new approaches to human–computer interaction such as instrumental genesis (Rabardel & Bourmaud, 2003), genre tracing (Spinuzzi, 2003) and systemic-structural activity theory (Bedny & Harris, 2005). Activity theory is also being used to reground ecological psychology and technology-affordance theories (Baerentsen & Trettvik, 2002; Béguin & Rabardel, 2000; Vyas, Chisalita, & Dix, 2016). The following theorisation engages in some measure of conceptual improvisation while remaining grounded within the work of Vygotsky, Leontiev and Engeström outlined above.

An activity-theoretical grammar

To theorise effective uses of digital technology, a compact activity-theory grammar of *elements* and *dynamics* was constructed. The six elements are those represented in Engeström's triangle (numbered in Figure 2) with the exception that *digital* tools are identified as mediating artefacts of interest. Seven interdependent dynamics are also introduced, based on the work of Vygotsky and Leontiev (appearing in grey in Figure 2 within a dotted oval signifying the ubiquity of digitality). These begin with human *agency* – that is, purposeful action taken by a subject to address physiological and/or psychological needs. The activity in which this action takes place is *object oriented* and *mediated* by tools and technologies. Tools and technologies function 'between' humans and their environment to augment capacities and facilitate both *internalisation* and *externalisation* of cognitive schema. The former relates to the social construction of the individual mind and the latter to an individual's capacity to restructure internalised schema and reintroduce them into the environment as an idea or artefact. Finally, *automatisation* and *de-automatisation* relate to routinised and de-routinised human action. Increasingly, human actions are routinised through digital automation, and such actions are sometimes de-routinised when there is system breakdown. These seven dynamics join the six elements as a grammar with which to theorise four 'sub-systems' of human–computer activity.

Positioning digital technologies

Within this grammar of activity theory, digital technologies emerge, on the one hand, as part of an historic legacy of tool-mediated human activity, and on the other hand, as especially powerful mediating means owing to their multi-functionality and sign-manipulation capabilities. This is not a technologically deterministic perspective. As much as humans may cherish their devices and

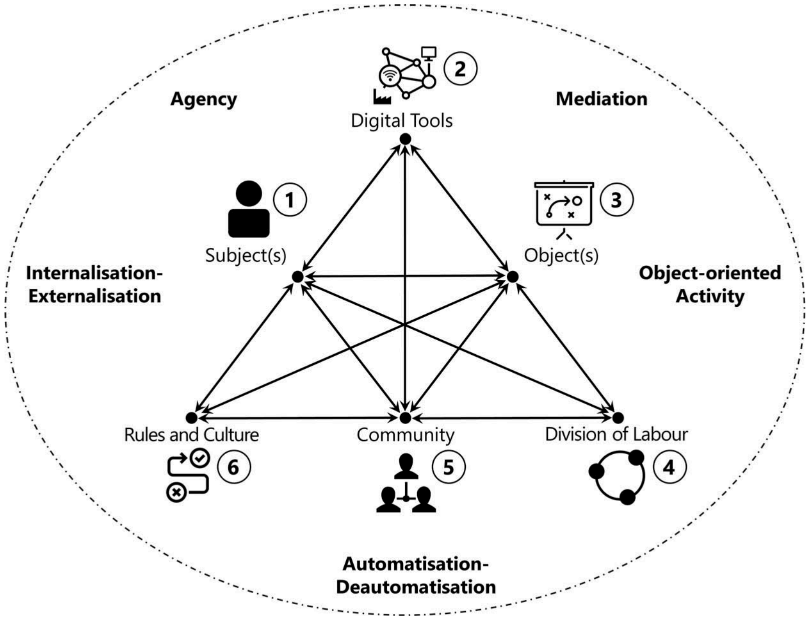

Figure 2. Elements and dynamics of digitally mediated activity.

routinely appear focused on them, they are most often seeking to achieve a meaningful objective beyond using hardware, software and data objects. On this view, digital technologies are not independent forces responsible for defining human action. Rather, they are social artefacts with *affordances*, presenting (culturally shaped and sometimes institutionally bounded) opportunities for action implemented by design and made visible in relation to human needs. Without question, digital technologies lend structure to activity and even call attention to themselves, particularly when there is a breakdown (Koschmann, Kuutti, & Hickman, 1998). Yet, they would remain unrecognisable and ultimately meaningless without an object of activity.

With respect to conceptualising *effective* uses of digital technology, activity theory offers an object-oriented, contextual and developmental focus. Any technology use enabling a subject to achieve a goal aligned with a socially meaningful object must be ascribed some measure of effectiveness. Where technologies are taken up obediently without a clear object in view, one might suspect the presence of less effective use. Yet, we must not be too hasty in our assessments. For example, playful and exploratory interactions are useful for gaining familiarity with affordances. This is one reason why the experiences of gamers, hackers and 'makers' have much to offer digital-learning communities. Additionally, effectiveness should always be understood in relation to developing and evolving sets of abilities produced through technology use in a variety of contexts.

Theorising sub-systems of digitally mediated action

Goal-directed action is the recommended analytical starting point for activity theorists because actions represent the stable core of any activity system (Leontiev, 2006). Working up through levels of action, one moves closer and closer to activities and the objects or motives driving them. Similarly, moving downward through levels of action, one eventually comes to sets of operations represented by procedural repertoires, and moving lower, constituent micro-processes, which may be difficult to detect particularly when executed by a human brain rather than a software system.

Within this theorisation, we will move up and down from the action level as required to explore each proposed sub-system and the key human abilities required for successful functioning.

Building functional (human–computer) systems

Desjardins (2015) and Eshet (2012), authors of major digital-abilities frameworks, describe digital technology as permeating society and requiring human adaptation. This discourse reflects the anxiety of many educators who have experienced digital-technology implementations orchestrated 'from beyond' (Bunz, 2009; Celik & Yesilyurt, 2013). Activity theory offers a less threatening point of departure. Rejecting the Cartesian split between people and technological artefacts, which both function in the world as products and generators of culture, activity theory draws attention to agentic humans inquisitively exploring and strategically instrumentalising digital technologies to extend their native capacities for achieving goals. Leveraging this empowering perspective, the first sub-system of interest relates to building and maintaining 'functional systems' (incorporating elements 1–3 in Figure 2). It also draws on the concept of technology *affordances*, which have garnered significant attention in HCI and IT-systems research (Baerentsen & Trettvik, 2002; Kaptelinin & Nardi, 2012; Pedersen & Bang, 2016; Vyas et al., 2016).

Originally attributed to the Russian physiologist Ukhtomsky, Leontiev adopted the idea of 'functional systems' to speak about human–tool combinations constructed to attain goals that could not be attained otherwise (Leontiev, 1978). Examples include the use of eye-glasses, telescopes and microscopes to extend human sight. Digital technologies, as general-purpose tools, present many ways to extend human abilities to achieve goals. The overall effectiveness of functional systems is a shared responsibility of an active subject and technology designers. From a subject perspective, *effective* functional systems are increased by a strong sense of agency (Bandura, 2006; Reeve & Tseng, 2011) and a positive disposition towards human–technology partnering (Hoff & Bashir, 2015). More specifically, three complexes of overlapping human competences can be proposed for building and maintaining highly functional systems: meta-functional, technical and operational competences.

Meta-functional competences, overlooked by digital-abilities researchers, relate to the creation and maintenance of human–machine partnerships, which begin with the subject's selection and application of available *affordances* to achieve a desired goal. Built on Gibson's (1977) notion of (natural or human-made) environmental provisions functioning as opportunities for action, affordances cut across the dichotomy of subjective-objective. Moreover, from an activity-theory perspective, affordances not only address a relationship between human characteristics/needs and the affording properties of a technological artefact, they also include cultural-historically transmitted use schemes (Baerentsen & Trettvik, 2002; Béguin & Rabardel, 2000; Kaptelinin & Nardi, 2012; Pedersen & Bang, 2016). Once the subject has selected a suitable affordance and a potential use scheme – a process that, when done poorly, can cause user frustration and task-completion problems (Barber & Blayone, 2018) – the challenge shifts to integrating the technological artefact into a desired workflow. Depending on the complexity and duration of the activity and changes to the object, this sub-system may have to be reconfigured over time. Such reconfiguration may include changing the workflow, adjusting the technology (e.g. through settings, macros or reprogramming) or improvising uses unanticipated by designers (Béguin & Rabardel, 2000). Traditionally, technology uses that deviated from expert schemes were frowned upon. As an expression of meta-functional competence, however, improvised uses of technological artefacts become a key facet of effective use and a catalyst for system-design improvements – a notion well aligned with subcultures of game 'modders', computer hackers and digital makers, and the democratisation of invention (Blikstein, Kabayadondo, Martin, & Fields, 2017).

Technical competences, which relate to fixing and maintaining digital technologies, are tool-focused endeavours often addressed through division of labour. That is, in many contexts, technical tasks are routinely handed off to specialists functioning within 'neighbouring' activity systems with their own motivating objects. A subject with well-developed technical competencies, however, would be able to troubleshoot at a rudimentary level and communicate effectively with technology specialists. Recovering from technology 'breakdowns' with minimal frustration and loss of focus is also vital. From an activity-theory perspective, such breakdowns call attention to the world around us and dispel the notion of tool transparency (Koschmann et al., 1998).

Finally, operational competencies, which are well addressed by digital-abilities frameworks (Desjardins, 2005; Eshet, 2012; van Deursen & van Dijk, 2010; van Dijk & van Deursen, 2014), relate to a subject's ability to maintain a sense of confidence and control when using devices and software. As a developmental perspective, activity theory highlights the value of acquiring operational skills through the instrumentalisation of digital technologies to solve authentic problems in 'real world' contexts. Activity theory also acknowledges the value of collaboration and machine augmentation in which an agent who/which has achieved proficiency in an activity system could support other agents within a zone of proximal development (Vygotsky, 1978).

Mediating cultural expression

All major digital-abilities frameworks address the informational uses of digital technology, most often through the lenses of information science and cognitive psychology. Most adopt a consumptive perspective focusing on skills related to searching, navigating, selecting and assessing the credibility of textual data (Calvani, Cartelli, Fini, & Ranieri, 2008; Desjardins, Davidson, Blayone, vanOostveen, & Childs, 2015; van Deursen & van Dijk, 2010). A few frameworks also address those abilities required to create and repurpose digital information in a broader variety of media formats (Eshet, 2012; Ferrari, 2013). From the perspective of activity theory, informational uses of digital technologies are a form of socio-cultural mediation involving all elements of an activity system and the dynamics of internalisation and externalisation.

For Vygotsky, the interpretive and meaning-making practices of humans always begin on an inter-psychological plane, as a property of others, and the social plane, as a property of tools/artefacts. They are subsequently internalised, thus enabling 'higher' (culturally mediated) mental functions (Vygotsky, 1981). Adopting this perspective, activity theory conceptualises *internalisation* as any redistribution of ideas or cognitive processes that result in a shift from the external to the internal plane. Activity theory also emphasises transitions moving in the opposite direction. Thus, digital technologies and the creative opportunities they afford for written expression, drawing, animating, videography etc., serve as powerful catalysts for *externalisation*. Of course, creative individuals may also *restructure* internalised culture, thus introducing innovations and transforming the status quo. Social-media technologies have introduced abundant opportunities for engaging in creative forms of internalisation and externalisation as an ongoing process of cultural development.

Effective uses of digital technologies for cultural appropriation, expression and innovation are invariably tied to the goals/values of social units and the objects of specific activity systems. Activity theory does not provide generalised criteria for discerning the quality of cultural internalisation or externalisation in digital environments beyond measuring actions against the object(s) of an activity system. Discussions of intellectual property, plagiarism, privacy, misinformation and 'fake news' fall well outside its scope, and are intricately connected to the social, economic and political contexts in which activity takes place. Granted, if digital networks continue to extend information sharing, access and storage, such issues will only increase in importance.

Automatising action and distributing cognition

Leontiev (2006) conceptualised activity as a hierarchical structure, and owing to divisions of labour and the complexity of activity, a subject's attention is generally focused on the middle layer of goal-driven actions. Actions appear as sequences of steps or repertoires that contribute, in some way, to the object of activity. *Operations* (the lowest layer of activity) emerge through (a) a spontaneous response to conditions in the environment, like a sudden manoeuvre to avoid colliding with another person on a busy sidewalk; or (b) the automisation of actions, like learning to drive a vehicle with a manual transmission – what starts as conscious actions eventually becomes automatic behaviours. Activities typically include countless complexes of operations. Yet they generally go unnoticed until they are brought to a subject's attention through meta-cognitive reflection or de-automisation, which happens when there is a breakdown in a routine (Koschmann et al., 1998). Recovering from a breakdown may involve implementing an improved repertoire of actions that presents new opportunities for automisation. Indeed, to become 'skilled' at something implies both an understanding of processes related to goal achievement, and a capacity for automatising actions without sacrificing outcome quality.

Rückriem (2009) notes that in addressing the significance of early computers and automated machinery, Leontiev 'freed himself of all restrictions of historical materialism and focused exclusively on the psychological components of activity and the possibility of their technical modelling' (p. 107). Predicated on a psychological conceptualisation of tools as externalised operations, digital computers were recognised for their ability to take on operationalised actions, thus decoupling them from human creativity. By construing digital technologies as cultural artefacts and psychological tools capable of cognitive processing, Leontiev showed no aversion to the consequence that frightens many educators.

> What today appears to human thinking as a not-to-be-formalised creative action could tomorrow already be changed into an operation. Thus there are no limits to the development of always smarter machines. (Leontiev, 2006, p. 32)

Automatisation competencies have largely eluded digital-abilities framework research (Ilomäki, Paavola, Lakkala, & Kantosalo, 2016; Iordache, Mariën, & Baelden, 2017), although there is growing interest in 'computational thinking' (Bocconi et al., 2016; Jun, Han, Kim, & Lee, 2014; Selby & Woollard, 2010; Wing, 2008). A significant exception is the General Technology Competency and Use (GTCU) framework's 'computational competences' (Desjardins, 2005; Desjardins et al., 2015), an adaptation of Jonassen's theorisation of computers as 'cognitive tools' (Jonassen, 1995), which intersected with activity theory (Jonassen & Rohner-Murphy, 1999). Within the GTCU, computational competences target both domain knowledge and the skilled use of data-analysis applications or programming environments to define task procedures and assign them to a computer. By highlighting the role of a human operator who controls the process of cognitive redistribution, the GTCU's theorisation aligns well with activity-theoretical approaches to operationalised action.

Increasingly, however, owing to the growing pervasiveness of digitally mediated activity (e.g. Internet of things and augmented reality) and the cognitive capacities of machines (e.g. artificial intelligence, natural-language processing and machine learning), some activity theorists are extending this linear, human-centric process to address a two-way distribution of agency and cognition between humans and machines. For example, Shaffer and Clinton (2006) introduce a new analytic category, 'toolforthoughts', to conceptualise a 'strong' distribution of intelligence across humans and objects in activity systems, drawing upon Latour (1996). According to Latour, action originates within systems of 'actants', which includes people and their machines – both of which express purpose (Elbanna, 2009). Within this system view, focus shifts from automatising individual-level actions to exploring new kinds of human–artefact interaction such as that afforded by video games and simulations. 'What is the ubiquitous avatar if not a representation of the tight coupling between computationally literate person and computational literate object?' ask Shaffer and Clinton (2006, p. 295). However, the degree to which activity theory can (or should) embrace distributed and non-human forms of agency and cognition is contested. On the one hand, Kaptelinin and Nardi (2012) emphasise that humans are uniquely capable of 'higher' mental functioning and acting with intention. On the other hand, Rückriem (2009) argues that our digitalised world has exceeded the limits of this anthropocentric view.

Although not addressing this theoretical impasse, it has been argued that a vital (human) capacity shaping human–machine partnerships is trust *in automation* (Hoff & Bashir, 2015; Lee & See, 2004). As with human–human partnerships, trust in human–machine partnerships cuts two ways. On the one hand, trusting automation too much may lead humans to violate critical assumptions, leading to system failures. On the other hand, lack of trust can create inefficiencies and safety issues that may compromise the sustainability of a system. Key variables affecting levels of trust include the degree of communication between system experts and users, and the level of algorithmic transparency (Lee & See, 2004). In the end, a key competency for building successful human–computer partnerships, therefore, relates to developing defensible levels of trust based on available knowledge and algorithmic transparency. This places some responsibility on system builders and experts to do their part in building and maintaining the user's trust.

Engaging in collective activity

Digital-abilities frameworks have addressed key facets of computer-mediated communication, including social interaction and assets sharing (Desjardins, 2005; Vuorikari, Punie, Gomez, & Van Den Brande, 2016), socio-emotional skills (Eshet, 2012) and ethics/netiquette (Calvani et al., 2008). However, these frameworks lack conceptual tools for addressing collaborative activity more broadly, and this is where the bottom of Engeström's activity-theory apparatus comes into play (Figure 2). In collective activity, the subject and *community* join together to form an assemblage of agents (Leonardi, 2011), which relies on *divisions of labour* and sets of *rules* for behaviour and communication. Rules may be explicit, encompassing managerial dictates, job descriptions, contracts and organisational hierarchies, or they may be implicit, such as those driven by cultural values (Hofstede, 2001; Hoftede, Hofstede, & Minkov, 2010). Importantly, complex divisions of labour separate individual goals from the objects of collective activity, a fundamental insight of activity theory. This heightens the need for communication among participants to maintain a shared sense of purpose and achieve mutually beneficial outcomes.

To explore digital-mediated, collective activity and associated digital abilities further, we draw on three existing theorisations. The first, developed by Engeström et al. (2015), distinguishes between four types of collective activity by focusing on *objects* and *instrumentalities*. Within contexts of collective work, participants may act with a strongly shared object or maintain different perspectives on the object. As such, the type of object functioning among collaborators can be 'heterogeneous' or 'unified'. Similarly, actors may pursue different forms of instrumentality, which includes all digital and non-digital technologies and affordances. The form of instrumentality guiding group interaction can be 'possibility oriented' (fluid) or 'task oriented' (stable). In combination, four types of collaboration observed in numerous ethnographic studies emerge from these distinctions (Engeström et al., 2015). *Coordination* represents a form of collaboration in which actors follow strict procedural scripts tied to established hierarchies/roles and mediating instruments and are motivated by role-specific objects (e.g. in highly regulated sectors such as healthcare). *Cooperation* addresses situations in which participants establish their own path to address a well-defined problem using a stable set of procedures and technologies. *Communicative collaboration* assumes a unified object but requires ongoing interaction between participants to adapt technologies and procedural scripts. Finally, *carnivalisation* is conceptualised as a radical form of collaboration in which hierarchies are suspended, transactional distances between people are closed, and both objects and instrumentalities are emergent. Carnivalisation aptly describes implementations of fully online collaborative-constructivist learning in which the teaching function is distributed and the selection of tasks and technologies are negotiated as needed by participants while engaged in authentic problem-solving activities (Blayone, 2017; vanOostveen, Childs, Clarkson, & Flynn, 2015; vanOostveen, DiGiuseppe, Barber, & Blayone, 2016; vanOostveen, DiGiuseppe, Barber, Blayone, & Childs, 2016).

This activity-theoretical typology of collaboration, focused on the objects and instrumentalities as co-defining elements, positions digital technologies alongside other instruments, mental models and human actors to form collaborative assemblages. To enable such assemblages, a variety of higher-cognitive abilities come into play including socio-emotional, communication, intercultural and strategic competencies. With respect to digital technology use, in those situations where specific instrumentalities are not prescribed, participants can negotiate the use of technologies and affordances as needed. Here, the focus is not on acceptance and use of technologies but rather on constructing robust instrumentalities aligned with a shared object of activity.

A second theorisation of collaborative activity strongly aligned with activity theory builds upon a distinction between *teamwork* and *taskwork* (Fiore & Wiltshire, 2016). Teamwork refers to those person-focused actions including member coordination and communication. Taskwork is focused on content-related procedures including managing hierarchies of tasks and monitoring technology-operations. Construing technological artefacts as potential collaborators for conducting teamwork and taskwork, Fiore and Wiltshire (2016) theorise that humans enable technologies in human–machine collaborative assemblages through two processes of *externalisation*. The first process, focused on externalising declarative knowledge, serves to distribute human memories to supporting technologies. The second process, focused on externalising cognitive schemes (procedural knowledge), facilitates the use of technology to scaffold team decision-making processes. Therefore, human team members require key competences for enabling the capabilities of digital technologies as external memory and cognitive scaffolding, both for teamwork and taskwork. These competences often relate to using data-organisation, -visualisation and -transformation applications effectively – what the GTCU framework groups together as computational competencies (Desjardins, 2005; Desjardins, Lacasse, & Belair, 2001).

A third theorisation of collaborative activity by Vyas et al. (2016) combines activity theory and structuration theory (McPhee, Poole, & Iverson, 2016) with a three-level approach to technology affordances (Vyas et al., 2016). At the user level (Level 1), a one-to-one relationship between an individual and a technological artefact determines how the subject uses and adapts to available technologies. At the organisational (Level 2) and society (Level 3) levels, one-to-many and many-to-many relationships emerge between the user(s) and technological artefacts. Focused on the organisational level, and through ethnographic observations of workgroups in several companies, four conditions are identified as mediating the identification, selection and use of technology affordances (Vyas et al., 2016). These are: (a) *technological conditions*, including the type of hardware and software available; (b) *cultural conditions*, including the roles and sub-cultures shaping uses of technology and the value ascribed to various team members; (c) *power conditions*, which directly affect levels of access and technology-related choices; and (d) *interpretive conditions*, relating to knowledge of, and attitudes toward, the technology systems which result in some being intimate with, and others feeling alienated from, mediating technologies. Within this scheme, even capable individuals with tremendous digital competencies may struggle to realise their full potential as members of the team when they find themselves on the wrong side of power and culture, for example. Conversely, in empowering environments, those with low starting levels of digital abilities may develop and thrive over time. Put into activity-theoretical terms, on this view, effective functioning of subjects within collective activity systems not only depends on individual capacities, but also on broader, contextual dynamics. Importantly, a concern for culture, power and interpretation have emerged as key themes within broader activity-theory research (Engeström, 2009).

Taken together, these three conceptualisations of collaborative human–technology activity ask us to push beyond the limited foci of current digital-abilities frameworks. We must consider (a) types of objects and instrumentalities; (b) the capabilities of human teams to leverage digital technologies as cognitive partners through the externalisation of declarative and procedure knowledge; and (c) environmental dynamics, which may nurture or thwart collective human functioning.

Discussion

It remains to organise this theorisation of effective digital-technology uses through the lens of activity theory on two levels. On the first level, the four proposed sub-systems are summarised as a contribution to digital-abilities research. On the second level, reflecting on this theorisation, the nature and conceptual affordances of activity theory itself are addressed.

An activity-theoretical model of effective digital technology use

Eschewing discourses of technological determinism, activity theory positions digital technologies (alongside other tools and artefacts) as mediators of activity driven by subjects and constituted by actions and operations. Activity theory provides researchers with an apparatus to conceptualise humans and technologies across contexts, including (physical and virtual) places of work, education and play. Within this conceptual frame, effective uses of digital technologies are defined as any set of human–computer interactions that move a subject and participating community closer to their object. Emphasis is on agentic people actively pursuing an objective, not passively accepting and using technology. Of course, recognising the growing complexity of human–machine assemblages in many organisational contexts also requires us to consider complex forms of agency, several types of collaboration, inter-connecting activity systems and distributed forms of cognition.

By constructing a grammar of elements and dynamics from Leontiev's activity approach, four sub-systems of digital-mediated action were proposed, focused on the action level. The first, relating to building and maintaining human–machine pairings, addressed three interrelated competences: meta-functional, technical and operational. Meta-functional competences relate to selecting appropriate technological affordances and maintaining an object-oriented focus even when this requires using technologies in ways that depart from established use schemes. Technical competences relate to maintaining technology functioning and recovering from breakdowns with minimal frustration or loss of focus. Operational competencies involve a sense of confidence and control during technology use. The second sub-system, relating to mediating cultural expression, addressed internalisation (e.g. content consumption) and externalisation (e.g. content creation, sharing and publishing). Effective technology use in this realm is largely determined by the (explicit and tacit) rules of participating communities. The third sub-system relates to the automatisation of actions by reducing them to formal procedures (algorithms) that can be run by the machine. This offloading of human cognitive labour requires a variety of application- and/or programming-level competencies, and the development of appropriate levels of trust in technology. The degree to which humans remain functionally distinct actors or become enmeshed within systems of human and machine agents/actants depends on context and analytical perspective. Finally, the fourth and most complex sub-system addresses digitally mediated collaborative activity. Effective collaboration requires flexible and robust instrumentalities, open communication, the externalisation of relevant declarative and procedural knowledge (to support teamwork and taskwork), and a shared commitment to identifying and challenging political and cultural barriers that thwart optimal group functioning.

Although these sub-systems overlap with some facets of established digital-abilities research (Iordache et al., 2017), they offer possibilities for conceptual expansion of current frameworks. Our theorisation may also present new opportunities for operationalising and measuring digital competences. For example, one line of inquiry might involve (a) mapping the suggested sub-systems to observable human–computer interactions (drawn from authentic educational activities), and (b) constructing a self-report instrument for measuring levels of (individual and group-level) activity/engagement in each sub-system. Of course, the interpretive focus would remain on relating digitally mediated actions to those objects driving an activity system.

The tradition and affordances of activity theory

During this study, activity theory emerged as a powerful conceptual tool and a rich intellectual *tradition*. It would be difficult to use activity theory without engaging both with the thought-worlds of Soviet psychologists from the 1920s (Kozulin, 1986) – a time of great socio-political turmoil and hope (Sannino, Daniels, & Gutiérrez, 2009) – and those of its later Western appropriators. As this tradition moved west in the late twentieth century, it was adapted to new intellectual and socio-cultural climates (Smagorinsky, 2009) in ways which are sometimes contested (Avis, 2007, 2009). Most notably, Engeström expanded the tradition in a distinctive way by (a) contextualising activity theory within a broader history of scientific thought; (b) melding it with a programme of interventionist research focused on collective activities; and (c) constructing accessible visual apparatuses (most notably the activity system triangle) for organising key concepts, stimulating critical reflection and supporting applied research (Engeström, 1987).

Despite the popularity of Engeström's triangle, those working within this tradition tend not to regard activity theory as a highly structured approach, but rather as a malleable cognitive toolset *affording* several activities, including abstracting (selecting and ignoring phenomena), explanation (naming concepts that undergird some phenomenon), contextualising (positioning phenomena within a broader spatial-temporal whole), positioning (establishing an investigative approach) and more (Bligh & Flood, 2017; Hammersley, 2012). Our effort to theorise effective uses of digital technologies leveraged each of these affordances, thus demonstrating activity theory's versatility. In the broader context of studying people and digital technologies, however, perhaps the most attractive characteristic of activity theory is its future-oriented concern with human development and transformation. This quality once caught the attention of Urie Bronfenbrenner, an American developmental psychologist, who wrote:

> [R]estriction to the status quo … represents … a delimiting characteristic of most American research on human development. The foreshortened theoretical perspective was first brought to my attention by Professor A. N. Leontiev of the University of Moscow. At that time, a decade ago, I was an exchange scientist at the Institute of Psychology. We had been discussing differences in assumptions underlying research on human development in the Soviet Union and the United States. In summing up his views, Professor Leontiev offered the following judgement: '*It seems to me that American researchers are constantly seeking to explain how a child came to be what he is; we in the USSR are striving to discover how he can become what he is not yet*.' (Bronfenbrenner, 1977, p. 528, emphasis added)

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No potential conflict of interest was reported by the author.

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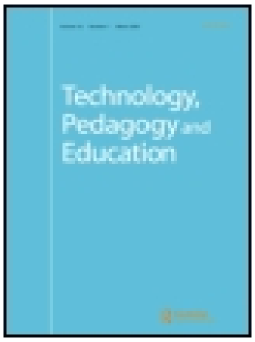

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Theorising effective uses of digital technology with activity theory

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