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Advanced Computational Thing-Kin: Sociomaterial Kinship and the MakerSpace

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ABSTRACT. The incursion of tech companies into wider aspects of our lives means that computational thinking has become increasingly enmeshed with physiological, emotional, creative and social aspects of human life. We suggest that advanced computational thinking should be considered in wider terms than the limited scope of computer sciences and that we should recognise the expansion of the ‘computer world’ and its incursion into lived life: the pervasive encroachment of technology into physical, emotional, spatial, culturally complex and, strictly speaking, non-logical areas of our lives. The proposal is that we use a new term, advanced computational thinking, with the appropriate and relevant acronym of ACT, to suggest a social performative bias to existing ideas of computational thinking in education. The expansion of the computer world is the backdrop for exploring thinking as a ‘kinship’ with things (thing-kin) traversing human and material forms. In this article, ACT engages with the cultural scaffolding of the makerSpace, supporting a thinking space where kinship between ‘things’ and makers promotes diversity of learning style and an idea of epistemological pluralism. By recognising thinking and things as being closely entangled with sociomaterial realms, advanced computational thinking incorporates the wider social consequences of technology: expanding early definitions of computational thinking as tools exclusively focused on mathematical, logical or algorithmic thinking.

Keywords: computational thinking; makerspace; datafication; makerfication; techno-kinship

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Introduction

Ideas and discussion about computational thinking (CT) are often framed narrowly, situated in a purely computer science context (Bell & Lodi, 2019, p. 3), as a technologically driven ‘literacy that needs to be a part of every 21st-century person's way of knowing the world' (Mazzone, 2020, p. 179). In Seymour Papert's book *Mindstorms* (1980), there is an additional claim that computers, and the types of thinking they enable, can bridge developmental gaps. Building on the writings of educational psychiatrist Jean Piaget (1896–1980), Papert views computers as tools for 'addressing what Piaget and many others see as the obstacle which is overcome in the passage from child to adult thinking' (cited in Lodi & Martini, 2021, p. 891). Whilst the importance of encouraging CT in education is widely supported across STEM school programs, there has been a relatively small amount of research published on what advanced computational thinking may look like for the wider humanities in the next few decades (Tedre & Denning, 2016).

The starting point for the most used definition of CT is that from Jeanette Wing (2006), who describes computational thinking as 'the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent' (Wing, 2010). The processing steps in CT have been broken down to further align CT with computer sciences so that 'processes might include recursion, repetition, parameterisation, automation, sorting, [...] which can be abstracted into layers or steps of a series of algorithmic processes [...] [that] should create the desired outputs' (Mazzone, 2020, p. 179). Following the rise of big data, computational thinking has been interpreted by Hu (2011), Katai (2014) and Doleck et al. (2017) as focused on algorithmic thinking: step-by-step sequences of instructions to achieve the desired outcome. On this basis, the focus of computational thinking has shifted towards the construction of coding algorithms, often taught in early education, through exercises that involve students writing simple logic-based instructions that even a computer could follow without error. Much of this thinking can be traced to the early work of educational theorists Sherry Turkle and Seymour Papert, situated in MIT media labs in the 1980s, who designed a computer-driven robot called a 'turtle' to follow algorithmic instructions, moving across a programmed grid space to draw geometric shapes (Lachney & Foster, 2020; Berry, 2015; Resnick, 1997). These exercises were designed to strengthen algorithmic thinking in students, but, inadvertently, they have also reinforced the idea that CT belongs within a mathematics and science discipline, with 'turtles' commandeered for drawing geometric shapes, tracing mathematical formulas embedded in their coded instructions. Stuart Brand, founder of the Whole Earth Catalogue, while managing the MIT Media Lab, recognised the problems with the education system as a bias towards planners: 'In the school system the planners are the ones who are treated clearly [...] Schools don't yet tolerate intellectual negotiations [...] [; however,] science is negotiable and not so rational' (Brand p. 1987, p. 126; cited in Lachney & Foster, 2020, p. 61).

The danger of fixing definitions of CT in the notoriously rapidly changing environment of technology runs the risk of an increasing 'digital discontinuity' between educational systems and technology, as a 'fracture between the curriculum itself and the society it is supposed to represent' (Reimers & Chung, 2016, cited in

Lodi & Martini, 2021, p. 895). One aspect of rapid change is the fluidity of Wing's 'information-processing agent[s],' increasingly distributed and embedded in our everyday lives through the objects around us: the so-called ubiquitous computing where 'a new view of computational thinking is required' moving beyond coding and mathematics and 'integral to our everyday lives and pervasive in many disciplines' (Henderson, 2009, p. 102).

As computer technologies bleed into so many aspects of social life, from the relative seclusion of a computer science discipline, so too does computational thinking come spilling out into the messy, social worlds of the humanities, as Randy Connolly (2020) points out,

> because computing as a discipline is becoming progressively more entangled within the human and social lifeworld, computing as an academic discipline must move away from engineering-inspired curricular models and integrate the analytic lenses supplied by social science theories and methodologies. (p. 55)

According to Mikael Wiberg and Erica Robles (2010), the aesthetics of ubiquitous computing is a striving for the 'disappearance' of the computer: an invisible tool where physical 'atoms and bits' of information become indistinguishable (p. 67). The same researchers also point to a 'material turn' occurring in interaction design: 'From the creation of computational materials and graspable interfaces to the development of rapid prototyping processes, a range of design projects are re-conceiving the relationship between atoms and bits' (Wiberg & Robles, 2010, p. 67), suggesting that computational thinking moves from datafication to the more practical methods of makerfication.

Our aim in expanding computational thinking across disciplines is to broaden the idea of computational thinking to include the material turn in education, the humanities and social sciences: which Christoph Richter (2020) sees as 'an intensified interest in the materiality of learning and education in the educational sciences,' using practice to build connections between 'humans and material objects' (p. 1). The educational dimensions of sociomateriality and 'relationally entangled' learning have been identified as an important addition to computational thinking where our technologies are inseparable from the culture of knowledge production (Fenwick, Edwards, & Sawchuck, 2011; Nohl & Wulf, 2013). In terms of computational thinking, our relationship with the tools of knowledge production is closely enmeshed kinships from which emerge artefacts and instruments of visualising and experiencing the world around us.

Thing-Kin

The proposal in this article is that advanced computational thinking emerges from a kinship we feel with our technologies, where the boundaries between humans and technology are less defined. Donna Haraway has used the idea of kinship to explore the closeness of cross-species connections between owners and their dogs and the ability to connect with more diverse species, including octopus, squids and other realm creatures (2015; 2007). Kinships are framed by Haraway (2007) as affiliations enacted across ‘diverse bodies and meanings [which] co-shape one another’ (p. 4), with a focus on the ‘beyond human’ qualities of our affinities. Connecting with the multiple species of materials and technologies reminds us of our more-than-individual nature of consciousness, where we are ‘vastly outnumbered by my tiny companions’ and where ‘to be one is always to become with many’ (Haraway, 2007, p. 4).

Haraway is, of course, better known for her *Cyborg Manifesto* (1985), which promoted the link between humans and objects of technology through emotional, physical, tactile and intangible connections between humans and things. It was written in 1985, at the height of the enthusiasm for the newly conceived personal computer. Nearly forty years later, we see clear examples of the connective spaces of social-media technologies, those ‘lived social and bodily realities in which people are not afraid of their joint kinship with animals and machines, not afraid of permanently partial identities and contradictory standpoints’ (Haraway, 2016, p. 15). ‘Partial identities’ describe the inseparable kinships between humans and technology. With kinship comes with responsibilities to protect and nurture, traits which in the late nineties manifested in Japanism techno-animism and the Tamagotchi, a palm-sized digital ‘pet’ created by Akihiro Yokoi and Aki Maita: an electronic version of the non-electronic ‘pet rock’ sold by Gary Dahl in 1975. Both objects predate the kinship we might feel with supposedly inanimate objects and things of technology with which we are increasingly entangled. Today we, understandably, would cry desperately if our constant companion, the cellphone, were somehow lost or ceased to exist. Such a companionship cannot fail to engage our emotions, a human-computer kinship that connects us and, at the same time, isolates us as individual data points on the quantitative grid: a process of ‘datification’ explored in the following section of this article. ‘Thing-kin’ is a way of describing the methods of thinking emerging through our entangled connections with material and technological ‘things,’ and advanced computational thing-kin is the term we propose to explore the sociomaterial kinship between technology and humans: a knowledge culture from which thinking emerges (Snake-Beings, 2023). Kinship is a closeness of bond that identifies us in a state of ‘we are one and the same,’ certain things provide that opportunity of connection at an emotional, psychological and physical level. Our pets, our family, our tribe, our computational devices are all things we think through. Thinking through and thinking with are both processes that are often invisible when the thinking is in full flow: we become unaware of the differences between ourselves and the things we are connecting with: such that it is difficult to see ‘who’ or ‘what’ is thinking. Kinship suggests the closeness of bond in which we become inseparable, no matter that the materials we are thinking through are conventionally perceived as non-living entities: they come alive and are part of the process.

We are as unaware of the influences of our kinship with technology on our thinking as we are of the internal processes of the brain. This reminds us that our own thinking processes are never individual but emerge from multiple sources of what Edwin Hutchins calls ‘distributed cognition’ whereby ‘a brain is known to be a huge distributed cognitive system [and] cognitive processes are believed to emerge from complex interactions among very large numbers of neurons’ (Hutchins, 2014, p. 37). Our kinship with things acts as another synapse, indistinguishable from the billions of internal brain cells we use. Martin Heidegger introduced the idea that our tools are inseparable from our thinking selves (1962), interpreted as ‘tool-being’ by Graham Harman (2002) and popularised in Wired.com by Brandon Keim: ‘The thing that does the thinking is bigger than your biological body[....] You’re so tightly coupled to the tools you use that they’re literally part of you as a thinking, behaving thing’ (Dotov Nie & Chemero, 2010, cited in Keim, 2010; see also Hasan & Sheeraz, 2020).

Kinship with our computational devices was the subject of Eric Pickersgill’s (2015) ‘Removed’ series of photographs showing the body postures of people operating their personal devices. To assist in the focus of the subject, the postures were reconstructed with the devices ‘removed,’ ‘a series that shows what we lose when we’re more connected to our phones than to each other.’ However, our kinships with technology have also allowed the dominance of algorithmic thinking to encroach on our perception of computational thinking, whereby the predictive forces of the algorithm work through

> using a wide variety of means (including words, equations, graphs, other agents, pictures and all the tools of modern consumer electronics), we thus stack the dice so that we can more easily minimise costly prediction errors in an endlessly empowering cascade of contexts from shopping and socialising to astronomy, philosophy and logic. (Clark, 2013, p. 195, cited in Hutchins, 2014, p. 38)

The role of algorithmic thinking, to make the world more predictable, has fully utilised commercial electronics and its ability to process large amounts of user data. This is the so-called ‘big data’ of what Shoshana Zuboff (2019) identifies as the basis of surveillance capitalism: ‘A new economic order that claims human experience as free raw material for hidden commercial practices of extraction, prediction and sales’ (p. iv). This places the algorithm at the centre of a major economic force driving perceptions of current popularised notions of computational thinking. Datafication and its role in creating dominant concepts of computational thinking, and the consequences for educational knowledge cultures, are discussed in the section below.

Datafication

By situating CT in the computer sciences, we recognise the most powerful artefact of this thinking is the algorithm and algorithmic thinking. As David Beer observes, ‘notions of the algorithm are evoked as a part of broader rationalities and ways of seeing the world,’ particularly in ways that ‘the algorithm is envisioned to promote certain values and forms of calculative objectivity’ (Beer, 2017, p. 7). In this way, CT has been repeatedly defined as a type of thinking narrowly contained by the ‘objective rationality’ (Connolly, 2020) of the algorithm. As an almost colonising force, to evoke algorithmic thinking is to draw on a powerful agent of contemporary meaning-making: the ‘power-constructing regimes of data and the algorithms that process it’ (Connolly, 2020, p. 56). In the present era of surveillance capitalism, the tools used to obtain and process data are a form of power that influences the shape of knowledge (Iliadis & Russo, 2016). In surveillance capitalism, the power of data has become the prime industry, evident in ‘the digitalisation of everyone’s life, [and] the substitution of information for the capital as the driving force of industrial innovation’ (Lodi & Martini, 2021, p. 895). Datafication through the algorithm also represents, according to Shoshana Zuboff (2019), ‘the origin of a new instrumentarian power that asserts dominance over society and presents startling challenges to market democracy’ (p. v).

In contrast to the predictive power of the algorithm, the material realms are messy worlds that can hardly be defined as logical in a strictly mathematical sense: bringing to mind the inability of quantitative methods to describe complex and culturally situated world views. This quantitative focus of algorithmic thinking has led to a ‘datafication’ of everyday life (Kennedy, Poell, & Van Dijk, 2015; cited in Beer, 2017, p. 4): a colonisation of thinking led by the perceived attributes of the computer and, more specifically, the cultural bias of the algorithm. Thus, the instrumentation of the algorithm should not be considered as part of a ‘neutral’ or ‘objective’ rendering of reality but as part of a wider context of active cultural agents which shape both instruments and methods of observation, as Michel Foucault (2004) has indicated as the work of knowledge apparatuses: ‘It is the actual instruments that form and accumulate knowledge, the observational methods, the recording techniques, the investigative research procedures’ (p. 34).

The active, constructivist nature of instruments, as expressions of dominance, can be applied to the algorithm to indicate its instrumental role in the construction of knowledge. Our entanglements and kinships with technology become the dominant way of seeing the world. According to Karen Barad, the observer and the observed are always entangled with the apparatus of observation and that ‘methodology is always a [constructive] part of the investigation’ (cited in Sicart, 2022, p. 147). This suggests that knowledge is constantly and inextricably entangled with the tools we use to produce it, that the algorithm is not a tool of ‘objective rationality’ thinking, as previously observed, but an active, productive and culturally situated influence on our world-view and the way we perceive thinking. This is an ontological apparatus that, according to Karen Barad, produces entangled artefacts: ‘phenomena do not merely mark the epistemological inseparability of observer and observed, or the results of measurements; rather, phenomena are the ontological inseparability [of] entanglement of intra/acting ‘agencies’ (Barad, 2007, p. 139, cited in Sicart, 2022, p. 147), so that ‘making knowledge is not simply about making facts but about making worlds, [...] making specific worldly configurations [...] giving it specific material form’ (Barad, 2007, p. 91, cited in Sicart, 2022, p. 147). The ‘specific worldly configuration(s)’ of the algorithm is, therefore, part of a network of productive agents that define both thinking in general and the applied skills of computational thinking.

Makification

The potential of the makerSpace in formal learning situations is ‘to transform education’ through its focus on ‘learner-driven’ education, in which the ‘agents of change will be the students themselves’ (Dougherty, 2013, p. 8). The hope is that the makerSpace provides a space where learners can participate in the co-production of a ‘cultural scaffolding’ supporting a culture of makerfication as kinships between ‘things’ and makers: as a tool for encouraging advanced computational thinking and ‘how technologies interact with the innate and socially supported human capacities to learn and develop’ (Martin, 2019, p. 425). In this sense, makerfication, according to Cohen et al. (2013), is ‘the process of taking characteristic elements from the maker movement and infusing them into formal educational activities in a variety of contexts’ (p. 3). The method of makerfication encourages learners towards construction, rather than instruction: a risky area of material engagement that is improvised, unplanned and experimental: a knowledge culture envisioned by Mitchel Resnick (2017) as comprising ‘Risk-takers. Doers. Makers of things [...] the creative thinkers [...] the driving force for economic, technological, political and cultural change throughout history’ (p. 32).

Makification is a learner-centric method, decentralised, peripheral learning using self-directed project work driven by the enthusiasm of the participants: the four ‘Ps of Seymour Papert; ‘projects, peers, passion [and] play’ (Resnick, 2014). Makification leads to ‘self-determined directions’ where ‘maker education projects and programs should go beyond pedagogical teaching [...] which becomes a heutagogical experience’ (Gerstein, 2019, p. 36).

The culture of the makerSpace relies on the development of a specific ‘maker mindset’ (Blikstein, 2013), situated and grounded in the practices of a collaborative learning environment and ‘formally integrated through the entire project’ (Cohen, Jones, Smith & Calandra, 2017, p. 6).

In contrast to the previous section situating computational thinking as a methodical algorithmic process centred on instruction, Sherry Turkle and Seymour Papert also wrote about another way of thinking using the term ‘bricoleur’ to describe a construction process. A bricoleur is a constructor of things, working piece by piece to put together an object that is initially unplanned, not visualised at the start but, instead, emerging from the process of making. The bricoleur, according to Papert, is a master of ‘associations and interactions,’ unexpected affiliations and negotiations, mistakes and ongoing corrections: not the ‘premeditated control’ of the planner, but a collaborative ‘conversation’ between the bricoleur and their materials (Papert & Turkle, 2022, p. 6). The methods of the makerSpace, according to Mitchel Resnick, are guided by 'the four Ps': projects, peers, passion and play (2014; 2017; see also Resnick & Rosenbaum, 2013). Play is a particular tool of learning which immerses the learner in an environment of materials, defined by Miguel Sicart (2022) as 'a relational practice of being in the world, characterised by the creation, recreation and appropriation of relations between agents and things and mediated by materialities' (p. 143). It should also be noted that play and improvisation strive towards 'entropy': the breakdown of the predictive forces of the algorithm through unplanned, improvised activities.

Figure 1
The tinkerer's table

The tinkerer's table is an exercise devised for learners to identify kinships with technological 'things.' As seen in a trial run with members of Negative Emissions and Waste Studies (NEWS), in figure one above, the tinkerer's table is a random assortment of broken technologies, components and ingredients for making. The table provides a space where learners can discover connections between objects and themselves in a process of makerfication. There are no set guidelines for how learners may approach or interact with the table. Each participant follows their own initiative, drawn by certain objects more than others, observing, sketching or placing parts in a pile. Sorting through with the hands of the tinkerer's table encourages unstructured interaction with materials as the bricoleur reacts and responds to each new stage in the project, building upon discovery and visualising prototypes from smaller components of what may eventually become a larger 'plan.' The aim is to develop the knowledge culture of the tinkerer as a self-taught enthusiast, following their passion and curiosity rather than a prescribed plan: typical of a way of working and thinking that values construction over instruction, following projects rather than problems. The table aims to allow the construction of advanced computational thinking, which is less prescriptive, guiding learners into appreciating a messier world of constructing meaning where the ability for visualising innovative thought begins with the concrete experiences of hands-on makerfication. The tinkerer's table relates to the larger concept of the 'mistakerSpace': a place where mistakes can be made without the worry of violating the unspoken rules of productivity; where, according to Mark Thompson (2011),

> Tinkering also allows for failure, an essential component of any process of evolution. Tinkering gives tinkerers a powerful sense of the possibility of things, which surely must be a wellspring of creativity' (cited in Washor & Mojkowski, 2013, p. 209)

The allowance of failure, in the 'mistakerSpace,' opens up the possibilities of 'things': components on the tinkerer's table represent unspecified, unstructured functions, yet to be discovered. The mistakerSpace is also part of a wider 'aesthetic of imperfection' (Tilbury, 2020; Hamilton, 2020), widening the definition of computational thinking to include a messier world of materials and ambiguous agents. Working without a prescribed outcome, a tinkerer allows a type of computational thinking to emerge which can complement the top-down algorithmic planner, instead: 'working from the bottom-up and messing around with different ideas to come up with a result. Planners tend to think top-down and need constraints or a systematic design process to complete a project. Tinkerers and planners can complement each other and learn from one another' (Bers, 2008). It is important to note, as Bers does, that the roles of tinkerers and planners are not oppositional but complementary. We should also consider the optimum of operating between the two mindsets and that the roles of tinkerer and planner need not represent a division of labour between project members. The makerSpace is an ideal learning situation in which students can fluidly switch between the roles of tinkerers and planners without creating 'specialisations' that may not be suitable for the rapidly changing workplace. The dominance of the algorithmic thinker creates the kind of educational dissonance that Dale Dougherty (2013) observes to be the 'increasing scepticism that even those who succeed academically are not the kind of creative, innovative thinkers and doers that we need' (p. 8).

Conclusion

There's a Spanish saying, 'pan con pan comida de tontos,' meaning that just having bread with bread is the dinner of fools. Although the saying seems a bit harsh, there is a logic in the proverb. To mix two very similar things together does make an unrewarding meal, but is this what we are doing when, within a computer science perspective, we place together the two words ‘computational thinking’? Through the dominance of the algorithm, it seems that our concept of thinking has shifted to emulate a narrow definition of machine thinking: the processing of data in a logical and predetermined way. Kinship with objects as thinking devices (thing-kin) offers a way for advanced computational thing-kin to expand its activities into the material realms without being narrowly tied to the dominance of the algorithm. The bricoleur, the tinkerer and methods which complement the ‘planner’ are ways of introducing new ingredients into the definition of computational thinking, which is hopefully ‘tastier’ than the computer science recipe of ‘bread with bread.’

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Authors’ contributions

The authors confirm being the sole contributors to this work and having approved it for publication. They take full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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