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THE SOCIAL CONSTRUCTIVIST MODE OF OPERATION FOR PERSONAL COMPUTING

Frédérik Lesage & Gwénaëlle André

Abstract: *This paper is an exploratory investigation into how social constructivist pedagogical theories shaped the development of personal computing in the mid to late 20th century. There are two main objectives for such an investigation. The first is to highlight the contingent historical nature of the application of these pedagogical theories in the development of human-computer interaction for personal computing. The second is to show how social constructivism as a theory of knowledge that links pedagogy to democratic thinking was implemented as a 'mode of operation' by key early designers of personal computing technologies before being taken up and adapted as part of capitalist modes of production and distribution. This account leads us to conclude that the social constructivist mode of operation for personal computing has become a technology of the self that privileges 'interaction for interaction's sake'. The paper concludes with a discussion of the consequences of this conceptualisation and analysis for how we understand personal computing as public pedagogy and elaborates potential implications for future research.*

Keywords: Interactivity, personal computing, social constructivism, mode of operation, public pedagogy

Introduction

Whether through mobile devices or desktop computers, most of the digital media we access today are accessed through graphical user interfaces (GUI) designed for individual users-consumers. The ubiquity of this particular techno-social configuration that we refer to in this paper as 'personal computing' has become so commonplace that it is often difficult to imagine alternatives. In order to begin to unpack the "taken-for-grantedness" of personal computing we will show how specific pedagogical theories shaped its development in the mid to late 20th century. Our objective is not to examine the development of personal computing as an instructional platform within pedagogical institutions. Instead, we set out to revisit how social constructivist theories of pedagogy were used to prescribe the interaction between humans and computers in the 1960s to early 1980s. Other scholars have touched on how theories of learning informed the early designs of personal computing (see for example Papert et al. (1993); Bardini (2000); Barnes (2000); Maxwell (2006)). We build on this previous research to show how social constructivist pedagogy worked as a 'mode of operation' for these designs. The paper will therefore begin with a theoretical outline of what we mean by social constructivist pedagogy as a mode of operation, followed by a historical survey of key moments and actors in the development of personal computing that render this mode of operation discernable. We then conclude with a discussion of the consequences of this discernment for our understanding of personal computing as a type of public pedagogy and elaborate potential implications for future research.

Social Constructivist pedagogy as a 'mode of operation'

Before diving into a historical examination of how social constructivist theories informed early conceptions of personal computing, it is important to unpack what we mean by social constructivist pedagogy as a 'mode of operation'. We draw the concept from an unlikely source: Erwin Panofsky's research on the impact of Scholastic philosophy on French gothic cathedral designs between the years 1130 and 1270 (1957, p.21). According to Panofsky, Scholasticism was the dominant philosophy taught around Paris at the time. A key concern for scholars in this moment in history was to express and reconcile a fundamental contradiction through their writing: how to use reason to argue for faith in God. One of the ways in which these scholars successfully addressed this concern was not by using reason to directly prove God's existence but to use it to effectively elucidate and clarify articles of faith:

> "[…]The principle of *manifestatio* which determined the direction and scope of their [scholastic thinkers'] thinking also controlled its exposition and subjected this exposition to what may be termed the POSTULATE OF CLARIFICATION FOR CLARIFICATION'S SAKE." (Panofsky, 1957, p. 34-35)

Panofsky found that the techniques they devised to structure their arguments in writing instilled a 'mental habit'—a 'principium importans ordinem ad actum' or 'principle that regulates the act' (Panofsky, 1957, p.21) or mode of operation—that was in turn reflected in the architectural designs of the cathedrals of this same period. "Like scholasticism on parchment, the Gothic cathedral sought to write in stone "a permanent peace treaty between faith and reason"" (Holsinger, 2005, p. 98). Panofsky's iconological analysis has influenced subsequent scholarship including Pierre Bourdieu's conception of habitus as something that transforms 'the collective heritage into an individual and collective subconscious' (Holsinger's (2005, p. 110) translation of Bourdieu). Michel Foucault (1994) also showed interest in Panofsky's work, writing that it helped identify a 'discourse subsumed to practice' which has some parallels to Foucault's conception of 'dispositif'. We believe Panofsky's approach can be usefully adapted for research on human-computer interaction and the graphical user interface because it creates a conceptual and methodological continuum between different media formats similar to the one called for by Johanna Drucker (2014, p. 139).

Taking inspiration from Panofky's approach, we define *mode of operation* as a technique for mediating an intractable ontological problem. Our goal in adapting elements of Panofsky's iconological method to the study of personal computing is to examine how a different theoretical tradition—social constructivist theories of pedagogy—developed into a mode of operation that expressed and resolved a different kind of ontological problem facing Western society and particularly the United States (U.S.) in the 20th Century. This ontological problem involved imagining how freethinking human beings, as a requirement for a working capitalist liberal democracy, could be taught to become better freethinkers. We show how the social constructivist mode of operation resolved this problem by positing that learning takes place through a human's *controlled interaction* with an environment. We then show how the postulate for this mode of operation was adapted by influential figures in the early days of personal computing by studying how this mode of operation was translated into design adages or mottos. In the final section, we argue that this mode of operation has since, thanks to the rapid dissemination of personal computing into almost every aspect of everyday life, become an important part of our 'individual and collective unconscious' in the form of a public pedagogy that can be summarised as interaction for interaction's sake.

The Ascendance of social constructivism as a pedagogical theory

Making education more 'democratic'

Behaviourist theories of the mind that dominated the early 20th century conceived knowledge as something that was imparted through repetition (Pavlov, 1927). Skinner (1968) envisioned the use of learning machines in order to shape behaviours. This conception of knowledge had important implications for understanding the role of media technologies in American society at the time. In particular, there emerged a concern for the role of media technologies in political perceptions and thinking between the two World Wars that, following the Second World War, would lead to concerns for the impact of 'mass media' (Peters, 1996). In the span of only a few generations, the U.S. saw the rapid rise of electronic media like the telephone, film, and radio. To some, the political propaganda of the 1930s onwards extended the manipulative tactics of commercial advertising into a new and dangerous realm (Turner, 2015). Mass media were accused of turning people into automata and of fostering the potential for totalitarianism due to its ability to centralize and distribute the ideas and emotions of an individual or institution. But for a number of critics, mass media mattered not only for their ability to deliver infectious messages, but also for the patterns of behaviour they demanded of their audiences.

Behaviourist conceptions of mind and how they could be applied to an understanding of the media were challenged by other competing theories like those of cognitivism and pragmatism. Part of this challenge involved successfully applying these alternative conceptions to the field of pedagogy (Piaget, 1972). Another of these challenges entailed the perceived link between education and democracy in the 20th century. According to John Dewey (1916), the explicit purpose of education was to reinforce democratic thinking in people in order to make better citizens. The focus was on individuals within collective modes of interaction. The individual was a vehicle through which the group lived. Dewey stressed the link between society, education, and communication by focussing on the interaction between individual thought, learning, and the collective environment surrounding the individual. Through this approach education became a social and political matter.

In response to the burgeoning Cold War in the 1950s and 60s, the American government and other American institutions began funding research that addressed questions of how to foster democratic thinking (Barbrook, 2007; Bowker, 2005); Turner (2015)) including through new pedagogical approaches. Of significant concern was to what extent individual psyches were malleable and/or independent. Social constructivism would emerge in this intellectual and political context as an intellectual tradition that, when applied to pedagogy, accentuated the interactive relation between individual and his/her environment as a means of learning. Although 'social construction' has been used to refer to a broad and heterogeneous set of intellectual traditions (Hacking, 1999) the focus in this paper is on the field of pedagogical theory. This approach posits that the learner constructs his/her own knowledge, according to his/her prior learning and experiences, by interacting with his/her specific environment. The educator, in such a model, is a facilitator who provides a safe and constructive learning context. Social constructivism is not an entirely unique theory of pedagogy and there are arguably as many constructivist theories as there are theorists. While it is impossible to adequately cover the entire breadth and depth of its application to the discipline, we instead focus on the work of a key scholar who was influential in the development of personal computing in the 1960s and 1970s: the American Jerome S. Bruner.

Jerome S. Bruner

During the Second World War, Bruner worked as a social psychologist exploring propaganda, public opinion, and social attitude for U.S. Army Intelligence (Smith, 2002). In 1960, he authored "The Process of Education" (Bruner 1960) which was the distillation of a national consultation of experts commissioned by the U.S. National Academy of Sciences to improve education in primary and secondary schools across the country. The book was quite successful and subsequently became a point of reference for international debates on the future of pedagogy (Bruner 1960/1977: vii).

A significant aspect of Bruner's research contribution to the field of pedagogy was how he combined elements of the theories of Jean Piaget and Lev Vygotsky to develop what some would refer to as 'optimal mismatch theory' (Kuhn, 1979) also referred to as 'scaffolding'. We will use the next few paragraphs to briefly explain some elements of Piaget and Vygotsky's work in order to show how they were used in this theory.

According to Piaget (1952), there are two processes in action when someone learns something: 'assimilation' and 'accommodation'. In assimilation, what is perceived in the outside world is incorporated into the learner's internal world without changing its structure. But in accommodation, the person's internal world has to accommodate itself to the evidence with which it is confronted and thus adapt to it. Piaget used this idea to help establish a model of a child's intellectual development. He argued that intelligence develops in a series of stages that are related to age and are progressive because one stage must be accomplished before the next can occur.

Vygotsky (1978) has been referred to as the 'father' of social constructivism for his emphasis on environment and the notion of 'zone of proximal development' – referring to "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers' (Vygotsky, 1978, p.86). He was partly inspired by Piaget's chronological stages of development but not tied to specific age constraints. Once again, interaction was essential in the process of learning: people learn by interacting with their environment. For Vygotsky, the introduction of the right interaction between learner and other actors in his/her environment was the key point of entry to improving pedagogy.

Bruner's innovation was to adapt the above conception of interaction and development to a systematic application of what has come to be known as 'scaffolding' (1976):

> "This scaffolding consists essentially of the [teacher] "controlling" those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence. The task thus proceeds to a successful conclusion. We assume, however, that the process can potentially achieve much more for the learner than an assisted completion of the task. It may result, eventually, in development of task competence by the learner at a pace that would far outstrip his unassisted efforts." (Bruner, 2006, p. 199)

According to Bruner, knowledge representation in learning took place in three modes: 1) enactive (knowledge is stored in the form of motor responses (action-based knowledge)); 2) iconic (knowledge is stored in the form of visual images (image-based knowledge)), and; 3) symbolic (knowledge is stored as words, mathematical symbols…(language based knowledge)). Any subject could learn through these modes of knowledge at any stage of development in a way that fit his/her cognitive abilities as long as the instructor could adequately identify the learner's level. Scaffolding involved ensuring that the instructor provided just the right level of challenge for the student so that he/she progressed through different levels of representation. For Bruner, media technology represented only one of many potential tools that constituted part of scaffolding for learning:

> "Clearly, the machine is not going to replace the teacher—indeed, it may create a demand for more and better teachers if the more onerous part of teaching can be relegated to automatic devices. Nor does it seem likely that machines will have the effect of dehumanizing learning any more than books dehumanize learning." (Bruner, 1960, p.84)

Bruner limited computer technology's role in teaching and learning as an automatic storage device analogous to a book. Scaffolding could therefore be characterised as an approach that could reconcile designing a pedagogical system for free thinking individuals by prescribing ways to design *interactions*: measure an individual human being's level of learning and intervene in this person's environment in controlled ways in order to progressively foster their development.

Contextualising the early days of personal computing

The above section elaborated some of the basic tenants of social constructivist approaches to pedagogy and how 'scaffolding' represented a design framework for teaching and learning based on the postulate that controlled interactions between a human and his/her environment could lead to learning. Before elaborating on the way in which this theory developed into a mode of operation for personal computing we must set the political, cultural, and social contexts of the development of personal computing, namely how key developments in personal computing, especially in California, coincided with the emergence of the counterculture (Turner, 2013).

Californian counterculture was a cornerstone of the early political and social formations of personal computing. The white middleclass American and European children of the Cold War era found themselves surrounded by educational and employment opportunities that their parents could hardly have imagined. This transformed adolescence into a space of personal experimentation between the freedom of childhood and the employment and family demand of adulthood. This new generation questioned the hierarchical structures of traditional institutions during the 1960s through social, political, economic and pharmacological means.

The seeds of personal computing were planted simultaneously in the east and in the west coast of the U.S. (Markoff, 2006). But California offered an environment that was unique, crossed by counterculture, research lab and entrepreneurship spirit that would later be recognized as the founding culture of personal computing (Barbrook & Cameron, 1996; Flichy, 2007).

Even if most of the funds for computing research at the time were granted by the military-industrial complex, the organization of its research labs eschewed hierarchical structures, preferring interdisciplinary collaboration. They found in places like Stanford the kind of political and cultural space they needed to develop their personal conceptions of computers. (Rheingold, 1991, p. 79) The specific context of California in the 1960s and 1970s allowed this geographic area to be a "trading zone" (Turner, 2015).

It allowed researchers and engineers to have a feedback of the first users of what will become the personal computer.

The belief that new technologies could be part of a different, more creative, approach to social arrangements in ways that challenged established institutional structures extended to teaching and learning. A growing body of scholarship and advocacy aimed at challenging the assumption that schools and other traditional pedagogical institutions were the only place to educate people. Scholars like Ivan Illich (1973) were highly critical of institutions of learning. Learning could be found everywhere and what people learned in schools was, he argued, official political communication. The higher education, the U.S. saw the emergence of many Free Universities that were speaking to a growing movement of people who were frustrated with the mainstream university system. Based on an open curriculum, anyone could offer a course in anything. The Midpeninsula Free University led by two computer scientists, Jim Warren and Larry Tesler and based at Berkeley, was one the largest and most successful (Markoff, 2005).

Ted Nelson's Project Xanadu in the 1960s was another example of this kind of anti-establishment approach to digitally mediated pedagogy. He saw in the emerging discipline of Computer Aided Instruction (CAI) an oppressive and paternalistic institutional order:

> "This [CAI] was not the tradition of literature. This was not the tradition of free speech. It was the tradition of the most oppressive aspects of the bureaucratic educational system, dandied up to look scientific." (Ted Nelson quoted in Fraase 1992, p.169)

The above examples briefly flesh out the broader social, cultural, and political contexts surrounding the emergence of personal computing. California in the 1960s was an ideal place to explore and blur social and cultural boundaries related to traditional institutions including education. This relatively small area was a fertile ground for alternative models of social agencies that privileged anti-establishment conceptions of agency and freedom.

Uncovering the social constructivist mode of operation in adages for early designs in Human-Computer Interaction (HCI)

While artificial intelligence represented a prestigious goal for many computer scientists in the 1950s and 1960s, other researchers set out to develop individual 'mind amplifiers' (Rheingold 1991 p.70) that directly tackled the challenge of designing practical interactions between humans and computers. An important challenge for these computer researchers was therefore to imagine how humans and computers could interact. It is through this challenge that we begin to see how social constructivist pedagogy as a mode of operation could contribute to early conceptions of personal computing. This mode of operation provided the grounds for a 'permanent peace treaty' for HCI by postulating that freethinking humans learn through controlled interaction with their environment. The question that remained was: what role would the computer play in this model?

As stated above, early experiments in personal computing were embedded in a complex and dynamic political and social context. In order to make our case for the significance of the social constructivist mode of operation for personal computing we need to revisit key moments in the history of the development of HCI. While an in-depth analysis of these moments is beyond the scope of this paper, we will focus in the following section on three key actors whose contributions to personal computing are well established: Douglas Engelbart, Seymour Papert and Alan Kay (Bardini, 2005; Barnes, 2000; Markoff, 2005). Specifically, we will examine how these three researchers articulated the social constructivist mode of operation in adages or maxims that defined their approach to HCI. This account will necessarily deal with the early experimental research stages of the development of HCI when utopian technical imaginaries played an important role in shaping technical designs (Flichy, 2007).

Douglas Engelbart: "bootstrapping"
One of Douglas Engelbart's important early influences was Vannevar Bush's article "As we May think" (Bush, 1945). Bush believed that humans would soon be overwhelmed by an overabundance of information. For Engelbart the solution to this problem was to create tools that enhanced human intelligence by organizing and sharing information. While much of the publically funded institutional focus for computing at the time was on artificial intelligence, Engelbart explicitly focused on human intellectual enhancement through computing (Bardini, 2005; Barnes, 2000; Rheingold, 1991).

Although we could not identify a direct connection between Engelbart's early work and the works of Piaget, Vygotsky or Bruner, his ideas shared important influences with theirs including the frequent references to Benjamin Lee Whorf and Alfred Korzybski. (Bardini, 2005; Barnes, 2000). For example, Lee Whorf's theory of linguistic relativity that humans' descriptions of the world and their cultures were shaped by the language they used to communicate—played a role in Engelbart's early reflections on how human thought could be amplified. By extension the way an individual communicated shaped what that individual thought. In 1962, Engelbart devised a 4-step model of development for understanding how a human could interact with computers designed for mind amplification:

> "For Engelbart, there were four stages in the evolution of the human intellect. In the first, "Humans rose above the lower forms of life by evolving biological capability for developing abstractions and concepts." In the second, they "made another great step forward when they learned to represent particular concepts in their minds with specific symbols." In the third, they took "another significant step" when they developed "means for externalizing some of the symbol manipulation activity, particularly in graphical representation" (1962, 21-23)." (Bardini, 2005, p.55)

The fourth stage was where the symbols with which humans represented concepts could be moved, stored, operated by means of special cooperative technological devices:

> "In the limit of what we might now imagine, this could be a computer, with which we could communicate rapidly and easily, coupled to a three-dimensional color display within which it could construct extremely sophisticated images with the computer being able to execute a wide variety of processes upon parts or all of these images in automatic response to human direction." (Engelbart, 1962, p25)" (Bardini, 2005, p.55)

This brief sketch of Engelbart's four stages of human intellectual evolution bare striking similarities to Piaget's cognitive steps of development: sensorimotor (where we are only aware of what is in front of us), preoperational (the thinking is based on intuitions), concrete operational (difficulty to think abstractly or hypothetically) and formal operational (ability to think with abstract concepts). For Engelbart this interaction between human and machine could be characterised as a type of co-evolution that he referred to as *bootstrapping* based on 'the cybernetic notion of positive feedback' (Bardini, 2005, p. 24). By interacting with machines, the human intellect would be improved which would in turn lead the human to improve the machine.

> "You build a system; you evaluate it. You make some improvements. You evaluate those, and you constantly take what you can learn and achieve to make the next improvement. That's evolution in the standard sense of the word. But add an ingredient to this evolutionary characteristic: we are evolving technics to help problem-solvers. Well, we're problem-solvers, so if the actual sample cases we build, use and evaluate are those we ourselves can use to do the analysis, design, instrumentation and operation of our systems, then we learn about how to make people work effectively, the more effectively we can work in harnessing these improvements. It's an added ingredient of our research strategy that we call "bootstrapping"" (Engelbart, 1968, 23) in Bardini, 2005, p.57)

According to Engelbart, humanity's evolution depended on humans becoming actors of their own evolution; to interact with tools and to have a good understanding of their context. In contrast to pure automation of thought as characterised by AI (Rheingold, 1991, p.82), Engelbart believed human evolution occurred in stages through interaction with its environment. As with scaffolding theory, a human learner occupied the central place in the process of development. He/she is empowered to control the interaction with the technology. Engelbart produced our first example of a social constructivist mode of operation for personal computing: knowledge could not be automated; it was instead produced by a freethinking human through his/her interaction with a computer under his/her control. Both approaches conceptualized the human as freethinking problem-solver who works towards solving harder and harder problems by interacting with his/her environment in order to gain more knowledge. The key distinction between bootstrapping and scaffolding was that the learner and the instructor were one and the same person. By reflexively analysing one's interaction with the computer, the human continually tried to improve how it could amplify his/her thinking. Engelbart's user was an "intellectual user" and then a "knowledge user".

Seymour Papert: "low threshold, no ceiling"

One of Seymour Papert's key contributions to the early years of personal computing was his work developing LOGO; a programming language designed to help children learn mathematics. Papert himself credited his five years working with Jean Piaget in Geneva as one of the significant early influences on his work. In his important book Mindstorms (1993), Papert explicitly framed his approach within Piaget's own views of learning while also taking great care to present this approach in a way that challenged traditional programmatic curriculum (p.31):

> "I see Piaget as the theorist of learning without curriculum and the theorist of the kind of learning that happens without deliberate teaching. To turn him into the theorist of a new curriculum is to stand him on his head. [ret] But "teaching without curriculum" does not mean spontaneous, free-form classrooms or simply "leaving the child alone." It means supporting children as they build their own intellectual structures with materials drawn from the surrounding culture. In this model, educational intervention means changing the culture, planting new constructive elements in it and

> eliminating noxious ones." (Ibid, pp.31-32)

Papert's approach was a direct counter to technologically deterministic or behaviourist views of teaching tools. He emphasized a view of learning that was critical of drill and practice yet also emphasized the importance of giving maximum freedom to the child-learner by introducing an open-ended yet controlled environment that responded to the child's development. Key elements of his vision included creating an open culture surrounding the learning process and making the computer a supportive tool within this culture. Computers could enable children to learn about complex situations, not by "learning computers" but rather by learning mathematics with the help of computers.

By the late 1970s, electronic media was taken seriously as a pedagogical tool that could be incorporated into the classroom but Papert remained critical of Computer Aided Instruction because of how it replicated traditional pedagogical models of instruction. Papert would apply his own insights, which he would later label 'constructionism', at Massachusetts Institute of Technology's Media Lab in the early 1980s. There was therefore an inherently political dimension to Papert's work in that he set out to challenge institutional pedagogical models.

> "But if, as I have stressed here, the model of successful learning is the way a child learns to talk, a process that takes place without deliberate and organized teaching, the goal set is very different. I see the classroom as an artificial and inefficient learning environment that society has been forced to invent because its informal environments fail in certain essential learning domains, such as writing or grammar or school math. I believe that the computer presence will enable us to so modify the learning environment outside the classrooms that much if not all the knowledge schools presently try to teach with such pain and expense and such limited success will be learned, as the child learns to talk, painlessly, successfully, and without organized instruction." (Papert, 1993, p.4)

A clear way in which Papert's approach applied scaffolding was through the design motto that the LOGO programming language should be "low threshold, no ceiling" (Brand, 1987 p.123): the initial level of knowledge required to use the programming language should be relatively low for any child but the possibilities afforded by the programming language should be limitless. Just as with Engelbart's vision, the individual human learner was considered the a priori agent of the interaction. Unlike Engelbart's vision, however, the learner and instructor were no longer one and the same person. The learner had no prior knowledge in computing and depended on the intervention of an instructor to guide the interaction. Any child had the inherent capacity for free thought but such capacity was under threat by either uncontrolled interaction or the stifling effects of traditional pedagogical institutions. The instructor took on a pastoral role and provided technology as part of a learning environment that fostered the learner's development. Whereas Engelbart's scaffolding supported a continuous evolutionary interaction between a self-reflexive expert and his/her environment, Papert's scaffolding entailed an instructor building a foundational base from which the learner's potentially limitless capacity to learn an 'essential learning domain' could be extended. These domains provided ballasts for the interaction between instructor and learner. Computers were tools that contributed to the scaffolding with which the child learned the domain independently of traditional preconceptions of how this child should learn this same domain.

Alan Kay: "Doing with images makes symbols"

Alan Kay is the last of the three characters in this account. His contribution to the development of a graphical user interface (GUI) is essential to any understanding of personal computing (Manovich 2013). Kay was known within computing research circles for having designed the 'Flex machine' while at the University of Utah in the late 1960s. In latter reflections on these early designs, Kay recounted how his early experiments led him to an insight that would drive subsequent work on GUIs, namely that a new age of personal computing was on the horizon, in which:

> ...millions of potential users meant that the user interface would have to become a learning environment along the lines of Montessori and Bruner [...] early on, this led to a 90-degree rotation of the purpose of the user interface from "access to functionality" to "environment in which users learn by doing." This new stance could now respond to the echos of Montessori and Dewey, particularly the former, and got me, on rereading Jerome Bruner, to think beyond the children's curriculum to a "curriculum of user interface." (Kay, 1996 *a*, p.552)

Kay called his new media machine the *Dynabook*; a dynamic book (Bardini and Hovarth, 1995). His goal would be to develop a computer as a medium like a book that could be controlled by the reader. It would provide cognitive scaffolding in the same way books and print media had done in recent centuries but it would take advantage of the new affordances of computation and provide the means for a new kind of exploration and expression.

Based on his early successes, and influenced by Engelbart's work on mind amplification and Papert's success with LOGO, Kay would go on to create the Learning Research Group (LRG) at Xerox PARC. Although the LRG's focus would also be on designing computers to support children's learning, a subtle but important difference with Papert's work was the conception of the computer as medium inspired by the likes of Marshall McLuhan (for example, see Kay & Goldberg (1976)) rather than as a tool (or Engelbart's own conceptions of the computer as a 'vehicle' (Kay, 1996a)). Children would not work towards understanding an essential learning domain like language or mathematics with the help of computers but would instead be invited to unlock the learning potential of the computer as medium through the 'curriculum of user interface'. This distinction of the computer as a medium instead of a tool allowed Kay to reinterpret certain key aspects of Papert's work.

By building on Papert's insights, Kay retained the principle that the child was a potentially limitless fount of creative free discovery and learning who should be unshackled from traditional pedagogical modes of control. The LRG would therefore continue to strive to maintain a 'low threshold and no ceiling' design principle. But while Papert's conception of 'no ceiling' to interaction was contained within an 'essential learning domain' like mathematics thereby tethering the computer to an instrumental purpose, Kay's media machine had no such limit or instrumental purpose. The computer was no longer a component of the scaffolding to support the learner's interaction with an environment. Instead, the computer *was* the environment; a McLuhan-inspired media ecology.

How this shift could take place can best be understood by examining Kay's famously Bruner-inspired adage "doing with images makes symbols." It is this adage that helped Kay conceptualise how the Dynabook's GUI would work. The adage created a 'synergy' (Barnes, 2007) of Bruner's different levels of representation and learning. The first two levels, the enactive ('doing') and iconic ('images') were incorporated into the design by enabling children to use a mouse to click on icons in order to run certain functions. The third level, the symbolic ('symbols') was afforded by creating a programming language, *Smalltalk,* that was used to create the entire operating system:

> 'The Smalltalk programming language was developed first, and it was then used to build an operating system and graphical interface. With Smalltalk, the Xerox researchers built an entire programming environment that included editors, debuggers, and compilers. In turn, they used these tools to implement several large-scale applications, such as paint, music, and animation systems.' (Barnes, 2000, p.25)

While Kay and his collaborators mostly placed the emphasis on 'doing', 'images', and 'symbols' as representative of Bruner's three interrelated levels, what we would like to emphasize here is the way in which the sentence structure prescribed *an implicit order to its synthesis of the three levels*. The preposition 'with' in this sentence established an agreeable, open-ended, relationship between 'doing' and 'images' (a statement like 'Doing *according to* Images makes Symbols' would have been entirely antithetical to constructivist conceptions of pedagogical interaction between an individual learner and a scaffolded environment that included the computer). But it is unclear whether 'doing' functioned as a noun or a verb in this adage. The verb *'makes'* in the adage suggested a significant order to the synthesis. This specific formulation classified the symbolic to a different priority than the other two levels. Symbols were the natural outcome of the interaction itself. The meaning of the adage would have been entirely different if stated as 'Doing with images *and with* symbols'? In Kay's approach to personal computing, programming was no longer part of a scaffolding that supported a means to an end – a tool that helped someone learn an essential learning domain like writing or mathematics. Instead, the programming language of the computer became the foundational ontology of the pedagogical interaction and programming computers became an essential part of HCI. This emphasis on the symbolic level as the source of control to interacting with the computer was reflected in Kay's acknowledgement that a certain basic understanding of programming would necessarily represent the minimum threshold to adequately participate in all forms of personal computing.

> "Although a personal computer will be supplied with already created simulations, such as a general text editor, the wide range of backgrounds and ages of its potential users will make any direct anticipation of their needs very difficult. Thus the central problem of personal computing is that nonexperts will almost certainly have to do some programming if their personal computer is to be of more than transitory help." (Kay, 1977, p.231)

By articulating a mode of operation with the personal computer as an environment, "doing with images makes symbols" subtly changed the conditions of peace treaty for interactions between humans and computers. The human learner remained the central figure of the interaction but his/her pedagogical interaction with the computer-as-media was split into two different types: learning with the help of the computer (enactive and iconic) and learning *the* computer (symbolic). In the following concluding section, we will elaborate what this split might mean for an understanding of contemporary digital media.

Discussion: HCI as public pedagogy?

From prototype to commodity

By the early 1980s, Alan Kay (1984) and other computer researchers interested in the pedagogical potential of personal computing like Arthur Luehrmann (1980) saw the advent of commercial application software, particularly Visicalc, as a significant threat to their original visions. For them, an approach to personal computing that emphasized an interaction with application software through a GUI that did not require an understanding of how to program computers (in other words, that did not require an understanding of the symbolic dimension of computer-mediated interaction) was detrimental to a true pedagogical engagement with computers. Their frustration suggested a degree of disillusionment with how personal computing had developed once it shifted away from the research lab and into everyday life. Personal computing was no longer purely experimental technological projects or pastimes. As personal computing took on economic, cultural and socio-political importance, the utopian (Flichy, 2007) ideals espoused in the various articulations of the social constructivist mode of operation articulated in the adages presented in the three cases above were re-appropriated to produce an ideological design that was more profitable and consumer friendly set of products. IBM's ambiguous marketing for its Personal Computer (PC) in the early 1980s presented this technology as a tool both for business and for home use. Companies like Apple, whose founders had close ties to the Californian counterculture and hobbyist movements of the 1970s, devised strategies for building computers for the growing consumer market of the 1980s. These hardware technologies and their related software were marketed as gendered middleclass tools (Reed 2000). But despite these transformations, it is important to stress that the personal computer itself had a modest early success compared to other electronic media at the time (Winston 1998, p.240).

We do not contest the claim that a progressive transformation in personal computing took place from the 1970s to the 1980; one that involved a shift away from a more interpretatively flexible, experimental interaction towards a dominant mode of interaction whereby consumer products were designed to promote a GUI as a standalone mode of interaction. But the dismay expressed by the likes of Kay and Luehrmann also highlighted to what extent HCI had become a contested topic of cultural, political, and social significance. What we would like to do in this final section is to call for a more in-depth reflection on how these pedagogical visions for personal computing, in combination with the implicit putting into practice through an underpinning social constructivist mode of operation, combined into a more generalised technological imaginary and its associated epistemic order for HCI in which the symbolic dimension of personal computing holds a privileged place.

A public pedagogy of personal computing as "make it work"?

As we have argued throughout this paper, a social constructivist mode of operation was embedded, from the beginning, into the development of personal computing. This mode of operation was based on the postulate that humans could learn to become better freethinkers through a controlled interaction with a digitally-mediated environment. The above analysis focused on three adages for designing HCI in the early days of personal computing. Engelbart's 'bootstrapping' mantra involved an adult knowledge worker who learned from designing a computer. Papert's 'low threshold, no ceiling' adage involved a child learning an essential learning domain independently of institutions like schools under the pastoral gaze of an instructor who tended to a computer-amplified learning environment. In Kay's 'doing with images makes symbols' the computer became the learning environment in which symbolic interaction took on a privileged role.

The pattern in all three of these axioms was that the interaction itself was the source of learning. Through this analysis we would argue that HCI based on the social constructivist mode of operation developed into a particular type of 'technology of the self' (Foucault, 1988; see also Bakardjeva & Gaden, 2012) that encouraged individuals to take on the responsibility of managing their own interactions with personal computing as forms of self-care and self-improvement. Stewart Brand's description of Papert's later work at MIT encapsulated how HCI could be deployed as a technology of the self:

> "Some people worry that [Papert's] kind of approach in school, or in life, can lead to loss of rigor and discipline, and indeed there are lots of fraudulent forms of interactivity that can relax into a self-perpetuating sloppiness. But when a teacher and student, or anyone, stick with the drive to make an actual connection, an actual program actually run (in a computer or in life), the rigor grows. Discipline flips from the external and oppressing "get it right" to the internal and intellectual "make it work."" (Brand, 1987, p.127)

The way in which Brand's account blurred the distinction between 'school' and 'life' as well as the distinction between running a program on a computer or running a program in life perfectly captured how the growing ubiquity of personal computing as a model for learning produced a complex entanglement between its technical imaginary and its implementation as part of social life in ways that extended beyond traditional pedagogical institutions. Interaction with the computer became an end in itself; a kind of 'interaction for interaction's sake' in that making the computer work became the means *and* the ends. This type of discipline of the self also continued to elevate symbolic interaction with the computer —making 'an actual program actually run'—to a higher level of epistemological and ontological importance. By implication, this elevation also meant that those who interacted with personal computers through commercial application software that did not require a symbolic level were deprived of personal computing's full pedagogical potential.

We have argued that the early designs for personal computing were informed by a mode of operation that conceived of 'interaction' as a pedagogical process. Our objective has not been to claim the value or detriment of constructivism as a paradigm for teaching and learning. Nor has it been to claim that this mode of operation determined all of the facets of personal computing. Rather, what we set out to do was to analyze and better understand how it was applied as a mode of operation for the early designs of personal computing. With the growing ubiquity of GUI and personal computing more broadly, the social constructivist mode of operation is now no longer bounded to experimental designs or to institutional pedagogy. It has arguably become a kind of 'public pedagogy' in the mould developed by scholars from Antonio Gramsci (1971) and Pierre Bourdieu (1967) to, more recently, Jean Giroux (2011). Giroux argues that digital media together represent one of the 'new sites of public pedagogy' that make-up 'the organizing force of neoliberal ideology' extending beyond the classroom and into nearly every aspect of our mediated lives.

What we need to better understand is how the logic of capitalism and its digitally mediated pedagogical address strategically appropriate and redeploy the social constructivist conception of pedagogy and its historically contingent modes of operation. For example, we need to ask if and how the prioritisation of the symbolic level of interaction over other levels is deployed to produce epistemological orders of worth within everyday social and cultural contexts beyond pedagogical institutions. Contemporary perspectives on public pedagogy interpret the proliferation of digital media as "new sites of public pedagogy which have become the organizing force of neoliberal ideology are not restricted to schools, blackboards and test taking" (Giroux 2004: 750) not due to some kind of technological determination but because of the "growing concentrations of corporate power, and unparalleled meaning producing capacities".

Conclusion

The main objective of this paper has been to examine how social constructivist pedagogical theories have shaped the development of personal computing in the mid to late 20th century. By demonstrating how social constructivism as a theory of knowledge that links pedagogy to democratic thinking was implemented as a 'mode of operation' by Douglas Engelbart, Seymour Papert, and Alan Kay we highlighted the contingency of certain taken-for-granted conceptions of interaction for personal computing. We also argued that these modes of operation for personal computing, once re-appropriated into mainstream commercial culture, produced a kind of public pedagogy based on 'interaction-for-interaction's sake' that privileged the symbolic over other levels of interaction.

By underscoring the significance of social constructivist pedagogical theories as part of the project of personal computing, we hope to initiate a reflection that may help identify and nurture alternative modes of operation that could nevertheless reconcile or reinterpret the kinds of intractable ontological problems for which it was initially developed.

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