Límite | *Revista Interdisciplinaria de Filosofía y Psicología*
Límite | *Interdisciplinary Journal of Philosophy & Psychology*
(2020) 15: 21

COGNITIVE ENHANCEMENT OR COGNITIVE DIMINISHING? DIGITAL TECHNOLOGIES AND CHALLENGES FOR EDUCATION FROM A SITUATED PERSPECTIVE

¿ENRIQUECIMIENTO O EMPOBRECIMIENTO COGNITIVO? TECNOLOGÍAS DIGITALES Y RETOS PAREA LA EDUCACIÓN DESDE UNA PERSPECTIVA SITUADA

Carlos de Aldama*
Universidad Europea de Madrid
Madrid - Spain
Department of Psychology, CES Cardenal Cisneros
Madrid - Spain

Recibido septiembre de 2018/Received September, 2018
Aceptado septiembre de 2019/Accepted September, 2019

ABSTRACT

Cognitive artefacts are thought to extend human cognitive capabilities. We use maps to navigate, pen and paper to organize ideas, and recently, smart applications to remind us of an appointment or check our physical conditions or finances. From a situated cognition perspective, these tools help us to overcome our cognitive limitations. Although digital technologies present remarkable positive effects on human cognition (*e.g.* visual representations, storing information, computing processing, etc.) some authors call for a deep reflection about the possible consequences that its pervasive use may have on human cognitive architecture (Barr, Pennycook, Stolz, & Fugelsang, 2015; Carr, 2011; Heersmink, 2017a). This is especially relevant for educational systems that in many cases have embraced digital technologies as means of innovation and progress with little discussion about the consequences on human cognition. After describing the main assumptions of situated cognition perspectives, I highlight some dimensions of technology integration in educational settings where these approaches can be applied, mainly focusing on how cognitive processes (in particular, attention, memory and thinking) are either enhanced or diminished when digital artefacts are used. In light of these reflections I suggest some ideas for instructional design and call for further theoretical developments and empirical research.
Key Words: Cognitive artefacts, situated perspectives, extended mind, ICT integration, digital technologies.

RESUMEN

Los artefactos cognitivos tienen la función de extender las capacidades cognitivas humanas. Así, usamos mapas para navegar, bolígrafo y papel para organizar ideas y más recientemente, aplicaciones móviles que nos recuerdan cuando tenemos una reunión o cuáles son nuestras condiciones físicas y el estado de nuestras cuentas financieras. Desde una perspectiva situada sobre la cognición, estas herramientas nos ayudan a superar nuestras limitaciones orgánicas. Aunque las tecnologías digitales presentan indudables beneficios desde el punto de vista cognitivo (p. ej. representaciones visuales, almacenamiento de información, procesamiento computacional, etc.), algunos autores hacen un llamamiento a la reflexión para pensar sobre las posibles consecuencias que su uso masivo puede producir sobre la arquitectura cognitiva humana (Barr et al.*, 2015; Carr, 2011; Heersmink, 2017a). Esta cuestión es especialmente relevante para los sistemas educativos, puesto que a menudo han adoptado la tecnología como medio para la innovación y el progreso sin apenas haber reflexionado sobre sus posibles consecuencias. Tras una descripción de los*

* Autor correspondiente / Corresponding author: carlos.dealdama@universidadeuropea.es

principios fundamentales de las perspectivas situadas, en el presente trabajo señalo alguna de las dimensiones en relación con la integración de las tecnologías digitales en contextos educativos donde estos enfoques pueden aplicarse. Fundamentalmente analizo cómo el uso de estas tecnologías afecta, tanto positiva como negativamente, a alguno de los procesos cognitivos básicos, en particular, la atención, la memoria y el pensamiento. A la luz de estas reflexiones sugiero algunas ideas en relación con los diseños instruccionales donde integrar estas tecnologías y hago un llamamiento para futuros desarrollos teórico-conceptuales e investigación empírica.
Palabras Clave: *Artefactos cognitivos, perspectivas situadas, mente extendida, integración TIC, tecnologías digitales.*

INTRODUCTION

Let's start with an anecdote. This happened a few months ago when a colleague of mine (let's call her Shanin) travelled to a foreign country where locals spoke a language unfamiliar to her. She was walking around the streets trying to make sense of the city when she came across an old man. As she did not know much about her surroundings, she politely asked the old man for directions using what is the most international language, that is English (which is not her mother tongue either). He stared at her and knitted his brows. He replied in his own language and waited for an answer. Shanin stared at him and knitted her brows as well. "I can't understand what you are saying, sorry", she said in English. The old man seemed quite disappointed and repeated the same words, this time louder and with energetic movements of his arms and hands. "I am so sorry, I can't, I really can't ", she apologized. There was total confusion and evident miscommunication. Just when Shanin was beginning to lose hope, she had a brilliant idea. "Wait, wait", she said, while she was searching for something in her pocket. A few seconds later, Shanin took out her smartphone and started typing into it. Right after, she smiled and showed the old man what was on the screen while a robotic voice emanating from the smartphone spoke in the old man's language. He smiled back and they then started a *real* conversation.

This anecdote is just one interesting example of how digital technologies enhance psychological, cognitive and communicational processes (Donald, 1991; Heersmink, 2014; Kaput & Shaffer, 2002; Shaffer & Clinton, 2006). We see how Shanin used a digital artefact or technology[1], in particular a common translator app, to transform what were just meaningless sounds into a meaningful and understandable message. She took advantage of the properties associated with this particular technology to develop a communicational act that otherwise would have not been possible without it. Like Shanin's case, we see examples of cognitive enhancement through technologies in our daily life at every moment: when using a calculator to solve a mathematical problem, when the GPS tells us whether to turn right or left to get our destination or when listening a podcast on the phone to learn more about a topic of interest. In any case, technology is supporting our mental activity, allowing us to reach some kind of *representational state* (Rowlands, 2009) that was not previously available before using the artefact (*i.e.* knowing the solution of the mathematical problem, knowing the steps you have to follow to get your destination, or knowing a new fact or concept from listening to a podcast).

Human interactions with digital technologies have become pervasive, but it does not mean we really understand what the implications of its usage are or if we are aware to what extent and in which direction they are changing us. For instance, Carr (2011) warns about the intellectual consequences derived from the constant use of digital technologies. Unlike books and printed texts that were thought to foster reflection and to maintain the readers' attention, the Internet and online information promote distraction and multitasking, which are considered incompatible processes with deep thinking and sustained concentration. Heersmink (2017a) alerts us to the ethical and moral consequences of using these cognitive artefacts, especially for brains, cognition and culture. The author suggests that an overreliance on external information may cause a diminishing of some of our onboard cognitive capabilities (defined by biological structures) and transform our brain and cognitive processes in perhaps undesirable ways.

Thus, the challenges for current societies regarding the way people integrate these technologies in their daily lives are complex and considering the consequences are important. Educational systems have embraced digital technologies as means of innovation and progress with little discussion (if any) about the cognitive consequences derived from their regular usage (Blumberg & Brooks, 2017; Cox

& Marshall, 2007; Healy, 2000). Moreover, the deep impact expected for so long regarding student learning and the developing of cognitive skills are still at stake (Price & Kirkwood, 2014; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011; Wastiau *et al*., 2013). Hence, recent research shows that the most sophisticated uses of Information and Communication Technologies (ICT from now on) in classrooms, such as the creation of multimedia artefacts, reflection and critical thinking, or the production and sharing deep knowledge are far from being a common practice (de Aldama & Pozo, 2016; OECD, 2015). Modern approaches in cognitive theory (*e.g.* situated cognition perspectives) provide new frames to rethink how to integrate digital devices in educational settings not just to improve student learning, but also to reflect on what cognitive skills we want to have in an information society (Heersmink, 2017a).

In the following sections I will try to articulate 1) how the integration of digital technology is affecting human cognitive capabilities from a situated cognition perspective, and 2) some of the cognitive pros and cons derived from the use of these artefacts. Bearing these approaches in mind, I will also formulate some questions we should address and some possible directions for integrating digital technologies in educational settings so as to maximize the positive cognitive synergies between agents and artefacts.

COGNITIVE ARTEFACTS AND DIGITAL TECHNOLOGIES

The history of human cognitive development cannot be understood without considering its relationship with cultural development (Clark 2007; Clark & Chalmers, 1998; Donald, 1991; Tomasello, 2000)[2]. The features of our cognitive system, with its properties and constrictions, define the nature of social interactions, as well as the cultural products elaborated (Donald, 1993). These creations, whether they are materials (*e.g.* tools for haunting) or symbolic (*e.g.* numeric system), influence the structure and functions of the mind. Language is a clear example, a cultural elaboration as well as a key tool for the developing of the mind (Clark, 1996; Nelson, 1998; Vygotsky, 1986).

Some of those artefacts are especially relevant for cognition due to their properties. They are known as *cognitive artefacts* (Heersmink, 2014; Hutchins, 1999; Norman, 1991), *intellectual technologies* (Curley & Pyburn, 1982), *toolforthought* (Shaffer & Clinton, 2006) or *tools of the mind* (Carr, 2011), among others. Hutchins (1999) defines them as "… physical objects made by humans for the purpose of aiding, enhancing or improving cognition" (p. 126), whereas Brey (2005) consider them as "…special class of artefacts that are distinguished by their ability to represent, store, retrieve and manipulate information"(p. 385). Calculators, maps, diagrams, books or mobile applications are, thus, *cognitive artefacts.* All of them are *information-bearing structures* (Rowlands, 2009) in the sense that they allow us to interact with information in some way, whether it is by computing (*e.g.* calculators), storing (*e.g.* books) or organizing and prioritizing elements (*e.g.* diagrams).

However, what makes digital technologies different from other cognitive artefacts such as books or calculators? According to Heersmink (2017a), there are basically two benefits of externalizing information using cognitive artefacts. First, off-loading information into an external artefact allows us to materialize our thoughts, thereby overcoming the limitations of our brains (thoughts diminish when they are held just in our biological equipment). This ability lets us retrieve information at any time that the external artefact is available. Examples of this are books or papers where we write down our ideas. The second benefit is the possibility of performing operations that would normally be difficult to do without assistance. For example, a mathematical operation like 27 multiplied by 15 is highly challenging when we try to solve it mentally. However, it becomes a fairly easy task when we extend our cognitive capabilities using pen and paper, or even better, a calculator.

Digital technologies are powerful tools combining both features. These artefacts have already increased the possibilities of creating and storing information up to unimaginable limits since few decades ago. According to Hilbert and López (2011), in 2007 humankind was able to store 2.9×10^{20} optimally compressed bytes[3] and the increasing rate of globally stored information was 23% per year. Regarding the performance of operations, computers have sped up information processing in an outstanding way. They can analyse and interpret huge amounts of data in milliseconds[4]. The constant growth and development of the high-speed processing is the basis of new disciplines that are popular nowadays, like *machine learning* (*i.e.* the field of computer sciences that uses statistical techniques to allow computer systems "learning" without being explicitly programmed) or *data mining* (*i.e.* the field of examining large amount of data with the aim of developing new information). The combination of these two properties are crucial in making digital technologies an interesting case of cognitive artefacts[5].

Situated and distributed cognition theories allow us to analyse cognitive artefacts (thereby, digital technologies as well) and extend our understanding of these instruments as tools of the mind. In the following section I will articulate some of the key concepts regarding situated and distributed perspectives as a framework to understand current issues and challenges for education concerning the integration of digital technologies.

SITUATED COGNITION AND DIGITAL TECHNOLOGIES

Situated perspectives of the mind stress the relevance of embodied interactions with the environment to better understand what cognition is (Clark 2003; Heersmink, 2017a; Rowlands, 2010). Whatever mental activity we consider (*e.g.* remembering, reasoning, judging, etc.) the cognitive subject or agent is deeply involved within the context she or he is engaged in. As Haugeland (1998) states, "the mind (is) intimately embodied and intimately embedded in its world (pp. 237, cited in Kiverstein & Clark, 2009, p. 1)". Under the umbrella of situated perspectives, different approaches have been grouped together, known as 4E cognition. The label refers to the embodied, embedded, enactive, and extended nature of cognition. As Menary (2010) pointed out there is no homogeneity on these approaches and the reason why they have been grouped together is that they all reject or at least reconfigure traditional cognitivism, which is usually understood as cognition in the sense of manipulation of representations[6].

From situated perspectives, the human cognitive capability of our naked brain (Wheeler, 2011) is limited and to overcome these limitations our cognitive system has evolved to integrate all sorts of instruments and artefacts (especially cognitive artefacts, already described in the previous section). Thus, human cognition happens not just within-the-skin but is distributed and extended along the brain, body and the world. There are two different schools of thought as to how the mind is extended, which are also known as extended mind theories: *parity-based extended mind theory* and *complementary-based extended mind theory* (Clark & Chalmers, 1998; Heersmink & Knight, 2018; Sutton, 2010). The former, which was coined by Clark and Chalmers (1998) as *active externalism,* suggests that artefacts become part of the cognitive system since they are coupled with the human organism. The authors argue that what matters is not where the information is stored (either inside or outside the brain) but the functional role the artefact plays. Clark and Chalmers illustrate their ideas with the Otto's example, a man with Alzheimer's who uses a notebook to replace his damaged memory. In this case, the notebook would count as an extended cognitive system since it plays the same role that the memory would have played if it had not been impaired. This approach however has received some criticism (Adams & Aizawa, 2001; Rupert, 2004). Adams and Aizawa (2001) argue that despite tools and artefacts having an obvious role and significance for cognitive human lives, it is *far from common sense* thinking that when tools are used, cognitive process is a "transcranial" or "extracranial" process (p. 44). The authors suggest what happens inside and outside the brain is different enough to be considered the same process. Returning to the Otto's example, the notebook used as alternative memory actually does not have the same informational and functional properties than his damaged biological memory. For instance, whereas human memories are to a large extent a reconstruction of the past (based on beliefs, feelings and emotions), external memories like videos, tapes or pictures are discrete and static.

To address this issue, another less radical version of the extended mind theory (*complementarity-based extended mind theory*) has been recently developed (Heersmink & Knight, 2018; Sutton, 2010; Sutton , Harris, Keil, & Barnier, 2010). From this approach, artefacts should be considered not as instruments that replicate brain functions, but as tools that provide complementary features. When using a GPS to get to our desired destination, there are several cognitive tasks (e.g, checking what the GPS screen is showing, making the correspondence with the physical environment, understanding the instructions, etc.) that are performed by the integration of both the naked brain and the artefact. If one fails, the process as a whole can fail too[7]. In this sense, the naked brain plus the artefact would constitute a cognitive system in its own right. According to Heersmink (2015), this wider cognitive system can be understood as a multidimensional phenomenon in which the integration between brain and artefact varies along various dimensions. These dimensions are information flow, accessibility, durability, procedural and informational transparency, trust and personalization (see Heersmink, 2015; Heersmink & Knight, 2018). The denser the integration in each dimension, the more robust and stronger the cognitive system brain plus artefact are. For instance, it seems obvious that cognitive systems largely differ when we use a smartphone just retrieve a contact's information compared to when we use the same device to undertake the learning of an online course. Whereas in the former the artefact barely scaffolds one cognitive process (*i.e.* remembering), in the latter its influence over the subject is bigger and deeper (*i.e.* learning, remembering, reasoning, etc.).

The reality seems to point towards a tendency to build cognitive systems that more and more complex. In other words, our current society increasingly presents situations in which the brain itself (without the aids of external artefacts) is not enough to fulfil certain purposes. For instance, many of the current jobs are based on the management and analysis of data (*e.g.* business, market, media, etc.), none of which can be fully understood without considering the system brain plus artefacts. Our reliance on digital technologies is increasing and the consequences for the human cognitive architecture are yet to be explored. Some authors suggest they are changing us, but not always for good (Carr, 2011; Loh & Kanai, 2016; Turkle, 2017). Carr (2011), for instance, claims that the Internet and digital technologies are diminishing our onboard cognitive capabilities, making us stupid, since they foster a shallow mind. Moreover, Turkle (2017) asserts that technology makes us forget what we know about life, referring to the current incapability to maintain face-to-face conversations.

Embracing technology without considering these issues is a risk. This is especially true for educational systems, which are responsible of developing cognitively capable individuals. In the next section I will described some issues regarding the integration of digital technologies in educational settings from a situated perspective and I will draw some lines of action for further research and reflection.

ICT INTEGRATION IN SCHOOLS FROM A SITUATED PERSPECTIVE: CHALLENGES FOR EDUCATION

> *"A revolution is happening in education. The instigator? Technology"* (Microsoft, 2017).
>
> *"The technological revolution shows absolutely no signs of abating. Quite the contrary, every aspect of life is being swept along on a trajectory that at times seems futuristic"* (Samsung, 2017).
>
> *"When we look at education over the years, it's amazing how the evolution of technology, availability of resources, and companies such as Apple and Google have drastically shaped the way we instruct and learn. This has ultimately revolutionized the way we view education in the 21st century"* (VistaCollege, 2015).

Revolution is by far one of the terms most often used in educational discourse. It usually refers to the radical changes in education as a consequence of the introduction and integration of digital technologies or ICTs in instructional environments. But this concept is not new. Since at least four decades ago computers and digital technologies have been described time and time again to be the panacea for the apparently permanent schooling crisis (Disessa, 1987; Johnson & Thomas, 1992; Splittgerber, 1979). Thus, their virtues especially as learning tools have been highlighted numerous times (Clark , Tanner-Smith, & Killingsworth, 2016; Coll & Monereo, 2008; Punie, Zinnbauer, & Cabrera, 2006) and as a consequence, a plethora of learning models mediated by technology has been posed (Koehler & Mishra, 2005; Siemens, 2004; Starkey, 2012). However, the empirical evidence paints a more complex landscape. We see in the literature many examples of both positive and negative outcomes. For instance, Biagi and Loi (2013), based on PISA 2009 data[8], studied the relationship between students' computer use and their achievements in reading, mathematics and sciences in 23 countries. They found that, overall, the students' performance in PISA increased with the intensity of computer use for Gaming activities but decreased with the intensity of computer use related with activities based on school curricula (*i.e.* communication and collaboration, creation of content and knowledge, etc.). Aristovnik (2012) analysed the impact of ICT on educational performance and its efficiency in EU and OECD countries. The author concludes that there is a large difference between countries in terms of educational efficiency for learning purposes, though countries showed a great potential for improving. Besides these examples, there are many other examples showing negative outcomes derived from the use of ICT in education, such as cyberbullying (Bhat, 2008), digital divide (Wei & Hindman, 2011), or addiction (Beranuy, Oberst, Carbonell, & Chamarro, 2009). Based on this evidence, Livingstone (2012) articulates an interesting reflection where she tries to understand why technology has not fulfilled expectations so far. The conclusion suggests that there is still a debate regarding the role ICT should play in educational settings.

Bearing this in mind, is it possible to rethink ICT integration in educational settings from a situated perspective in order to develop a better practice and uses? Furthermore, can situated perspectives bring us new frames to analyse what cognitive skills do we want to foster in our students by using digital technologies in schools? Next, I describe some dimensions of educational contexts in which the use of ICT from a situated perspective can be applied.

Dimensions of ICT integration from a situated perspective

Educational practice presents different dimensions and levels of analysis. They can be macro (*e.g.* national and international policy), meso (*e.g.* school program) or micro (*e.g.* teaching and learning processes in classroom) dimensions. They can also change over and across the same level. For instance, when analysing what is going on in classroom (micro level), we can see how different dimensions change over time, like social organization, the psychological processes involved or participation. I will focus on the micro level in this paper. Considering this, the use of ICT in classroom can be studied from at least three approaches. First, it is essential to take into account the nature of the activities. For instance, one activity can be either a learning activity, assessment activity or a review activity depending on the aim pursued. Traditionally ICT integration has been mainly focussed on learning activities. Thus, a large number of studies have been conducted to see how different uses of ICT might foster knowledge learning (de Aldama & Pozo, 2016; Sutherland, 2004), collaborative learning (Lehtinen, 2003) or attitudes (Park, Khan, & Petrina, 2009). These learning activities are supported by a broad variety of technologies, like virtual environments (Ketelhut, Dede, Clarke, Nelson, & Bowman, 2017; Prestridge & de Aldama, 2016), social media platforms (Dabbagh & Kitsantas, 2012) or videogames (Gee, 2003), among others. Although most of the studies regarding ICT integration have analysed this dimension, there have been remarkable attempts to unravel the implications of situated perspectives in cognition for other type of activities (*e.g.* assessment). For instance, both Wheeler (2011) and Heersmink and Knight (2018) argue that if we take seriously situated perspectives of the mind (and they do), then it does not make sense to only assess what the brain is able to perform without the aid of external artefacts. Furthermore, they challenge the extended belief that only pens and paper should be allowed as external aids during assessments. Instead, they argue that we should consider the wider cognitive system brain-plus-artefact, including digital technologies.

A second approach to analysing ICT integration in educational settings from a situated perspective is to consider the nature and properties of the artefacts used. From this perspective, the external aids (*i.e.* tools/devices) used to perform a given task partially determine and configure it, having different cognitive consequences for the user. For instance, one can send an email using different devices (*e.g.* smartphone, laptop, desktop computer, etc.), but since they have different properties (size, weight, screen, keyboard, etc.) the action is reshaped under the artefact's constraints. Thus, emails sent by either smartphone or desktop computer usually do not pursue the same aims[9].

Similarly, another example of cognitive consequences derived from the use of different external artefacts is described by Mueller and Oppenheimer (2014). The authors found that when taking notes during a lecture, students who took them on laptops performed worse on conceptual questions than those who took notes longhand. The authors conclude that laptop note takers tend to transcribe notes verbatim and in doing so, foster shallow information processing. Similar results were found by Fried (2008), who related low academic performance of laptop users to the negative consequences of multitasking and disruption.

Finally, the third approach to studying ICT integration is considering the cognitive ability that is expected to be enhanced when using digital devices. Any activity mediated by ICT involves some sort of cognitive process as a part of the interaction between agent and artefact. For instance, when a teacher asks students to conduct research on-line and thereafter construct their own opinions after reviewing different sources, the teacher, explicitly or implicitly, is employing technology in a way that fosters critical thinking. A very different example would be a teacher asking students to access the platform where pictures from the last excursion were uploaded. In this case, technology would play the role as some sort of external collective memory.

Next, I will reflect on how different cognitive processes are affected by technology usage (in particular, attention, memory and thinking) and I will draw some implications for technology integration in educational settings.

Is attention enhanced or diminished when using digital technologies in educational settings?

"ICT are excellent tools to keep your students motivated and focused on the activity". This was a common response that I got from teachers during a study I conducted in 2015 regarding ICT integration in educational contexts (de Aldama & Pozo, 2016). Besides my personal experience, literature typically supports this claim (Harandi, 2015; Passey, Rogers, Machell, McHugh, & Allaway, 2004; Underwood, 2009). Thus, we find evidence of positive motivational effects in different contexts, such as learning geography (Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009), when constructing an educational videogame (Vos, Van Der Meijden, & Denessen, 2011) or when conducting research (Passey *et al.*, 2004), among others.

Although motivation and attention are related[10], they are not the same. Surprisingly, there is a large body of literature showing negative impacts of digital technology usage on attention (Chen & Yan, 2016; Fried, 2008; Rheingold, 2012; Tindell & Bohlander, 2012). Far from being neutral, technology shapes our intentions and desires. The concept of *dispersion ecology* was developed to explain how hyper-connectivity fosters continuous attentional shifting. At any time we are connected, a new stimulus is trying to catch our attention. Tristan Harris, ex-Google design ethicist and co-founder of the Center for Humane Technology, gives some insight into how technology hijacks our minds, especially our attention. The author argues that technology works as a slot machine. When we check our emails, news feed, social media notifications and so on, it is like we are playing slot machines that reinforce our behaviour at an intermittent rate. This reality, combined with the fear of missing something important, is the ideal combination to keep our attention continuously moving (2016).

So, what are the implications for ICT integration in educational settings? Harris calls for a better design in technology, one that is more respectful and helpful for people. He suggests, for instance, that when we want to message someone, technology could make us aware of someone's time and that by messaging that person, we are disturbing and interrupting their activity. Thus, before messaging a simple pop-up as "are you sure you want to interrupt this person?" or "Is your message so important at this moment?" could be helpful. However, we cannot wait for a better design in order to make a better use. There are already available applications with a similar purpose that is making people aware of their technology usage. For instance, applications such as AntiSocial or Freedom, track your computer and phone usage and give you stats about different parameters, like the times you turn on your phone or the time spent using applications or surfing websites. They let you block or limit the time you spend on those pages. Using these applications (*i.e.* AntiSocial or Freedom) under a proper pedagogical plan when working with ICT in educational settings helps us to understand and be aware of our technology usage. Another measure suggested to avoid the *dispersion ecology* is training oneself in mindfulness techniques (Heersmink & Knight, 2018; Rheingold, 2012). As Rheingold (2012) points out, mindfulness is a useful strategy to develop a focused mind, making oneself disciplined and serene.

Is memory enhanced or diminished when using digital technologies in educational settings?

Another cognitive process that is usually affected by using digital artefacts is memory. I have already highlighted in previous sections the two main properties of cognitive artefacts, each of them related with one type of memory. I argued that off-loading information onto an external artefact allows us to fix our thoughts, ideas and memories and retrieve them at any time that the external artefact is available. Such a feature would be related to our long-term memory. The second property, I argued, is the possibility of performing operations that would be hard to do in our brains, like mathematical operations or to get a far location. This feature would be related with our short-term memory or working memory. Although I argued that these two features are positive ones since they are at the core of almost any progress in human history, they also change us in a deep way and, as I mentioned before, not always for the good. Heersmink (2017a) suggests some examples. For instance, if we constantly use calculators to resolve mathematical operations (and by this I mean, "artificially" extending our working-memory capabilities) it may result in lesser developed calculations skills. Overreliance on Google and Wikipedia to get information may result in a diminishing of our knowledge base since we do not need to memorize it anymore. The same happens with our memories, already distributed along pictures and videos dispersed everywhere. In this regard, Sparrow, Liu, and Wegner (2011) found that when people expect to get access to future information, they make efforts in remembering where to find the information rather than recalling the information itself. According to Ward (2013), Google and the Internet would play a similar role to the notebook in the Otto's case (Clark & Chalmers, 1998) as a sort of transactive memory system (TMS)[11]. Although there is an obvious influence on human remembering practices, it is not that clear that the Internet and the web meet the requirements to fully reach the status of TMS since the information flow mainly follows in a one-way direction, that is from the Internet to the user (for further discussion, see Heersmink & Sutton, 2018).

So, what are the implications for ICT integration in educational settings? There are many approaches to try to answer this question. First, I assume that formal education should prepare students to deal with real world situations, situations in which quite often digital technologies are involved (Pritchard, 2014). Therefore, the answer is not about removing technology from classrooms. As Heersmink (2017a) points out, one way to look at this problem would be to evaluate what the cognitive gains and losses are (in this case, in terms of memory) from using digital artefacts. He stressed "if the advantages outweigh the disadvantages, then the changes to our onboard cognitive capabilities are acceptable" (Heersmink, 2017a;p. 27). Without having enough empirical evidence to determine cognitive gains and losses, it is safe to say that the integration of ICT in educational contexts should consider these risks and adopt a responsible position. One way to do this is by combining activities with and without the mediation of technology. For instance, when working on a project, such as learning about local nature, technology should never replace the physical experience and the direct contact with animals and plants. On the contrary, it might help to deepen an understanding in some aspects that we were not able to access by other means. As another example, when recalling past experiences in a classroom (*e.g.* what we did in the last lesson or what we saw during an excursion), instead of always relying on technology (*e.g.* using pictures, slides, videos, etc.), it might be helpful to give students opportunities to recall those memories and experiences on their own. Further research should test these hypotheses.

Is thinking enhanced or diminished when using digital technologies in educational settings?

Thought is at the core of human activity. It is a higher-order process involved in problem solving, reasoning or making decisions, among others. Historically, it has been enhanced through a plethora of means, including material and symbolic tools (see in this article the section regarding cognitive artefacts). Thus, when humans were hunting using sticks and stones 50, 000 years ago, these tools were a key part of the planning and hunting strategy and in doing so, they shaped to some extent the thinking process. Other symbolic human developments, such as languages or notational systems, have had a much deeper impact over human thinking (Nelson, 1998; Vygotsky, 1986). Digital technologies can be seen as part of this human development too, but the consequences of its advent and spread for human thought are yet to be explored. We see how they have become common place in our daily lives, taking many (if not most) of our cognitive tasks that we used to do by ourselves (e.g, remembering contact information or getting to a place). It is said that in many ways they are making us smarter and more intelligent (Davis, 2008), or that they give us super intellectual powers (Chalmers, 2011). However, some of the empirical evidence we have so far seems to indicate we should take this issue seriously. Barr *et al*. (2015) conducted three interesting studies in which they examined how using smartphones influences the way we think from an extended mind perspective. The findings showed that those who thought more intuitively and less analytically when giving reasoning problems tended to rely more on their smartphones to get information and solve the problems than those who were more willing to engage in effortful cognitive tasks. The authors concluded, based on the miserliness cognitive notion (Kahneman & Egan, 2011), that smartphones worked as off-loading the cognitive effort involved in the reasoning problems.

Another example of how digital technologies might supplant thinking was provided by van Nimwegen (2008). In this case, the author conducted an experiment where two groups of volunteers had to solve a puzzle using a computer. One of the groups used a sophisticated program that provided assistance when solving the problem, like highlighting the allowed movements or giving some clues when the user experienced some difficulties. The second group, however, used a simpler program that did not provide any help when solving the puzzle. The findings showed that the users of the enhanced program tended to apply a non-thinking strategy based on trial-and-error in order to get the solution as fast as they could. By contrast, the users of the simpler program, because they did not get any help, were more likely to develop a more thoughtful and reflective plan. The author concluded that the more we externalize our cognitive processes into digital devices, the more difficult it is for us to develop solid and stable cognitive and knowledge structures.

IMPLICATIONS FOR THE INTEGRATION OF DIGITAL ARTEFACTS IN EDUCATIONAL SETTINGS

So, bearing this in mind, should we remove computers and digital devices from our classrooms to prevent the downsides? Should we stop thinking about digital artefacts as tools for thought? In my opinion, not really. There are two aspects in which I will focus on next to rethink the implications for ICT integration in educational settings. The first refers to the way we design learning activities mediated by ICT and the second refers to the attitudinal dimension of thought. I will start with the former, and to do so, I will use Bruner's notion of scaffolding (Bruner 1966, 1986) in order to respond to van Nimwegen's conclusions. Generally, scaffolding refers to the pedagogical support during the learning process given to students to help them achieve their goals. It is usually provided by the teacher, another more expert student or, in van Nimwegen's case, a computer or digital device. If an activity aims to develop students' thinking strategies, the scaffold should not supplant students' thinking. Furthermore, the activity should be designed in such a way that it should not be possible to succeed without thinking or in other words, just by trial-and-error methods. Going back to van Nimwegen's example, one way to solve it would have been pushing the user to write down (for instance, in a pop-up open-box) the strategy and reasons behind the movements. In doing so, the user is forced to take the time to think about the resolution of the problem and to make explicit the reasoning involved. Once the path traced is externalized and the user is aware of the ideas, beliefs and reasons that drove her performance, then she is in position to think about possible alternatives (*e.g.* "I chose the square rather than the triangle because I thought it would fit it but after paying a closer attention I realized that it does not make any sense since the figure has only three sides"). Therefore, a problem in the van Nimwegen's study was a design problem. Following this line of argumentation, we can ask how learning activities may be designed so that digital devices can properly scaffold the student's learning and thinking processes. One way to look at this problem is by considering the distinction between pragmatic and epistemic goals, a distinction that is built upon Kirsh and Maglio's notion of pragmatic and epistemic actions (Kirsh & Maglio, 1994). According to these authors, pragmatic actions refer to "actions performed to bring one physically closer to a goal", whereas epistemic actions are "actions performed to uncover information that is hidden or hard to compute mentally" (Kirsh & Maglio, 1994; p. 513). Slightly different, pragmatic goals refer to a person's aims to succeed in a given task, whereas epistemic goals refer to the purposes of someone who aims to understand the nature and the relationship between the elements involved (De Aldama, 2016; de Aldama & Pozo, 2020). Thus, when a student is preparing an exam in Biology guided by pragmatic goals his or her worries are limited to "*what will the exam questions be?*" and the learning strategies will be aligned with this motivation. However, another student guided by epistemic goals will face the same situation (*i.e.* the exam) questioning the functioning of the mitochondria or the meiosis process, trying to understand how the world works around us.

Returning to ICT integration in educational settings, I might argue that digital devices work as extended minds, enhancing our thinking process, when they are used guided by epistemic goals. For instance, de Aldama and Pozo (2020) conducted a study where a popular videogame (*i.e.* Angry Birds) was used as a means to learn Physics, in particular projectile motion. The researchers split the sample in four groups; two were asked to play the game scaffolded by specific instructions (*i.e.* guided by questions that pursued epistemic goals, such as when playing try to find out how the angle or the mass affects the projectile motion). Another group was asked to play without any instruction (*i.e.* playing just for fun) and the fourth group was a control group (*i.e.* not playing the videogame). The results showed that those who played guided by epistemic goals learnt about the relationship between variables involved in the projectile motion and were able to give better explanations than those who played without any instruction and the control group. The authors concluded that the potential of digital technologies as tools for thought is materialized when they are integrated in a well-designed instructional context.

The example described above links to the second aspect I mentioned before, the attitudinal dimension of thought. The evidence found by Barr *et al*. (2015) seems to point out that technology itself reinforces the personal thinking style already adopted before the interaction with the devices. In other words, there are people more and less willing to engage in effortful cognitive activities and, under this attitude, it is likely they use technology in an aligned way. If we want technology to serve as an extension of our minds and thought while we keep the control of the processes, instructional designs need to include the education of thinking attitudes as a priority. In the same regard, Heersmink (2017b) calls for including intellectual virtues as part of the schooling curriculum to improve our information-seeking behaviours while navigating the Internet. By intellectual virtues the author understands cognitive character traits, such as curiosity, autonomy or tenacity, among others, that can be acquired or learnt and "…are truth-conducive and minimalize error" (p. 3). Like other conceptual or procedural knowledge, intellectual virtues can be acquired and learnt through formal instruction (Battaly, 2016). Educators and practitioners should emphasize the value of engaging in reflective and critical thinking, providing opportunities and encouraging students with their own examples. For instance, when a student is undertaking an intellectual effort (*e.g.* traying to construct an argument) it is worthwhile to reward the intention, even if the result might not be expected or aligned with the topic discussed. In doing so, the teacher is delivering a clear message to their students, that having an epistemic thinking attitude is a priority, and that there is nothing more important. Only through this way can the positive aspects of getting involved in an arduous and reflective activity make the time and cognitive investment worthwhile.

CONCLUSIONS

As cognitive artefacts, digital technologies are increasingly taking control over our cognitive processes. We no longer memorize contact information, isolated facts or geographical locations. The consequences for the human cognitive system are not fully understood yet, although there is already some empirical evidence showing negative impact (*e.g.* attentional shifting, thinking diminishing, etc.). Educational systems have generally embraced digital technologies as a means of innovation and progress with little discussion about these issues. A more reflective and careful approach thus needs to be adopted. Situated perspectives on cognition allow us to rethink ICT integration in educational settings, giving us new frameworks to analyse and understand technology usage. Throughout this paper I have pointed out some dimensions of ICT integration where situated perspectives can be applied and I have drawn some ideas regarding how cognitive processes are enhanced (or diminished) when using digital technologies. As the main lesson learnt, I might conclude that in order to use digital technologies as proper extensions of our minds, we first need to be aware of how these artefacts are changing us (in terms of cognitive processes, such as attention, memory or thinking) and second, we need to put more thought in how we are using technology as opposed to simply relying on it for everything. From these reflections, we will be in a better position to elaborate more sophisticated instructional designs in which to embed technology. Further theoretical development and empirical research needs to be conducted to face the challenges we have ahead.

REFERENCES

Adams, F. (2010). Why we still need a mark of the cognitive. *Cognitive Systems Research, 11*(4), 324-331.

Adams , F., & Aizawa, K. (2001). The bounds of cognition. *Philosophical Psychology, 14*(1), 43-64.

Adams , F., & Garrison , R. (2013). The mark of the cognitive. *Minds and Machines, 23*(3), 339-352.

Aristovnik, A. (2012). The impact of ICT on educational performance and its efficiency in selected EU and OECD countries: a non-parametric analysis. *The Turkish Online Journal of Educational Technology, 11*(3), 144-152.

Barr, N., Pennycook, G., Stolz, J. A., & Fugelsang, J. A. (2015). The brain in your pocket: Evidence that Smartphones are used to supplant thinking. *Computers in Human Behavior, 48*, 473-480.

Battaly, H. (2016). Responsibilist virtues in reliabilist classrooms. In H. Battaly (Ed.), *Intellectual virtues and education: Essays in applied virtue epistemology* (pp. 163-187). London: Routledge.

Beranuy, M., Oberst, U., Carbonell, X., & Chamarro, A. (2009). Problematic Internet and mobile phone use and clinical symptoms in college students: The role of emotional intelligence. *Computers in Human Behavior, 25*(5), 1182-1187.

Bhat, C. S. (2008). Cyber bullying: Overview and strategies for school counsellors, guidance officers, and all school personnel. *Journal of Psychologists and Counsellors in Schools, 18*(1), 53-66.

Biagi, F., & Loi, M. (2013). Measuring ICT use and learning outcomes: Evidence from recent econometric studies. *European Journal of Education, 48*(1), 28-42.

Blumberg, F. C., & Brooks, P. J. (2017). *Cognitive Development in Digital Contexts*. London: Academic Press.

Bostrom, N., & Sandberg, A. (2009). Cognitive enhancement: methods, ethics, regulatory challenges. *Science and engineering ethics, 15*(3), 311-341.

Brey, P. (2005). The epistemology and ontology of human-computer interaction. *Minds and Machines, 15*(3-4), 383-398.

Bruner , J. (1966). *Toward a theory of instruction*. Cambridge: Harvard University Press.

Bruner, J. (1986). *Actual minds, possible worlds*. Cambridge: Harvard University Press.

Calcott, R. D., & Berkman, E. T. (2014). Attentional flexibility during approach and avoidance motivational states: The role of context in shifts of attentional breadth. *Journal of Experimental Psychology: General, 143*(3), 1393.

Carr, N. (2011). *The shallows: What the Internet is doing to our brains*. New York: Norton.

Chalmers, D. (2011). Is it your phone part of your mind? *TEDxTalk*. Sydney.

Chen, Q., & Yan, Z. (2016). Does multitasking with mobile phones affect learning? A review. *Computers in Human Behavior, 54*, 34-42.

Clark , A. (1998). *Being there: Putting brain, body, and world together again*. Cambridge: MIT press.

Clark , A. (2003). *Natural-born cyborgs: Minds, technologies, and the future of human intelligence*. Oxford: Oxford University Press.

Clark , A. (2007). Re-inventing ourselves: The plasticity of embodiment, sensing, and mind. *The Journal of Medicine and Philosophy, 32*(3), 263-282.

Clark , A., & Chalmers, D. (1998). The extended mind. *Analysis, 58*(1), 7-19.

Clark , D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational research, 86*(1), 79-122.

Clark, H. (1996). *Using language*. New York: Cambridge University Press. .

Coll, C., & Monereo, C. (2008). Educación y aprendizaje en el siglo XXI: Nuevas herramientas, nuevos escenarios, nuevas finalidades. *Psicología de la educación virtual*, 19-53.

Cox, M. J., & Marshall, G. (2007). Effects of ICT: do we know what we should know? *Education and information technologies, 12*(2), 59-70.

Curley, K. F., & Pyburn, P. J. (1982). " Intellectual" Technologies: The Key to Improving White-Collar Productivity. *Sloan Management Review, 24*(1), 31.

Dabbagh, N., & Kitsantas, A. (2012). Personal Learning Environments, social media, and self-regulated learning: A natural formula for connecting formal and informal learning. *The Internet and higher education, 15*(1), 3-8.

Davis, P. (2008). Is Google Making Us Stupid? Nope! *The Scholarly Kitchen. Retrieved October, 1*, 2014.

De Aldama, C. (2016). *Integration of Information and Communication Technologies (ICT) in educational contexts, beliefs and practices.* [Doctoral Dissertation, Autonomous University of Madrid]. UAM Dissertations Publishing.

De Aldama, C., & Pozo, J. I. (2016). How Are ICT Used in the Classroom? A Study of Teachers' Beliefs and Uses. *Electronic Journal of Research in Educational Psychology, 14*(2), 253-286.

De Aldama, C., & Pozo, J.I. (2020). Do you want to learn physics? Please play angry birds (but with epistemic goals). *Journal of Educational Computing Research, 58*(1), 3-28.

Disessa, A. A. (1987). The third revolution in computers and education. *Journal of Research in Science Teaching, 24*(4), 343-367.

Donald, M. (1991). *Origins of the modern mind: Three stages in the evolution of culture and cognition*. Cambridge: Harvard University Press.

Donald, M. (1993). Human cognitive evolution: What we were, what we are becoming. *Social Research*, 143-170.

Fried, C. B. (2008). In-class laptop use and its effects on student learning. *Computers & Education, 50*(3), 906-914.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment, 1*(1), 20.

Harandi, S. R. (2015). Effects of e-learning on Students' Motivation. *Procedia-Social and Behavioral Sciences, 181*, 423-430.

Harris, C. B., Keil, P. G., Sutton, J., & Barnier, A. J. (2010). Collaborative remembering: when can remembering with others be beneficial? In W. Christensen, E. Schier, & J. Sutton (Eds.), *ASCS09: Proceedings of the 9th conference of the Australasian* *society for cognitive science*. Sydney: Macquarie Centre for Cognitive Science.

Harris , T. (2016). How Technology is hijacking your mind: From a magician and Google design ethicist. *Thrive Global*. Retrieved from https://medium.com/thrive-global/how-technology-hijacks-peoples-minds-from-a-magician-and-google-s-design-ethicist-56d62ef5edf3

Haugeland, J. (1998). *Having thought. Essays in the mataphysics of mind*. Cambridge: Harvard University Press.

Healy, J. M. (2000). Failure to connect: How computers affect our children's minds: for better or worse. *The Phi Delta Kappan, 81*(5), 1-11.

Heersmink, R. (2014). The metaphysics of cognitive artefacts. *Philosophical Explorations, 19*(1), 78-93.

Heersmink, R. (2015). Dimensions of integration in embedded and extended cognitive systems. *Phenomenology and the Cognitive Sciences, 14*(3), 577-598.

Heersmink, R. (2017a). Extended mind and cognitive enhancement: Moral aspects of cognitive artifacts. *Phenomenology and the Cognitive Sciences, 16*(1), 17-32.

Heersmink, R. (2017b). A virtue epistemology of the Internet: Search engines, intellectual virtues and education. *Social Epistemology, 32*(1), 1-12.

Heersmink, R., & Knight, S. (2018). Distributed learning: Educating and assessing extended cognitive systems. *Philosophical Psychology*, 1-22.

Heersmink, R., & Sutton, J. (2018). Cognition and the Web: Extended, transactive, or scaffolded? *Erkenntnis*, 1-26.

Hilbert, M., & López, P. (2011). The world's technological capacity to store, communicate, and compute information. *Science, 332* (6025), 60-65. .

Hutchins, E. (1999). Cognitive artifacts. *The MIT encyclopedia of the cognitive sciences, 126*, 127.

Johnson, S. D., & Thomas, R. (1992). Technology Education and the Cognitive Revolution. *Technology Teacher, 51*(4), 7-12.

Kahneman, D., & Egan, P. (2011). *Thinking, fast and slow* (Vol. 1): Farrar, Straus and Giroux New York.

Kaput, J. J., & Shaffer, D. W. (2002). On the development of human representational competence from an evolutionary point of view: From episodic to virtual culture. In K. Gravemeijer, R. Lehrer, B. van Oers, & L. Verschaffel (Eds.), *Symbolizing, modeling and tool use in mathematics education* (pp. 269-286). Dordrecht, The Netherlands: Springer.

Ketelhut, D. J., Dede, C., Clarke, J., Nelson, B., & Bowman, C. (2017). Studying situated learning in a multiuser virtual environment. In E. Baker, J. Dickieson, W. Wulfeck, & H. F. O'Neil (Eds.), *Assessment of problem solving using simulations* (pp. 47-68). New York: Routledge.

Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science, 18*(4), 513-549.

Kiverstein, J., & Clark, A. (2009). Introduction: Mind embodied, embedded, enacted: One church or many? *Topoi, 28*(1), 1-7.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131-152.

Lehtinen, E. (2003). Computer-supported collaborative learning: An approach to powerful learning environments. In E. de Corte, L. Verschaffel, N. Entwistle, & J. v. Merrienboer (Eds.), *Powerful learning environments: Unravelling basic components and dimensions* (pp. 35-53). Oxford: Elsvier Science.

Livingstone, S. (2012). Critical reflections on the benefits of ICT in education. *Oxford review of education, 38*(1), 9-24.

Loh, K. K., & Kanai, R. (2016). How has the Internet reshaped human cognition? *The Neuroscientist, 22*(5), 506-520.

Martí, E. (2003). *Representar el mundo externamente. La adquisición infantil de los sistemas externos de representación*. Madrid: Antonio Machado Libros.

Menary, R. (2010). Introduction to the special issue on 4E cognition. *Phenomenology and the Cognitive Sciences, 9*(4), 459-463.

Microsoft. (2017). The technology revolution transforming education. Retrieved from https://news.microsoft.com/europe/2017/06/13/the-technology-revolution-transforming-education/

Mueller, P. A., & Oppenheimer, D. M. (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note taking. *Psychological science, 25*(6), 1159-1168.

Nelson, K. (1998). *Language in cognitive development: The emergence of the mediated mind*. Cambridge: Cambridge University Press.

Norman, D. A. (1991). Cognitive artifacts. *Designing interaction: Psychology at the human-computer interface, 1*, 17-38.

OECD. (2015). *Students, Computers and Learning: Making the connection*. Paris: OECD Publishing.

Park, H., Khan, S., & Petrina, S. (2009). ICT in Science Education: A quasi-experimental study of achievement, attitudes toward science, and career aspirations of Korean middle school students. *International journal of science education, 31*(8), 993-1012.

Passey, D., Rogers, C., Machell, J., McHugh, G., & Allaway, D. (2004). The motivational effect of ICT on pupils. *Department of Educational Research*.

Prestridge, S., & de Aldama, C. (2016). A classification framework for exploring technology-enabled practice-FrameTEP. *Journal of Educational Computing Research, 54*(7), 901-921.

Price, L., & Kirkwood, A. (2014). Using technology for teaching and learning in higher education: A critical review of the role of evidence in informing practice. *Higher Education Research & Development, 33*(3), 549-564.

Pritchard, D. (2014). Virtue epistemology, extended cognition, and the epistemology of education. *Universitas: Monthly Review of Philosophy and Culture, 478*(2014), 47-66.

Punie, Y., Zinnbauer, D., & Cabrera, M. (2006). *A review of the impact of ICT on learning*. Luxembourg: European Commission.

Rheingold, H. (2012). *Net smart: How to thrive online*. Cambridge: MIT Press.

Rowlands, M. (2009). Extended cognition and the mark of the cognitive. *Philosophical Psychology, 22*(1), 1-19.

Rowlands, M. (2010). *The new science of the mind: From extended mind to embodied phenomenology*. Cambridge: MIT Press.

Rupert, R. D. (2004). Challenges to the hypothesis of extended cognition. *The Journal of philosophy, 101*(8), 389-428.

Samsung. (2017). Next-level Education Embraces Technology as an Essential Tool. Retrieved from https://news.samsung.com/za/next-level-education-embraces-technology-as-an-essential-tool

Shaffer, D. W., & Clinton, K. A. (2006). Toolforthoughts: Reexamining thinking in the digital age. *Mind, Culture, and Activity, 13*(4), 283-300.

Siemens, G. (2004). Connectivism: A learning theory for the digital age. Retrieved from http://www.elearnspace.org/

Sparrow, B., Liu, J., & Wegner, D. M. (2011). Google effects on memory: Cognitive consequences of having information at our fingertips. *science, 333*(6043), 776-778.

Splittgerber, F. L. (1979). Computer-based instruction: A revolution in the making? *Educational Technology, 19*(1), 20-26.

Starkey, L. (2012). *Teaching and learning in the digital age*. New York: Routledge.

Sutherland, R. (2004). Designs for learning: ICT and knowledge in the classroom. *Computers & Education, 43*(1-2), 5-16.

Sutton, J. (2010). *Exograms, interdisciplinarity and the cognitive life of things. The extended mind.* Cambridge: MIT Press.

Sutton , J., Harris, C. B., Keil, P. G., & Barnier, A. J. (2010). The psychology of memory, extended cognition, and socially distributed remembering. *Phenomenology and the Cognitive Sciences, 9*(4), 521-560.

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational research, 81*(1), 4-28.

Tindell, D. R., & Bohlander, R. W. (2012). The use and abuse of cell phones and text messaging in the classroom: A survey of college students. *College Teaching, 60*(1), 1-9.

Tomasello, M. (2000). Culture and cognitive development. *Current Directions in Psychological Science, 9*(2), 37-40.

Turkle, S. (2017). *Alone together: Why we expect more from technology and less from each other*. New York: Basic Books.

Tüzün, H., Yılmaz-Soylu, M., Karakuş, T., İnal, Y., & Kızılkaya, G. (2009). The effects of computer games on primary school students' achievement and motivation in geography learning. *Computers & Education, 52*(1), 68-77.

Underwood, J. D. (2009). *The impact of digital technology: a review of the evidence of the impact of digital technologies on formal education*. Coventry: Bectra.

van Nimwegen, C. (2008). *The paradox of the guided user: assistance can be counter-effective*. Utrecht: Utrecht University.

VistaCollege. (2015). How Apple and Google Revolutionized Education. Retrieved from https://www.vistacollege.edu/blog/resources/how-apple-and-google-revolutionized-education/

Vos, N., Van Der Meijden, H., & Denessen, E. (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education, 56*(1), 127-137.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge: MIT Press.

Ward, A. F. (2013). Supernormal: How the Internet is changing our memories and our minds. *Psychological Inquiry, 24*(4), 341-348.

Wastiau, P., Blamire, R., Kearney, C., Quittre, V., Van de Gaer, E., & Monseur, C. (2013). The Use of ICT in Education: a survey of schools in E urope. *European Journal of Education, 48*(1), 11-27.

Wei, L., & Hindman, D. B. (2011). Does the digital divide matter more? Comparing the effects of new media and old media use on the education-based knowledge gap. *Mass Communication and Society, 14*(2), 216-235.

Wheeler, M. (2011). Thinking beyond the brain: Educating and building from the standpoint of extended cognition. *Computational Culture*(1).

Yildiz, M. N., & Keengwe, J. (2015). *Handbook of research on media literacy in the digital age*. Pensilvania: IGI Global.

NOTES

1 By *digital technology* I understand *"*any technological device that functions through a binary computational code such as mobile phones, tablets, laptops, computers, etc" (Yildiz & Keengwe, 2015)

2 By *cognition* I hold the broad definition coined by Bostrom and Sandberg (2009), who write "cognition can be defined as the processes an organism uses to organize information. This includes acquiring information (perception), selecting (attention), representing (understanding) and retaining (memory) information, and using it to guide behaviour (reasoning and coordination of motor outputs*)"*. (p. 312, cited by Heersmink (2017a, p. 18). For the interesting discussion about what make a process being cognitive, see Adams (2010), Adams and Garrison (2013) and Rowlands (2009). By *cultural development* I understood the evolution of ideas, costumes and social behaviour, as well as material and symbolic products (*e.g.* language, tools, devices, etc.) emerged in society and are not included in our biological equipment.

3 To give a sense what this number means, consider that 1 million online books would require 10^{12} bytes or so.

4 Using a simple program called *Infinity Lagger* I checked that my personal computer, a good one but nothing exceptional (i7 processor), was able to perform 172413849 operations per second.

5 Digital technologies present other interesting features, such as interactivity, multimedia, dynamism, etc., relevant for cognition as well, but I will not elaborate on this due to limitations of length. For a review, see De Aldama (2016) and Martí (2003).

6 It is not the purpose of this paper trying to unravel the nuances of these approaches but provide a broad conceptualization of situated perspectives as base to reinterpret current challenges and issues of education concerning the use of digital technologies. For a discussion see Clark (1998), Kiverstein and Clark (2009), Menary (2010) or Rowlands (2010).

7 In this very example one can imagine that if the GPS fails, the user might find another way to get the destination (*e.g.* asking someone else, checking a physical map, etc.). In any case, the brain functions would be enhanced or extended by other means (people, external representations, etc.). See the interesting example provide by Harris, Keil, Sutton, and Barnier (2010) that illustrate how people work as scaffolding or *transactive memory* when remembering.

8 "*The OECD's Program for International Student Assessment (PISA) is a collaborative effort among the Member countries of the OECD to measure how well young adults, at age 15 and therefore approaching the end of compulsory schooling, are prepared to meet the challenges of today's knowledge societies"* (retrieved from https://stats.oecd.org/glossary/detail.asp?ID=4817).

9 I cannot imagine applying for an academic position using my smartphone.

10 The more motivation to do something, the more likely one keeps the attention on it. See Calcott and Berkman (2014) to deepen how motivation has different effects on attentional shifts depending on the context.

11 Heersmink and Sutton (2018) define transactive memory system (TMS) as "a cognitive system comprising people in close relationships in dyads or larger groups who engage collaboratively in encoding, storing, and retrieving information (p. 7)".