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The myths of the digital native and the multitasker

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HIGHLIGHTS

- Information-savvy digital natives do not exist.
- Learners cannot multitask; they task switch which negatively impacts learning.
- Educational design assuming these myths hinders rather than helps learning.

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ABSTRACT

Current discussions about educational policy and practice are often embedded in a mind-set that considers students who were born in an age of omnipresent digital media to be fundamentally different from previous generations of students. These students have been labelled *digital natives* and have been ascribed the ability to cognitively process multiple sources of information simultaneously (i.e., they can *multitask*). As a result of this thinking, they are seen by teachers, educational administrators, politicians/policy makers, and the media to require an educational approach radically different from that of previous generations. This article presents scientific evidence showing that there is no such thing as a digital native who is information-skilled simply because (s)he has never known a world that was not digital. It then proceeds to present evidence that one of the alleged abilities of students in this generation, the ability to multitask, does not exist and that designing education that assumes the presence of this ability hinders rather than helps learning. The article concludes by elaborating on possible implications of this for education/educational policy.

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Many teachers, educational administrators, and politicians/policy makers believe in the existence of yeti-like creatures populating present day schools namely *digital natives* and *human multitaskers*. As in the case of many fictional creatures, though there is

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no credible evidence supporting their existence, the myth of the digital native (also called *homo zappiëns*) and the myth of the multitasker are accepted and propagated by educational gurus, closely followed and reported on by the media (both traditional mass-media, Internet sites, and social media) and dutifully parroted by educational policy makers at all levels. But while the myth of the existence of a yeti or other creature is fairly innocuous, the myth of their digital variants is extremely deleterious to our educational system, our children, and teaching/learning in general.

In what follows this article aims – in the context of teaching, learning, and teacher training - to describe and discuss the state of research about the problems related to accepting the widely held premises of the existence of the digital native and of our ability to multitask. This article hopes to play an important role in teaching and teacher education by providing the reader with up-to-date knowledge about these two topics and ultimately eradicating these two very pervasive myths.

1. Digital natives

In discussions of educational innovation, especially those discussions relating to either implementing specific information and communication technologies, the need for more effective pedagogies, or experienced problems with motivation, the term *digital native* (Prensky, 2001, 2006) is inevitably thrown into the arena. Take, for example, Teräs, Myllylä, and Teräs (2011) who state that there is "a gap between higher education and 21st century skills. Although these are the natural skills of digital native learners, they are not being supported in education" (p. 1) and Lambert and Cuper (2008) who state that "preservice teachers need to use multimedia technologies within the context of students' familiar, technology-rich living spaces" (p. 264).

According to Prensky (2001), who coined the term, digital natives constitute an ever-growing group of children, adolescents, and nowadays young adults (i.e., those born after 1984; the official beginning of this generation) who have been immersed in digital technologies all their lives. The mere fact that they have been exposed to these digital technologies has, according to him, endowed this growing group with specific and even unique characteristics that make its members completely different from those growing up in previous generations. The name given to those born before 1984 - the year that the 8-bit video game saw the light of day, though others use 1980 - is *digital immigrant*. Digital natives are assumed to have sophisticated technical digital skills and learning preferences for which traditional education is unprepared and unfit. Prensky coined the term, not based upon extensive research into this generation and/or the careful study of those belonging to it, but rather upon a rationalisation of phenomena and behaviours that he had observed. In his own words, he saw children "surrounded by and using computers, videogames, digital music players, video cams, cell phones, and all the other toys and tools of the digital age" (2001, p.1). Based only upon these observations, he assumed that these children understood what they were doing, were using their devices effectively and efficiently, and based upon this that it would be good to design education that allows them to do this. Prensky was not alone in this. Veen and Vrakking (2006), for example, went a step further coining the catchy name *homo zappiëns* to refer to a new breed of learners that has developed – without either help from or instruction by others – those metacognitive skills necessary for enquiry-based learning, discovery-based learning, networked learning, experiential learning, collaborative learning, active learning, self-organisation and self-regulation, problem solving, and making their own implicit (i.e., tacit) and explicit knowledge explicit to others. Other names are Net generation (Oblinger & Oblinger, 2005; Tapscott, 1997), Generation I or iGeneration (Rosen, 2007), Google® Generation (Rowlands et al., 2008), App Generation (Gardner and Davis, 2013), and so forth. One cannot deny that this does seem to contain a certain appeal, as many youngsters have helped adults in their use of technology (Correa, 2014).

What do we actually know about the knowledge and skills of this generation? A growing number of research studies (e.g., Bullen, Morgan, Belfer, & Qayyum, 2008; Ebner, Schiefner, & Nagler, 2008; Kennedy et al., 2007; Kvavik, 2005) in a number of different countries and cultures (e.g., Austria, Australia, Canada, Switzerland, the United States) question whether the digital native actually exists, let alone if their existence would be a valid reason to adapt education to them. These researchers found that university students, all born after the magical year 1984, do not have deep knowledge of technology, and what knowledge they do have is often limited to the possibilities and use of basic office suite skills, emailing, text messaging, Facebook®, and surfing the Internet. A study carried out by Margaryan, Littlejohn, and Vojt (2011) reported that while university students (i.e., again all born after 1984 and thus belonging to the generation of digital natives) do make frequent use of digital technologies, the range of technologies they use for learning and socialisation is very limited. According to Bullen et al. (2008), "… it appears they [university students] do not recognize the enhanced functionality of the applications they own and use" (p.7.7) and that significant further training in how technology can be used for learning and problem-solving is needed. When used for learning, this was mostly for passive consumption of information (e.g., Wikipedia®) or for downloading lecture notes.

A report commissioned by the British library and the UK Joint Information Systems Committee (JISC; Williams & Rowlands, 2007) also overturns the assumption that the Google generation is web-literate. Rowlands et al. (2008) concluded: "… that much professional commentary, popular writing and PowerPoint presentations overestimates the impact of ICTs on the young, and that the ubiquitous presence of technology in their lives has not resulted in improved information retrieval, information seeking or evaluation skills." (p. 308).

Finally Selwyn (2009) notes that "there are few ways in which the current "digital native" generation can be said to constitute a total disjuncture and discontinuity from previous generations" (p. 375) and that "young people's engagements with digital technologies are varied and often unspectacular – in stark contrast to popular portrayals of the digital native [with] … a misplaced technological and biological determinism that underpins current portrayals of children, young people and digital technology" (p. 364). Or as Ito et al. (2008, p. 4) conclude, we should be "wary of claims that a digital generation is overthrowing culture and knowledge as we know it and that its members are engaging in new media in ways radically different from those of older generations".

However, maybe digital natives were not born in 1984, but in 1994 or 2004? In a study of first-year undergraduate students at Hong Kong University, Kennedy and Fox (2013) found that while students appear to use a large quantity and variety of technologies for communication, learning, staying connected with their friends and engaging with the world around them, they are using them primarily for "personal empowerment and entertainment, but not always digitally literate in using technology to support their learning. This is particularly evident when it comes to student use of technology as consumers of content rather than creators of content specifically for academic purposes" (Kennedy & Fox, p. 76).

Looking at pupils younger than university students, the large-scale *EU Kids Online* report (Livingstone, Haddon, Görzig, & Ólafsson, 2011), placed the term 'digital native' in first place on its list of the ten biggest myths about young people and technology. They state: "Children knowing more than their parents has been

exaggerated … Talk of digital natives obscures children's need for support in developing digital skills" and that "… only one in five [children studied] used a file-sharing site or created a pet/avatar and half that number wrote a blog … While social networking makes it easier to upload content, most children use the internet for ready-made, mass produced content" (p. 42). While the concept of the digital native explicitly and/or implicitly assumes that the current generation of children is highly digitally literate, it is then rather strange to note that many curricula in many countries on many continents (e.g., North America, Europe) see information and technology literacy as 21st century skills that are core curriculum goals at the end of the educational process and that need to be acquired.

Two more recent studies show that the supposed digital divide is a myth in itself. A study carried out by Romero, Guitert, Sangrà, and Bullen (2013) found that it was, in fact, older students (>30 years and thus born before 1984) who exhibited the characteristics attributed to digital natives more than their younger counterparts. In their research, 58% of their students were older than 30 years who "show the characteristics of this [Net Generation profile] claimed by the literature because, on analysing their habits, they can be labelled as ICT users more than digital immigrants" (p. 176). In a study on whether digital natives are more 'technology savvy' than their middle school science teachers, Wang, Hsu, Campbell, Coster, and Longhurst (2014) conclude that this is not the case.

A final word on this topic is offered by Hargittai. She concludes in a blog post on Huffington Post (2014) which, in turn, is based on her earlier research (Hargittai & Hinnant, 2008; Hargittai, 2010) who states that:

> Intergenerational assumptions of relative know-how are incorrect as well. Analyzing data from the Federal Communication Commission's Broadband Survey about the Internet skills of adults of varying ages, I found that among people 50 and under, there was no relationship between age and Internet know-how. Rather, higher income and higher education were related to higher Web-savvy.

2. A non-solution for a non-existing problem?

Based on Prensky's original concept, one could argue that (1) teachers of these digital natives are digital immigrants who, through their lack of digital knowledge and skills, impede the natives' learning, and (2) when and if digital natives themselves become teachers, this problem can and will be solved. Valtonen et al. (2011), studied *Net Generation student teachers* (i.e., student teachers born between 1984 and 1989) in Finland. The results revealed, "that the technological knowledge of student teachers is not what would be expected for representatives of the Net Generation" (p. 13–14). They also studied what is known as the technological pedagogical knowledge (Mishra & Koehler, 2006) of these student teachers, which they defined as the "understanding of the benefits and disadvantages of various technologies related to different pedagogical aims and practices" (p. 7). While they expected that these Net Generation student teachers would be adept at learning through discovery and thinking in a hypertext-like manner (Oblinger & Oblinger, 2005) and that they would be able to transfer those skills to their teaching practices upon entering the teaching profession (Prensky, 2001), the results showed, just like the results of Margaryan et al. (2011) and Bullen et al. (2008), that the range of software used by them was very limited and that, for example, social media was used as a passive source of information reception and not as a tool for actively creating content, interacting with others, and sharing resources. Valtonen et al. (2011) concluded that the expectations and assumptions about this group of student teachers and their "abilities to adopt and adapt ICT in their teaching are highly questionable" (p. 1).

In the earlier reported study on whether digital natives are more 'technology savvy' than their middle school science teachers (Wang et al., 2014, p. 655) the authors state that their results "indicated that teachers use a variety of technologies as often as their students do, even surpass them, whether inside or outside of school".

3. What does this mean for teachers and teacher training?

There are a number of consequences of this non-existence of Digital Natives for both teachers and teacher training. A first element is that it will help teachers avoid the pitfall of assuming that their students possess talents and abilities that they do not actually have. The skills and competences attributed to this generation of students are the same as any other skills and competences, namely that they need to be properly taught and acquired before they can be applied.

A second element is that it may alleviate the widely held notion that if there is a generation of digital natives that is digitally proficient, then there is also a generation of digital immigrants that lacks this proficiency. This is not the case, especially since there is a generation of teachers born and educated after 1984 and who are now experienced teachers (see e.g., Valtonen et al., 2011). Waycott, Bennett, Kennedy, Dalgarno, and Gray (2009) reported that students and teachers use many of the same technologies in their everyday lives and that how students and staff perceive and use technologies "might be better understood in terms of their different roles as students or staff, rather than age-related differences" (p.17). Research by Jones and Shao (2011) has also shown that

> [T]he gap between students and their teachers is not fixed, nor is the gulf so large that it cannot be bridged. In many ways the relationship is determined by the requirements teachers place upon their students to make use of new technologies and the way teachers integrate new technologies in their courses. There is little evidence that students enter university with demands for new technologies that teachers and universities cannot meet.

Finally, McNaught, Lam, and Ho (2009) found that "so-called digital natives (students) were not always more digitally-oriented than the so-called immigrants (teachers)" (p. 10).

As a third element – and related to the first - this realisation explains why 'Digital Literacy' is an important subject in education for present students, future teachers, and even sitting teachers. When discussing digital literacy, both the dangers and the changes should be addressed (Livingstone et al., 2011) Teachers and future-teachers, therefore, should teach and be taught how to deal with (online) information (Wineburg & McGrew, 2016).

Finally, this non-existence of digital natives makes clear that one should be wary about claims to change education because this generation of young people is fundamentally different from previous generations of learners in how they learn/can learn because of their media usage (De Bruyckere, Hulshof, & Kirschner, 2015). The claim of the existence of a generation of digital natives, thus, cannot be used as either a motive or an excuse to implement pedagogies such as enquiry-based learning, discovery-based learning, networked learning, experiential learning, collaborative learning, active learning, self-organisation and self-regulation or problem solving as Veen and Vrakking (2006) argued. This does not mean education should neither evolve nor change, but rather that proposed changes should be evidence informed both in the reasons for the change and the proposed changes themselves, something

that 'digital natives' is not.

The non-existence of digital natives is definitely not the 'reason' why students today are disinterested at and even 'alienated' by school. This lack of interest and alienation may be the case, but the causes stem from quite different things such as the fact that diminished concentration and the loss of the ability to ignore irrelevant stimuli may be attributed to constant task switching between different devices (Loh & Kanai, 2016; Ophir, Nass, & Wagner, 2009; Sampasa-Kanyinga & Lewis, 2015). This, however, is the topic of a different article.

4. Multitasking

Closely related to the myth of the digital native is the pervasive myth that people can multitask. The digital native myth deals primarily with the naturally occurring (i.e., not learned) acquisition by a generation of children of the metacognitive skills necessary for a multitude of learning strategies (Veen & Vrakking, 2006). In comparison, the myth of human multitasking deals with the presumed capabilities of the human cognitive architecture and information processing by them. This second myth is often heard in relation to either children (the homos zappiëns) and women. Many publications and media sources claim that young people are not only able to multitask, but that they are also experts at it and even education should adapt to it (e.g. Clark & Ernst, 2009; Dochy, Berghmans, Koenen, & Segers, 2015; Skiba & Barton, 2006) or at least accept this is a way of life today (e.g. Barnes, Marateo, & Ferris, 2007).

Before proceeding, it is important to define what human multitasking actually is. Originally used in the computer sciences, the term multitasking denoted a computer that was able to carry out two different computing/processing tasks at the same time. It referred specifically to a microprocessor's ability to 'apparently' process several tasks simultaneously. The word *apparently* is important here as computer multitasking in a single-core microprocessor does not actually exist. What is really the case is that the single processor in the computer carries out a form of time-sharing with only one task (i.e., one process) actually being active or carried out at a time, but that there is a very quick shifting or switching between tasks multiple times a second. Multitasking in a computer can only take place in a multi-core computer, where each core is able to carry out a separate task and the multiple cores can, thus, process multiple tasks at the same time.

With respect to humans and human information processing, the term multitasking means that a person is capable of simultaneously and/or concurrently carrying out two or more information processing (or thinking) tasks; that is they a person is capable of carrying out multiple tasks, each requiring cognition and/or information processing (e.g., reading one's email or chatting with someone online while listening to a lecture in class or participating in a workgroup). This is similar to what Ruthruff, Pashler, and Hazeltine (2003) refer to as carrying out dual-tasks with equal task emphasis. The problem here is that the human brain is single core and this architecture of the human cognitive system (i.e., how our brain functions) – as is the case for a single-core computer - only allows for switching between the different tasks; here carrying out a number of different cognitive tasks or partial tasks in quick succession rather than simultaneously carrying them out. Salvucci and Taatgen (2008) refer to this as *threaded cognition* (i.e., alternating blocks of procedural processing and processing peripheral resources) where:

> Cognition maintains a set of active goals that produce threads of goal-related processing across available resources.
>
> All resources— cognitive, perceptual, and motor— execute processing requests serially, one request at a time.
>
> Threads acquire and release resources in a greedy, polite manner.
>
> When multiple threads contend for the procedural resource, the least recently processed thread is allowed to proceed. (pp. 107–111)

Since, as in computer processing, this switching between threads sometimes occurs so quickly that performance *seems* to occur simultaneously. In other words it is the 'apparent' performance of someone carrying out more than one information-processing task at the same time and not them actually doing this.

Human beings, due to their cognitive architecture (Sweller, Ayres, & Kalyuga, 2011) are capable of doing more than one thing at any one time only if all of the activities that they are carrying out are fully automated (i.e., require no cognitive processing) save the one requiring processing (e.g., walking and talking at the same time, though even this has been found to lead to falls and other accidents; Herman, Mirelman, Giladi, Schweiger, & Hausdorff, 2010). We know this since at least the late 1980s/early 1990s when scientists such as Gladstones, Regan, and Lee (1989) and Pashler (1994) conducted experiments showing that trying to carry out a number of tasks at once is not more efficient than carrying out a single task or a series of single tasks consecutively.

Gladstones et al. (1989), for example, found "no evidence that people can process dual-task information any faster than they can process single-task information when performing genuinely independent tasks at their maximum sustainable rates" (p. 12). They further conclude that where "two or more genuinely independent and low redundancy tasks require continuous attention and response, designers should not count on any capacity for parallel processing. Nor should they think that sharing such tasks between different input and/or output modalities will necessarily improve performance" (p. 16). Pashler (1994), in a review of studies dealing with simultaneously carrying out relatively simple tasks, found that "people have surprisingly severe limitations on their ability to carry out simultaneously certain cognitive processes that seem fairly trivial from a computational standpoint" (p. 241). This is due to what is called the *psychological refractory period*; the period of time during which the response to a second stimulus is significantly slowed because a first stimulus is still being processed. He concluded that the results of the research that he reviewed "indicate a stubborn bottleneck encompassing the process of choosing actions and probably memory retrieval generally, together with certain other cognitive operations" (p. 220).

In general, research has shown that when thinking or any other form of conscious information processing is involved in carrying out a task, people are *not* capable of multitasking and can, at best, switch quickly and apparently seamlessly from one activity to another. The key word here is again 'apparently'.

Thus, what we are actually talking about is *task-switching*. When task-switching, a person first shifts the goal and thus makes a 'decision' to divert attention away from the task being carried out to another task, and then activating a rule so that the instructions and procedures for carrying out that task are switched off, and those for executing the other task are switched on. This task-switching involves dividing one's attention between tasks, and because each of the tasks competes with all of the others for a limited number of cognitive resources available, performing one of the tasks interferes with that of the other/others. This interference has been shown at the cognitive, information processing level in many empirical studies, for example by Brumby and colleagues in their studies of the intersection of human-computer interaction and cognitive science (e.g., Brumby & Salvucci, 2006; Brumby, Salvucci, & Howe, 2009; Janssen, Brumby, Dowell, & Chater, 2010). According to

Brumby and Salvucci:

> Constraints on the human cognitive architecture often limit perfect task parallelism during such multitasking situations. As a consequence, task operators must be interleaved … there is a central cognitive bottleneck that operates to limit performance and that control between two or more primary tasks must be passed through a queuing mechanism (p. 2451).

This interference has also been shown to exist at the neuronal level in the brain (Dux, Ivanoff, Asplund, & Marois, 2006; Tombu et al., 2011). Tombu et al., in their functional magnetic resonance imaging (fMRI) study of simultaneous perceptual encoding and response selection, report neurobiological evidence supporting "the existence of a unified attentional bottleneck responsible for capacity limitations in domains as diverse as the encoding of perceptual information and response selection" (p. 13426). Dux et al. (2006) concluded:

> When humans attempt to perform two tasks at once, execution of the first task leads to postponement of the second one. This task delay is thought to result from a bottleneck occurring at a central, amodal stage of information processing that precludes two response selection or decision-making operations from being concurrently executed … a neural network of frontal lobe areas acts as a central bottleneck of information processing that severely limits our ability to multitask. (p. 1109).

Thus, what people really mean when they say that a person is able to or are even good at multitasking is that this person, be it children, adolescents or young adults have, through practice, developed the ability to quickly switch between carrying out different tasks or using different media. However, though they apparently do this, it does not mean that doing it is: (1) beneficial to/positive for them, (2) beneficial to/positive for learning (i.e., that learning occurs more effectively, more efficiently, or both), and/or (3) not harmful to accurately carrying out any or all of those tasks. It has been broadly shown that rapid switching behaviour, when compared to carrying out tasks serially, leads to poorer learning results in students and poorer performance of the tasks being carried out (Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001). This is primarily due to the fact that switching requires people to juggle their limited cognitive resources to accomplish the different tasks successfully. This juggling leads to greater inefficiency in performing each individual task, namely that more mistakes are made and it takes significantly longer as compared to sequential work. As noted by the American Psychological Association (2006), "[D]oing more than one task at a time, especially more than one complex task, takes a toll on productivity".

Further, this is not only the case for novices or learners, but it has also been shown to be the case when experts (i.e., doctors with high levels of expertise) are required to switch between tasks, for example in hospital emergency rooms. The increased burden of memory-load resulting from the need to combine multiple, simultaneous tasks and deal with numerous interruptions, has been found to result in an increase in the number of medical errors (Coiera, Jayasuriya, Hardy, Bannan, & Thorpe, 2002; Laxmisan et al., 2007).

In the learning setting, Fox, Rosen, and Crawford (2009) demonstrated that in order to comprehend a text to 'mastery', students who text messaged while reading needed to invest significantly more time in reading the text than those who were not text messaging; approximately 1.66 times as long. In other words, equal comprehension can be achieved if significantly more time is invested. Though the time difference is negligible for short texts such as those used in the experiment (5.53 min versus 3.33 min), think of what the time difference would become if the assignment was a normal university reading assignment e.g., a chapter in a text book or an article in a scientific journal?

5. Deleterious effects of multitasking

Kirschner & Karpinski (2010), however, found that high-intensity users of social media (in their study Author et al. studied Facebook® use) studied just as long as low-intensity users. In other words, high-intensity Facebook-users did not make the extra time investment needed to master the content. What was then found was that the grade point averages (GPAs) of the high-intensity users were also significantly lower. This was especially the case for U.S. students who did this 'disruptively'; that is stopped their studying each time a new message popped up to deal with that message. The European respondents in their study noticed the messages but did not react to them immediately. Research by Junco and Cotten (2012) and Junco (2012) also found that students who, while studying, surf the web and update/follow Facebook for both related and unrelated information to the class, have depressed GPAs. Even more important, multitasking behaviour of one university student during a lecture may negatively affect the learning of other students in direct view of that student (Sana, Weston, & Cepeda, 2013). They found that multitasking on a laptop during a lecture not only led to lower scores for these students than those who did not multitask during the lesson, but also that students who could directly view what their multitasking peers were doing also performed more poorly than those who could not view this. In other words, multitasking on a laptop during a lesson poses a significant distraction to those doing the multitasking as well as peers students and this can be detrimental to the learning of both.

Ophir et al. (2009) in a study in which university students who identified themselves as proficient multitaskers were asked to concentrate on rectangular stimuli of one colour on a computer monitor and ignore irrelevant stimuli entering their screen of a different colour observed that

> … heavy media multitaskers are more susceptible to interference from irrelevant environmental stimuli and from irrelevant representations in memory. This led to the surprising result that heavy media multitaskers performed worse on a test of task-switching ability, likely because of reduced ability to filter out interference from the irrelevant task set (p. 15583).

Ophir et al. (2009) concluded that faced with of distractors, heavy multitaskers were slower in detecting changes in visual patterns, were more susceptible to false recollections of the distractors during a memory task, and were slower in task-switching. Heavy multitaskers were less able than light/occasional multitaskers to volitionally restrain their attention only to task relevant information.

Sanbonmatsu, Strayer, Medeiros-Ward, and Watson (2013) found a similar phenomenon in the students they studied. They write, "people often engage in multi-tasking because they are less able to block out distractions and focus on a singular task" (p. 7). This might be why US students exhibited the earlier discussed 'disruptive' social media behaviour (Kirschner & Karpinski, 2010) whereby they were inclined to immediately respond to incoming messages from their social media. Research by Rosen, Carrier, and Sheever (2013) also backs this insight. They observed 263 middle school, high school and university students studying for 15 min in their homes. They found that while students studied less than 6 min before switching to a technological distractor, those who

preferred to task-switch had more distractors and were more off-task and had lower GPAs.

Finally, Loh and Kanai (2014) used fMRI to examine the grey matter in the brains of self-proclaimed multitaskers; respondents (average age ≈ 24.5 years) with high Media Multitasking Index (MMI; Ophir et al., 2009) scores. What they found was that those with higher MMI scores – that is who spent more time on 12 primary forms of media such as television, video or computer games, instant messaging, text messaging, and web surfing - had smaller grey matter density in the anterior cingulate cortex, the region of the brain responsible for controlling executive function (e.g., working memory, reasoning, planning, execution). As this was a descriptive, cross-sectional study looking at possible links between media multitasking and brain structure, there is no way to know whether people with smaller anterior cingulate cortex are more likely to multitask or if the grey matter of multitaskers is shrinking.

In other words, there is evidence that constantly switching between tasks may be lead to a person losing the ability to focus on a single task and/or ignore distracters and that intensive multitasking may impair performance and learning and possibly even concentration and thinking. Further, there are preliminary signs that such behaviour may even affect brain development.

6. What does this mean for teachers and teacher training?

Apart from the elements discussed as a consequence of the non-existence of digital natives, the negative effects of multitasking add several elements to consider.

First, there is a need to teach pupils, students, and teachers about the importance of focus and the negative effects of multitasking on learning as discussed. This is not only important for the study methods pupils, students, and teacher trainees themselves use, but also important for what teachers do in the classroom. For example, the fact that such behavior is paired with shallow information processing (Carr, 2011). Also, the cognitive processing of non-linear information has been found to negatively impact cognitive load leading to poorer learning (Zumbach & Mohraz, 2008). As such, one could argument that learning how to achieve focus could be included in the curriculum.

Second, knowing the effects of multitask behaviour gives teachers and student-teachers a handhold on how to eliminate the negative effects of multitasking in the classroom. As a recent study by Payne Carter, Greenberg, and Walker (2017) shows, even the presence of tablets with limited possibilities can have negative consequences on learning in a more traditional approach. It is even the case that multitasking on a laptop not only poses a significant distraction to users but it is also a distraction to fellow students not using a laptop in class and can, thus, be detrimental to comprehension of lecture content for both (Sana et al., 2013). This means that it is the task of the teacher and future teachers to know where and when technology should be present (e.g., to permit students to look things up, to collaborate online, …) and when this is a bad idea.

The latter makes clear that the negative effects of multitasking does not mean that technology should either be abolished from education. It is all about using the right tool at the correct time for the correct goal within a given context, with a crucial role for the teacher to decide what is used and when (Clark & Mayer, 2016). This does mean that in teacher training there should be a strong emphasis on the efficient and effective usage of technology both by the teachers and by their pupils and students, both knowing when to use it and when it is a bad idea to use it.

7. Conclusion

As has been shown, there is quite a large body of evidence showing that the digital native does not exist nor that people, regardless of their age, can multitask. This corpus of research also shows that though learners in this generation have only experienced a digital connected world, they are not capable of dealing with modern technologies in the way which is often ascribed to them (i.e., that they can navigate that world for effective and efficient learning and knowledge construction). Finally, the research shows that these learners may actually suffer if teaching and education plays to these alleged abilities to relate to, work with, and control their own learning with multimedia and in digitally pervasive environments.

For both teachers and teacher trainers this has several consequences. For teacher trainers it's at first important to not further spread these myths. But there is more. Even if the digital native does not actually exist and even if present-day learners cannot actually multitask, the question remains as to how education can or should be redesigned such that effective, efficient and enjoyable use is made of the tools and technologies available – with their concomitant pedagogies - in a digital and connected world. Twenty-first century education not only allows, but actually requires, seamless and ambient integration of technologies in physical environments in the sense of Weiser's (1991) notion of ubiquitous computing. Essential in this are links between (1) learners with their 'baggage' including their cognitive knowledge and skills, their attitudes and dispositions, and their meta-cognitive knowledge and skills (2) teachers with their knowledge and skills in the domain that they teach, the pedagogy for that domain (i.e., pedagogical content knowledge) and the pedagogy using digital tools and media (i.e., technological pedagogical content knowledge) and (3) the design of digital tools and their affordances, physical spaces, physical and virtual environments and the services and digital information within these environments (Kirschner, 2015).

Paraphrasing Kirschner, (2015) one could argue that both teachers and teacher trainers should rather look at *learners with their 'baggage' including their cognitive knowledge and skills, their attitudes and dispositions, and their meta-cognitive knowledge and skills* rather than assume the pupils are different because of their multimedia use. In designing the learning environment, teachers and teacher trainers should be wary of arguments for pedagogical change based on the non-existing digital natives. Even more, both teachers and teacher trainers should take into account in their *design of digital tools and their affordances, physical spaces, physical and virtual environments and the services and digital information within these environments* when digital technology can have a detrimental effect on learning, when digital technology has a positive effect on learning and why focus is an asset. Of course, this all comes above and beyond *their subject-specific knowledge and skills, their mastery of the pedagogy for that subject (i.e., pedagogical content knowledge) and the pedagogy using digital tools and media there (i.e., technological pedagogical content knowledge)*, To make the last concrete: in times when schools are promoting using tablets and laptops and BYOD (bring your own devices), it is as imperative that teachers know when to use which devices and when not to, making schools both hot and cold spots. By doing this, one could say this is also teaching by example.

This all requires further solid empirical research in many fields, but again not research on imaginary generational differences or non-existent cognitive capacities.

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