Learning in the Age of Distraction: Evidence, Karl Sebire

1.1. ICT in the Classroom

An extensive review of the literature has found a range of ICT interventions or intrusions have been investigated in classroom settings, including mobile phones (Duncan, Hoekstra, & Wilcox, 2012; Fauquet-Alekhine, 2015; Kuznekoff & Titsworth, 2013); tablets (McCoy, 2013; Mueller & Oppenheimer, 2014); laptops (Fried, 2008; Gulek & Demirtas, 2005; Sana, Weston, & Cepeda, 2013; Stephens, 2005); and social media (Gray, Annabell, & Kennedy, 2010; Pempek, Yermolayeva, & Calvert, 2009). As technology advances at a rapid rate, the finding of many of these studies highlight the ongoing challenge to remain relevant to a resource that evolves faster than pedagogical discourse. Eshet-Alkalai (2004, p. 104) deemed digital literacy a "survival skill in the digital era" over a decade ago, before the advent of social networking, smartphones and one-to-one laptop programs. Although the definition of digital literacy is somewhat fluid amongst theorists (Buabeng-Andoh, 2012; Gilster, 1997; Leu, 2000; Ottestad, 2013), having the cognitive capacity to focus and manage attention between media is becoming a valuable currency in learning (Rheingold & Weeks, 2012). Studies have revealed that students that are able to focus, attend to and process information are better equipped to apply their knowledge more flexibly to new contexts (Foerde, Knowlton, & Poldrack, 2006). Educators must therefore focus on what qualifies as being digitally literate instead of just being literate in one form of hardware, software or resource that may vanish from the educational landscape as quickly as it arrived.

1.2. Age of Distraction

The Pew Research Institute conducted a survey of key stakeholders and technology experts to ascertain whether the hyperconnected lives of millennials would result in a net positive or net negative by 2020. The report highlighted the need for vital education reform in areas where students "thirst for instant gratification, settle for quick choices, and lack patience" (Anderson & Rainie, 2012, p. 2). The report determined that this generation of students will both

benefit and suffer from a state where being online and immersed in technology is a way of life. Some proponents of raising awareness to the detriments of technology suggest that this "rewiring" of the brain can have deleterious effects (Greenfield, 2015), where the need to constantly be engaged is impacting the ability to focus. In a study investigating reading comprehension between screen and paper, Mangen, Walgermo, and Brønnick (2013) found that reading texts on a screen resulted in poorer comprehension than reading the same material on paper. For teachers charged with maintaining the attention of their audience, this impact on dwindling focus is an increasing concern for educators (Anderson & Rainie, 2012; Dandolo Partners, 2013; Schmid et al., 2014). Fried (2008) undertook a study in the US to support anecdotal evidence from educators who claimed that laptops were detracting from the learning process. Although laptops can increase rates of in-class participation and student motivation (Fitch, 2004; Gulek & Demirtas, 2005; Stephens, 2005), the study revealed that laptop use negatively related to several measures of student learning.

Evidence is needed to provide informed rationale behind technology's implementation in the classroom, as it can be met by resistance for those ready to decry the advent of technology and its implications for learning (Fauquet-Alekhine, 2015; Yamamoto, 2007). As Giedd (2012, p. 7) observes, technologies enable adolescents to "...broaden their exposure to ideas, customs, and ways of life." However, what needs to be investigated further is the balance between integration and saturation to assist in determining what approaches a modern teacher can take to ensure that their pedagogy has adapted to students who have a very different style of learning, retaining and recalling information. One of the most recent controlled studies to assess the impact of multitasking on learning was conducted by Sana et al. (2013). Participants who multitasked scored 11% lower on post-lecture comprehension than peers that had undivided focus on the lecture content. Students were evaluated on application of knowledge using a multiple choice comprehension test, whilst randomly assigned to varying levels of digital interruption. The study concluded that there was more research required to determine under what conditions would the benefits of laptops outweigh their detriments (Sana et al.,

2013). From the perspective of neurobiology, Giedd (2012, p. 104) questions what the rapidly increasing dependence on digital devices will have on the adolescent brain, asking "will the availability of technologies that can persistently keep dopamine levels so high raise the threshold for what our brains deem rewarding in terms of relationships, studying, or working toward other long-term goals that may not have immediate reinforcements?"

1.3. Ubiquitous Technology

Millennial students are increasingly predisposed to engage with their devices, with electronic interruption often becoming an "unpredictable stream of interactions" both educationally and recreationally (Anderson & Rainie, 2012, p. 27). However, research suggests that oscillating between multiple tasks can hinder an individual's ability to complete a single task effectively and efficiently (McCoy, 2013). Rubinstein, Meyer, and Evans (2001) found that multitasking lead to a dramatic increase in processing time and memory errors when learning topics that involved a significant cognitive load. As students are now equipped with an abundance of Information Communication Technology (ICT) resources (Brand & Todhunter, 2015), with 99% of 15–17 year olds using the Internet (Australian Bureau of Statistics [ABS], 2016), it is imperative to equip them with necessary skills to manage the distractions that come with such connectivity. Giedd (2012, p. 101) contends that the way in which adolescents "learn, play and interact" has changed more in the past 15 years than in the previous half millennium since the advent of Gutenberg's printing press. In a critical review on the evidence of digital natives, Bennett, Maton, and Kervin (2008, p. 781) observed that "education has a vitally important role in fostering information literacies that will support learning." The proposed research aims to better understand the influence that ever-present technology has on meaningful learning and how pedagogy will evolve to adapt to the needs of students. A comprehensive search of the relevant literature indicates that research on the impact of technology on adolescent learning, specifically distraction and comprehension, is limited. The majority of studies have focused on the tertiary environment, where learning habits and attitudes have already been formed to a certain extent (Brinkworth, McCann, Matthews,

& Nordström, 2009; Mutsotso & Abenga, 2010). Many existing studies have relied on students self-reporting their technology use, which Junco and Cotten (2012) suggests should be remedied in future research by more accurate logging or observation. Teachers are mandated to integrate technology into their curriculum (Australian Institute for Teaching and School Leadership [AITSL], 2015) in order to address the needs of a generation of millennials that are considered by Howe and Strauss (2007) to be optimistic, team-orientated achievers who are talented with technology. However, assuming that students born of a certain age are equipped with inherent digital literacy skills, unlike previous generations of students, can be misguided. Carrier, Cheever, Rosen, Benitez, and Chang (2009, p. 72) observe that "the net generation do not appear to be getting any better at multitasking than prior generations and seem to be bound by the same mental limitations as other individuals."

In contrast to most educational resources, digital devices pose a dichotomous situation where they can be both beneficial and detrimental to learning (Sana et al., 2013). Scheiter and Gerjets (2007) assert that computer based learning environments (CBLEs) have the capacity to increase the accessibility of complex topics that would otherwise be difficult to comprehend in more traditional learning environments. For adolescents, being able to delineate between their device as a tool for learning and that of recreation poses a significant challenge for the developing mind. Educational theory relating to the Habits of Mind (HOM) framework indicate that managing impulsivity is instrumental to the current learning context (Campbell, 2006). The lure of engaging with technology for non-learning activities requires the development of metacognitive strategies to remain on task in the face of such digital intrusion. A traditional analogue resource such as a textbook or worksheet serves a singular purpose, whereas a digital device encompasses a raft of options unrelated to learning objectives, such as social networking, entertainment and gaming. Albeit garnering the label of 'weapons of mass distraction' from some detractors, the solution is not to banish ICT resources from the classroom; to do so would deprive students of the myriad opportunities available to them as the result of a technologically rich world (Dandolo Partners, 2013; Wood et al., 2012). Instead, teachers need to

acknowledge the new challenges precipitated by these devices and adapt their practice to one that recognises that distractions must be addressed before meaningful learning can occur.

1.4. Rate of Technology Advancements

Understanding technology and its implications for teaching and learning is an ever-evolving field. With such rapid development occurring in software, hardware and bandwidth, education is forever challenged to adapt to the changing pedagogical landscape. This exponential growth is often illustrated by Moore's Law, which suggests that since the mid 20th Century, processing chips have halved in physical size whilst doubling in power every 24 months (Malonis, 2002). This self-fulfilling prophecy is most apparent in enabling computing power to become increasingly affordable, accessible and portable. Such global accessibility has led to ICTs becoming embedded in the education system. However, with inexorable advancements in tools that can be used for learning comes the challenging proposition of determining their pedagogical efficacy. Kuznekoff, Munz, and Titsworth (2015, p. 346) state that focusing attention on the implications of ICTs in the classroom is of "paramount importance" if educators are to continue to address the academic needs of students. A tension between advocates and integrators of technology and those that see its place in the classroom as detrimental to learning continues to exist. Craft (2012, p. 1) suggests that there are two competing discourses in this digital age, where young people are viewed as either "vulnerable and at risk" or "capable and potent." Therefore, determining the benefits that effective integration of technology can have on teaching and learning is important to the debate surrounding technology's place in the classroom.

The NSW Department of Education and Training (2010, p. 7) contends that there is a need for more research to understand the "technological world of students." Their report on digital literacies declares there is a partition between classroom practices and everyday use of technologies, which suggests that students can feel conflicted when the device they are using outside of the classroom then needs to be repurposed within the classroom. The challenge

therefore is to delineate between two diametrically opposed functions offered by the same resource (Dede, 2005). Giedd (2012, p. 105) suggests further investigation is needed to "optimize the good and minimize the bad" when it comes to learning technologies. Often it is 'the bad' that receives greatest attention in public discourse and the saturation of technology within modern society can be derided by those that are not comfortable with its use. The enthusiasm that adolescents embrace technology with can be met with resistance by teachers and parents who were exposed to a predominantly analogue learning environment in their developing years. Kivunja (2015, p. 167) affirms that educators, from preparatory through to tertiary, must "preserve the essentials" of 20th century education whilst acknowledging that 21st century tools must be embraced for this new learning paradigm.

1.5. ICT in the Classroom

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to new contexts (Foerde et al., 2006). Those who are proactive and able to take control of their learning are able to engage more effectively in self-regulated learning (SRL). Zimmerman (2002, p. 65) defines SRL as a "self-directive process by which learners transform their mental abilities into academic skill." However, SRL is presented with greater opposition since the theory first developed, with students now at the mercy of a multitude of distractions interfering with their learning that previously didn't exist. Educators must therefore focus on what qualifies as being digitally literate instead of just being literate in one form of hardware, software or resource that may vanish from the educational landscape as quickly as it arrived. Educators must also be conscious of the fact that being born of a certain age does not necessarily equip the individual with innate digital literacies. These are skills that still need to be taught as digital natives may be adept at using their devices for recreation, entertainment and socializing (Prensky, 2010), but the skills required for effective learning with technology are not always immediately apparent. Although Chen and Tzeng (2010) found that using the internet could improve academic performance, Kirschner and Karpinski (2010, p. 1238) state that students may lack "the knowledge to adequately determine the relevance or truth of what they have found." They suggest that simply accessing Google is not the same as using it effectively, citing examples such as students referring to British artist Francis Bacon when attempting to refer to the 16th century natural philosopher, or struggling to distinguish the difference between Martin Luther and Martin Luther King.

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constantly engaged is impacting the ability to focus. In certain cases, the fixation with the screen over analogue resources can prove to hinder the learning process. In research investigating reading comprehension between screen and paper, Mangen et al. (2013) found that reading texts on a screen resulted in poorer comprehension than reading the same material on paper. For teachers charged with maintaining the attention of their audience, this impact on dwindling focus is an increasing concern for educators (Anderson & Rainie, 2012; Dandolo Partners, 2013; Schmid et al., 2014). Fried (2008) undertook research in the US to support anecdotal evidence from educators who claimed that laptops were detracting from the learning process. Although laptops can increase rates of in-class participation and student motivation (Fitch, 2004; Gulek & Demirtas, 2005; Stephens, 2005), the research revealed laptop use negatively related to several measures of student learning. Fried (2008, p. 911) concluded that laptops "interfered with students' abilities to pay attention and understand the lecture material." The research established correlations between lower test performance and greater laptop use within lectures. However, causality is more difficult to determine, as students of a lower academic ability might be more inclined to stray from the learning objectives. Fried suggests that using other data relating to student's capabilities and academic performance would attenuate this issue.

1.6. In class results: technology and comprehension

As many schools move to a Bring Your Own Device (BYOD) model (Ricci, 2015), students are now bringing a range of personal devices into the classroom and the access to tablets and mobile phones presents challenges beyond those of the laptop. Wei, Wang, and Klausner (2012, p. 186) looked at the impact that texting can have on attention in the classroom, suggesting that it "may undermine learners' attention from classroom instruction and adversely affect the capacity of short-term memory to process the multiple tasks in which students are engaging (texting and learning), leading to negative cognitive learning outcomes." As students are as inclined to communicate with their peers via text as previous generations might have been to whisper at the back of the class, the challenge presents itself in how to restrict a behaviour that is

so integral in the social discourse of modern adolescent behaviour. Each educational institution implements their own policies and guidelines for technology use and this variance needs to be considered when addressing the use of technology on a broader scale. Whilst some secondary schools might prohibit the use of mobile devices within the classroom, others might actively encourage its integration and implementation of teaching strategies that enable students to engage with multiple devices (laptop, tablet, phone etc.) within the one lesson. Regardless of the level of technology saturation within the classroom, there is significant evidence relating to its implication for comprehension and academic performance when poorly managed (Lepp, Barkley, & Karpinski, 2015; Levine, Waite, & Bowman, 2007; Sánchez-Martínez & Otero, 2009).

Lepp, Barkley, Sanders, Rebold, and Gates (2013) denote the 'cell phone as disrupter' hypothesis, where the presence of a mobile device may hinder behaviours "conducive to academic success" (Lepp et al., 2015, p. 1). Students that use their phones habitually can find it difficult to regulate their use during academic endeavours where there is a demand on their attention. Many studies have concluded that mobile phones can have a detrimental effect on academic outcomes (Duncan et al., 2012; Jacobsen & Forste, 2011; Lepp et al., 2015; Sánchez-Martínez & Otero, 2009); however, as schools and universities embrace BYOD, this once prohibited device is now becoming a sanctioned ICT within the learning environment. Students may struggle to resist the lure of the phone in their pocket, regardless of whether it a prohibited device or not (Lawson & Henderson, 2015; Wood et al., 2012). Jacobsen and Forste (2011) found that total mobile phone use was a significant negative predictor of Grade Point Average (GPA) amongst American university students. The mobile phone can serve as a trigger for constant, habitual use (Oulasvirta, Rattenbury, Ma, & Raita, 2012), where the motivation to access information is not always aligned with the classroom learning objectives. This inclination to respond rapidly to interrupting incoming messages can result in resumption lag, where returning to the task at hand is hindered by a loss of focus. Borst, Taatgen, and van Rijn (2015, p. 2972) suggest that the longer and more complex an interruption, the higher the resumption costs, "especially if they interrupt the

primary task at high workload moments." Borst et al. (2015) suggest that the duration of the interruption, the complexity of the interrupting task and the moment that the interruption occurs can all contribute to the length of the resumption lag.

Research by Rosen, Lim, Carrier, and Cheever (2011) found that students who opted to respond immediately to incoming messages performed significantly worse than their peers who opted to wait up to five minutes before responding to the interrupting text. They concluded that "we should be teaching our students metacognitive strategies that focus on when it is appropriate to take a break and when it is important to focus without distractions" (Rosen et al., 2011, p. 174). Encouraging students to develop an attitude of responsible use should be considered when developing digital literacy skills, as an inability to manage digital interruptions can be detrimental to sustained focus. Rosen et al. (2011, p. 75) assert that "making strategic decisions about technology usage that benefit learning" is a form of metacognition. Self-regulation is therefore key to adapting to a space where distractions are constant and the immediate instinct is to attend to tasks that may not complement the learning objectives at hand.

1.7. Cognitive Theories

In adolescents, the prefrontal cortex is constantly developing and adapting as synapses are perpetually being established (Konrad, Firk, & Uhlhaas, 2013). Research relating to the brain suggests that the centre responsible for executive functions, and consequently multitasking, are not fully developed until after puberty (Blakemore & Choudhury, 2006; Dux, Ivanoff, Asplund, & Marois, 2006). This region of the brain serves as the control centre that facilitates goal management and the decision making process (Powell, 2006) and the demands on this region are high as students navigate their way through school and beyond. During task switching, Foerde et al. (2006) identified a shift in neural activity from the hippocampus, which is responsible for purposeful thought processing and memory to the striatum, which is the brain region associated with more rote or habitual learning. Due to the limited capacity that an

individual's brain has to process and encode information, the strain of multitasking can result in what is described as the *central bottleneck theory* (Pashler, 1994). This immutable limitation in human information processing suggests that when two tasks require immediate responses, they must be placed in a queue. Research indicates that when there are two cognitive tasks being simultaneously performed, there were decrements in performance in at least one of the tasks (Dux et al., 2006). *Resource theory*, or capacity theory, offers an alternative to the central bottleneck explanation (Kahneman, 1973). According to resource theory, only when the demands of concurrent tasks exceed available resources, a loss in performance is expected. Resource theory enables parallel processing together with an executive function or cognitive control mechanism to manage the resources (Meyer et al., 2002). *Threaded cognition theory* (Salvucci & Taatgen, 2008) suggests that multiple objectives can be maintained as threads; threads can swap resources as deemed necessary; and once a thread has accessed a resource, other threads reliant on perceptual, motor, and declarative cognitive resources must be put on hold until their resources are freed up by the previous thread. This theory suggests that it is possible to undertake multiple tasks concurrently, albeit suffering a performance tradeoff in the process. The *motivated cognition model* provides an insight into why it is so challenging to resist distractions when studying. Lang (2006) explains motivation as a strategic activation of appetitive and aversive systems. Whilst the appetitive systems seek to maximize positive affect through new experiences, the aversive system seeks to avoid negative affect. Allocating resources is considered a volitional function, where appetitive activities such as interacting with friends would receive more attention than more aversive activities such as completing homework.

1.8. Self-Control and Regulation

Pintrich (2000, p. 453) states that self-regulated learning (SRL) is 'an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment." For students to set meaningful goals for learning, they need

to be intrinsically motivated by the content with which they are presented. In the absence of such engagement, the propensity to monitor, regulate and control becomes hindered. Devolder et al. (2012, p. 3) suggests that "values, interest and affective reactions" can all contribute to the motivational beliefs of the student. Bandura and Cervone (1986) assert that self-regulated academic learning behaviour is a combination of self-generated and external sources of influence. Kalyuga and Liu (2015, p. 6) undertook an analysis of empirical studies, which highlighted that learning environments with a primary focus on ICTs "might pose a variety of cognitive, metacognitive and self-regulatory demands on learners and most learners might not be able to regulate their learning." Self-control, interchangeable with self-regulation (Baumeister & Alquist, 2009), is defined as "the voluntary regulation of attentional, emotional, and behavioral impulses when immediate temptations conflict with more enduringly valued goals" (Duckworth, Gendler, & Gross, 2014, p. 200), and has been used to predict cognitive learning outcomes such as GPA and broader academic performance in schools. Young people are presented with the pressures of school whilst also the need for the social approbation of their peers, which often result in a conflict between electing to do what is beneficial in a learning environment and what satisfies a broader range of emotional needs. Junco and Cotten (2011, p. 376) observe that whilst students might be aware of the detrimental effects of divided attention towards their academic performance, they "continue to engage in the behavior." Wang, Tchernev, and Solloway (2012) declare that the driving force behind multitasking is the emotional rewards gained, even if it proves detrimental to learning. Rosen et al. (2011, p. 173) advises that we should be teaching students "metacognitive strategies that focus on when it is appropriate to take a break and when it is important to focus without distractions." Metacognition is an individual's knowledge of their cognitive abilities and the ability to "consciously and deliberately monitor and regulate one's knowledge, processes and cognitive and affective states" (Hacker, Dunlosky, & Graesser, 1998, p. 11). Adolescents must undertake a "self-directive process" in order to convert their mental abilities into task-related academic skills (Zimmerman & Schunk, 2001, p. 1). In order to achieve this, volition, or "willful and conscious focus and sustained awareness" is instrumental to progressing goals into actions (Roeser & Peck,

2009, p. 120). Studies indicate that individuals with a high level of self-regulation can sustain their attention on both assigned learning tasks during class and exert self-control to avoid off-task behaviours, resisting activities such as texting in class (Wei et al., 2012). Beyond academic achievement and performance, the ability to exercise self-control is a predictor of other key factors such as social competence and forming positive relationships (Eisenberg, Hofer, Sulik, & Spinrad, 2014). Moffitt et al. (2011) conducted research into self-control in childhood which predicted success and well-being in adulthood, including wealth, physical and mental health with effect sizes analogous in size to those of general intelligence or family socioeconomic status.

1.9. Divided Attention vs Multitasking

Debate continues around multitasking and what can more accurately be described as divided attention (Aagaard, 2015b; Baumgartner, Weeda, van der Heijden, & Huizinga, 2014). Whilst some theorists have argued that digital natives are adept multitaskers (Brown, 2000; Prensky, 2010), others contend that this propulsion to multitask is really just diluting the effectiveness of completing any one singular task (Fernandes & Moscovitch, 2000; Kraushaar & Novak, 2010; Sana et al., 2013). Junco and Cotten (2012, p. 506) declare that a decade of research has established "clear evidence that human information processing is insufficient for attending to multiple input streams and for performing simultaneous tasks." Dzubak (2008, p. 1) questions whether multitasking involves "simultaneous engagement in various activities or is it sequential engagement in multiple tasks?" Dzubak suggests that it is very challenging to perform multiple tasks concurrently and still be able to "effectively attend to and encode information associated with each task." When distinguishing between simultaneous and sequential processing, the performance of one task is likely to be detrimental to the second task (Delbridge, 2002). At best, individuals can switch quickly from one activity to another (Sweller, 1988). Kirschner and Karpinski (2010, p. 1237) assert that there is extensive empirical evidence, not necessarily specific to technology use, that relates to the negative implications of attempting to "simultaneously

process different streams of information." Mistakes are increased and the time taken to achieve learning parity is lengthened by attempting to process information concurrently, instead of sequentially. Multitasking is coordinating a series of parallel tasks by switching between them in a sequential process, as opposed to simultaneously attending to multiple tasks at once (Judd & Kennedy, 2011). The demands placed on cognitive load mean that an individual has a limited capacity at any one point to attend to, process and encode a stream of information. Regardless of how proficient an individual considers themselves at multitasking, there are neural limitations to what they can achieve at any one point. Individuals are only able to perform multiple tasks concurrently when these tasks are automated, or rehearsed (Kirschner & Karpinski, 2010). Examples of this include listening to music whilst jogging, talking whilst driving or whistling whilst walking. When behaviours are automated, they present a diminished strain on cognitive load. If both tasks require cognitive control, individuals are not able to parallel process information. This process of neural network switching can be associated with a "decrease in accuracy, often for both tasks, and a time delay compared to doing one task at a time" (Gazzaley & Rosen, 2016, p. 76). Frequent multitasking has the potential to become self-reinforcing and consequently a habit if individuals are not capable of self-regulating their inclination to multitasking (Olson & Fazio, 2001; Wang, Tchernev, et al., 2012). The pressing challenge of divided attention applies to the classroom environment where there is a high cognitive load placed on adolescents attempting to learn new content. This division of attention can impair the cognitive processes that mediate "the encoding of information into short and longer-term memory" (Judd & Kennedy, 2011, p. 626). As lesson content is often unfamiliar and unrehearsed, the demand on the brain to process streams of information can be high. Learning is maximized when a student is paying attention (Galluch, Long, Bratton, Gee, & Groeber, 2009), which is a contest in an age where attention is divided amongst increased modalities within the classroom. Gazzaley and Rosen (2016, p. 72) state that sustained attention, or vigilance, is measured by "how well someone maintains consistently high-level performance on a repetitive task over a long period of time." Sustained attention has been found to be one of the major variables in affecting academic performance (Steinmayr, Ziegler, & Träuble,

2010), with students who are more adept at regulating their attention, emotions and behaviour earning higher course grades (Duckworth, Tsukayama, & May, 2010) and higher standardised test scores (Duckworth, Tsukayama, & Kirby, 2013; Mischel, Shoda, & Rodriguez, 1989). Conversely, Kraushaar and Novak (2010, p. 248) observe that "students with a greater extent of distractive multitasking compared to productive multitasking exhibit lower academic performance."

In an educational context, seeking gratification within the classroom can now be superseded by the stream of contact that is coming to the student from beyond the confines of the room. As opposed to an age of mind-wandering or day-dreaming, where the student's mind drifts to distraction, technology now actively pushes distraction onto the student. As Aagaard (2016a, p. 11) observes, "just as laptops and tablets open up the possibility of bringing the outside world into the classroom, they also constitute a backdoor through which students may occasionally escape." Whether it be instant messaging, 'likes' on their social media stream or content that is more enticing than the lesson being presented, the adolescent mind is confronted with an overwhelming array of information at any one point in time. Bailey and Konstan (2006) suggest that distractive tasks, where cognitive resources are reoriented away from the primary task, can lead to increases in learning errors, learning times, annoyance and anxiety. Studies have shown that the learner can feel an increase in stress as the result of excessive multitasking, as the time to "effectively master material" is also increased (Gazzaley & Rosen, 2016, p. 126). It is incumbent upon teachers to be sensitive to the demands on their students' cognitive load, with Mayer and Moreno (2003) recommending that effective instructional design is dependent on understanding how the human mind works. Rosen (2010, p. 95) suggests that teachers should "develop educational models that allow for appropriate multitasking that improve learning." Rosen, Carrier, and Cheever (2013, p. 956) advise that the answer is not to demand that students unitask, as all it will achieve is a "shift from external auditory, visual and tactile distractors to an internal, anxiety-laden need to check in with their electronic worlds." If teachers do not integrate technology intentionally and meaningfully into the classroom, then Kay and

Lauricella (2011, p. 39) warn that students will "engage in a wide range of non-productive laptop behaviours."

Kuznekoff et al. (2015) assert that attending to unrelated lecture content during a lesson may be too cognitively taxing for students and the result may lead to limited comprehension. The number of memory errors and processing time required to learn new topics that "involve a significant cognitive load" dramatically increase when students are attempting to complete too many tasks concurrently (Kraushaar & Novak, 2010, p. 241). As technological innovations continue to evolve in teaching and learning, teachers must construct activities that encourage more durable knowledge. Students might be engaged and gratified by the introduction of various ICTs into the learning process, but the process of encoding knowledge for later retrieval can be undermined if the ICTs' implementation is not carefully considered. Kalyuga and Liu (2015, p. 3) suggest "it is not technology itself that matters but how it is used." If students are attempting to learn while engaged in multitasking behaviour, the result can be the acquisition of less flexible knowledge that cannot be easily recalled and/or applied in new situations (Foerde et al., 2006).

1.10. Resumption Lag

There is a time cost associated with the rapid changing from one task to another, due to the limitations on which the brain can process changing modes of information (Allport & Wylie, 2000). This cognitive juggling can be referred to as 'resumption lag', where switching tasks requires a "changing of gears" as different parts of the brain and its circuitry can be engaged by different activities (Dzubak, 2008, p. 2).

1.11. Technology as a learning distractor

Studies have shown that attempting to either attend to or process more than one task at a time can overload the capacity of the human information processing system (Drews, Pasupathi, & Strayer, 2004; Marois & Ivanoff, 2005; Wood & Cowan, 1995). As multitasking consumes cognitive resources that could be otherwise used for processing primary information, Aagaard (2015b, p. 888)

suggests that it is not surprising that media multitasking "impairs academic performance." Evidence indicates that the memory of students who engage in computer mediated non-lecture related activities will be significantly compromised (Risko, Buchanan, Medimorec, & Kingstone, 2013). Even if distraction does not decrease academic performance, it can make it more difficult for newly acquired knowledge to be applied flexibly in new situations where the information needs to be applied to new learning contexts (Foerde et al., 2006). Several studies have identified a negative relationship between the use of social-networking sites and academic performance (Fried, 2008; Kirschner & Karpinski, 2010; Kraushaar & Novak, 2010; Risko et al., 2013; Rosen et al., 2013; Rosen et al., 2011; Sana et al., 2013; Stollak, Vandenberg, Burklund, & Weiss, 2011). This includes negative relationships between students using their mobile devices in class and students' scores on a multiple-choice test (Kuznekoff et al., 2015); responding to messages during a lesson resulting in significantly fewer notes and significantly diminished quiz scores (Kuznekoff & Titsworth, 2013); hierarchical linear regression indicating Facebook use and texting during class were negatively predictive of overall semester GPA (Junco, 2012); texting while attending lectures impairs academic performance (Dietz & Henrich, 2014); students who allocate greater cognitive resources towards distractive rather than productive online work achieve lower academic performance (Kraushaar & Novak, 2010, p. 249); a negative relationship between time spent instant messaging and reading comprehension scores and overall reported GPA (Fox, Rosen, & Crawford, 2009); and media multitaskers' laptop use posing a significant distraction to participants sitting in their vicinity (Sana et al., 2013).

In research by Junco and Cotten (2012), they found that there was a strong, negative relationship between the time spent on Facebook and cumulative GPAs, where engaging in social media use while trying to complete schoolwork may preclude deeper learning due to the strain on their cognitive capacity. Kirschner and Karpinski (2010) found that Facebook users reported a lower GPA and fewer hours of weekly study than nonusers. Such negative relationships are not just confined to the United States, as populations across Europe and Asia are identifying similar trends (Helou & Rahim, 2014;

Karpinski, Kirschner, Ozer, Mellott, & Ochwo, 2013). However, evidence from Australia, especially in the secondary school environment, is currently scarce. Judd and Kennedy (2011, p. 630) call for further research to "enable us to better distinguish between learning activities that are well suited to and/or are not adversely impacted by media multitasking."

Research examining the influence of multitasking with a range of electronic media on the ability to learn from university lectures determined that lower scores were associated with students who were more inclined to multitask, as opposed to those who did not (Wood et al., 2012). Although the majority of studies focus on the tertiary learning environment, similar approaches to learning are pertinent to the structure of the secondary classroom. One of the most considerable differences between the two is that adolescents have a greater inclination to become distracted (Konrad et al., 2013). Research on a middle school, high school and university students, (Rosen et al., 2013) observed that students typically became distracted by social media after less than six minutes of studying. Lepp et al. (2015) found that the negative relationship between technology use and academic performance could be attributed to the decrease in time afforded to uninterrupted studying and the decreased focus that comes as the result of ongoing technological distraction and interruption. Beyond increased time to complete tasks, Carr (2011) argues that shallow thinking has replaced deep, contemplative thought and analysis. He allegorizes the search for information today as skiing across the surface compared to diving into the depths to find material. The Internet's propensity to provide surface level information easily and immediately, at the expense of rich content, is often attributed to our decreased ability to remember key details. Known as *transactive memory*, the minutiae of facts and details that organise our daily lives can now be outsourced to the online space, in theory freeing up our brains to remember more vitally important information (Sparrow, Liu, & Wegner, 2011). Sparrow et al. (2011) observe that we are becoming symbiotic with our computers and the importance of knowing where to find information has superseded the ability of remembering it.

1.12. Benefits of Technology

Effective integration of technology within the learning environment is key to responding to the needs of a generation that greatly differ from those that have gone before them (Howe & Strauss, 2009). Wood et al. (2012, p. 365) declare "there is a consensus that existing and emerging digital technologies have the potential to expand the reach and effectiveness of current educational tools." Students are predisposed to engage with technology as an extension of themselves and they interact in a world where the division between real life and online space is greatly diminished (Anderson & Rainie, 2012). Educators' reaction to the current evidence of decreased academic performance and overloaded cognitive strain is often to instinctively remove ICTs from the classroom as a solution to the perceived problem. However, what needs to be achieved is a greater understanding of how to balance the positives brought to learning by technology, whilst acknowledging its hindrances if not managed effectively. As Taneja, Fiore, and Fischer (2015, p. 142) assert "banning technology is not a solution since technology could allow for positive learning outcomes when used appropriately." As educators seek to maintain step with the evolving technological landscape, embracing its place in the classroom instead of deriding it is key, as resistance to its place in society will ultimately be futile. Aagaard (2015a, p. 96) declares that the banning of digital devices from the classroom is "not only impossible, but also highly unwarranted." Physically removing devices from students is not a guaranteed approach to obtaining focus in the classroom, where focus can so often be elusive in the presence of digital distractions. Rosen et al. (2011) outlines neurological research that indicates students will be thinking about their online activity and connectivity even if their device is not within their reach. Rosen et al. (2013, p. 956) suggests that restricting students' ability to connect to their online worlds can create highly anxious individuals, advising that "out of sight is most definitely not out of mind." Wang, Tchernev, et al. (2012) propose that emphasis on academic performance as the key outcome neglects the emotional or social functions of multitasking, where students may be willing to forego academic performance for entertainment, emotional or social gains (David, Kim, Brickman, Ran, & Curtis, 2015).

1.13. Future Research and Conclusions

Lee, Lin, and Robertson (2012) undertook research on tertiary students to determine the implications of media multitasking on cognitive load and attention, which found that digital distractions interfered with knowledge acquisition. They concluded that there were considerable implications for students and educators alike, declaring an "unquestionable and urgent" (p. 102) need for further research to be conducted in order to understand the impact that multitasking has on society. This call for further research is reiterated by a multitude of researchers who have studied a range of implications of technology on learning in recent years (Ackerman & Goldsmith, 2011; Duncan et al., 2012; Mangen et al., 2013; Mueller & Oppenheimer, 2014; Sana et al., 2013). Schmid et al. (2014, p. 285) suggest that "learning is best supported when the student is engaged in active, meaningful exercises via technological tools that provide cognitive support," whilst acknowledging that we are still in need of greater understanding of how to precisely integrate cognitive support tools into instruction. Thus far, the majority of studies conducted in this field have focused on higher education students, predominantly in North America, where the constructs of the classroom, content delivery and learning behaviours vary significantly from those of an adolescent within a school classroom. This further highlights the need for research specific to adolescent education in order to advance the knowledge required to effectively implement technology for meaningful learning. The predominant focus on technology's efficacy and distractive qualities within the learning environment has studied adult behavior, which varies greatly from that of the developing adolescent mind (Konrad et al., 2013). There is a need to turn attention towards secondary level education, where learning behaviours can be established, developed and carried through to post-compulsory education (Pendergast et al., 2005).

Kraushaar and Novak (2010, p. 241) acknowledge that research on how students use laptops does exist; however, they highlight a lack of research that addresses the "unstructured or unsanctioned use of computers in the

classroom." The demand for further research in this area is echoed by many researchers who have begun to assess the efficacy of technology integration for learning. Wang, David, et al. (2012, p. 974) suggest that investigating how we optimize resources allocation when multiple tasks are competing for our attention is "an exciting area of research." Giedd (2012, p. 105) calls for strong research to be developed, funded and undertaken to "optimize the good and minimize the bad impacts of the digital age."

Evidence is needed to provide informed rationale behind technology's implementation in the classroom, as it can be met by resistance for those ready to decry the advent of technology and its implications for learning (Fauquet-Alekhine, 2015; Yamamoto, 2007). As Giedd (2012, p. 7) observes, technologies enable adolescents to "...broaden their exposure to ideas, customs, and ways of life." However, what needs to be researched further is the balance between integration and saturation to assist in determining what approaches a modern teacher can take to ensure that their pedagogy has adapted to students who have a very different style of learning, retaining and recalling information (Prensky, 2010). In research to assess the impact of multitasking on learning, Sana et al. (2013) found participants who multitasked scored 11% lower on post-lecture comprehension than peers that had undivided focus on the lecture content. Students were evaluated on application of knowledge using a multiple choice comprehension test, whilst randomly assigned to varying levels of digital interruption. The research concluded that there was more research required to determine under what conditions would the benefits of laptops outweigh their detriments (Sana et al., 2013). From the perspective of neurobiology, Giedd (2012, p. 104) questions what the rapidly increasing dependence on digital devices will have on the adolescent brain, asking "will the availability of technologies that can persistently keep dopamine levels so high raise the threshold for what our brains deem rewarding in terms of relationships, studying, or working toward other long-term goals that may not have immediate reinforcements?"

There is a need for research that looks at emerging platforms in the evolving digital space to address the fact that one stream of social media or distraction

may be rendered obsolete as new trends and offerings emerge. Previous classroom studies on specific social media platforms such as Facebook (Ellison, Steinfield, & Lampe, 2007; Gray et al., 2010; Kirschner & Karpinski, 2010; Rosen et al., 2013) now have diminished relevance as young people move onto the next wave of social media (Duncan, 2016). For broader applicability, future studies should not confine themselves to the implications of just one social media or application as it is likely to be usurped (Saul, 2014). Preliminary studies have looked at the impact that instant messaging and texting can have on academic performance (Kirschner & Karpinski, 2010; Levine et al., 2007); however, many of the studies were prior to the advent of the smartphone and its capabilities which are far richer than just synchronous communication.

One of the main challenges evident in many studies assessing students' use of classroom technology and its perceived efficacy is the reliance on self-reporting (Jacobsen & Forste, 2011). For a variety of reasons, students might provide responses or indications of their technology use that are not truly representative of their digital behavior (Fried, 2008). Known as the Hawthorne Effect, research participants that are aware they are being studied may alter their behaviour as a consequence (McCambridge, Witton, & Elbourne, 2014). Kraushaar and Novak (2010, p. 250) suggest the need for data that explicitly measures learning outcomes and actual use to address the "self-reported perceptions of use or anecdotal descriptions." One individual's perception of their use might be in stark contrast to another if their understanding of what constitutes as heavy use varies. As the majority of studies are quasi-experimental, or in lab conditions, it is important to develop research that can best replicate the conditions of the standard classroom, with minimal disruption and inconvenience to students and teachers. Kuznekoff et al. (2015, p. 362) suggest that future research "should expand to include data from a more naturalistic setting." Aagaard (2015b, p. 887) concedes some skepticism regarding the evidence that overtly refutes claims about digital natives' media multitasking abilities, stating that "it is unknown to which extent these artificial situations correspond to real life situations." With direct applicability to this research, Kraushaar and Novak (2010, p. 249) suggest that an investigation of a

"direct causal relationship between the frequency of multitasking and academic performance requires an in-class assessment at the end of the class period."

As this is an emerging field, there are a variety of avenues that still demand further research. Although experimental psychology has investigated multitasking and the resultant significant memory disruptions (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Jacoby, Woloshyn, & Kelley, 1989), Rosen et al. (2013) suggest that very little research has been conducted into how often students switch tasks during actual schoolwork. Academics have identified a need for further research relating to loss of volitional control with mobile phones and its long term effects (David et al., 2015); the influence of devices on everyday social interaction (Aagaard, 2016b); memory recall of "lecture material with interruptions in the classroom environment" (Rosen et al., 2011, p. 166); the need to examine the effect of multitasking on educational outcomes (Junco, 2012); the difference between children, teens and young adults in task switching behaviour (Rosen et al., 2013); and an 'urgent need' for research on self-control in school-age children (Duckworth et al., 2014, p. 212). Beyond this, future research needs to clarify the relationship between academic outcomes and characteristics of each ICT, as well as the frequency of use and whether it is used for social or academic purposes. With regard to further research, Aagaard (2015b, p. 894) outlines additional factors that could potentially influence media multitasking, such as "the rhythm of lessons, social norms, presented material, or even the physical layout of a classroom influence media multitasking." In an increasingly technology-reliant workforce, Junco and Cotten (2012) suggest that future research could also focus on how internet skills and academic outcomes relate to employability.

Wood et al. (2012, p. 373) advocate that "we must fully identify, understand and overcome potential shortcomings resulting from inappropriate use of technology in the classroom" if we are to maximize the educational benefits associated with it. The call for further studies is voiced by researchers who have begun to look at the pedagogical benefits of ICTs. Tallvid, Lundin, Svensson, and Lindström (2015, p. 246) suggest that further research is needed

"to investigate the relationship between rules and students' use of laptops in the classroom." Kuznekoff et al. (2015) highlight the pressing need for this area to be investigated further:

> Focusing attention on the effects these devices and services have on student learning and the college classroom is of paramount importance if we, as educators, are to continue to work with students effectively in helping them achieve their educational goals. (p. 346)

The ubiquity of technology demands that educators are constantly at the forefront of effective ICT integration and pedagogical practices to cater to the world of the digital native (Prensky, 2010). Teachers are therefore mandated to perpetually adapt to the rapid pace with which such tools advance. It is imperative for schools to not only provide students with access to technologically rich resources, but to educate them in how to use them appropriately. A paucity of relevant research, specific to the impact of technology on adolescent learning, highlights the need for further investigation. Presently, there are a range of studies undertaken in higher education environments that highlight the cognitive influence that dual tasking has on effective comprehension of learning materials. There is a need to research how adolescent students' learning is impacted by digital distractions in order to develop strategies to address this shift in attention and learning.

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