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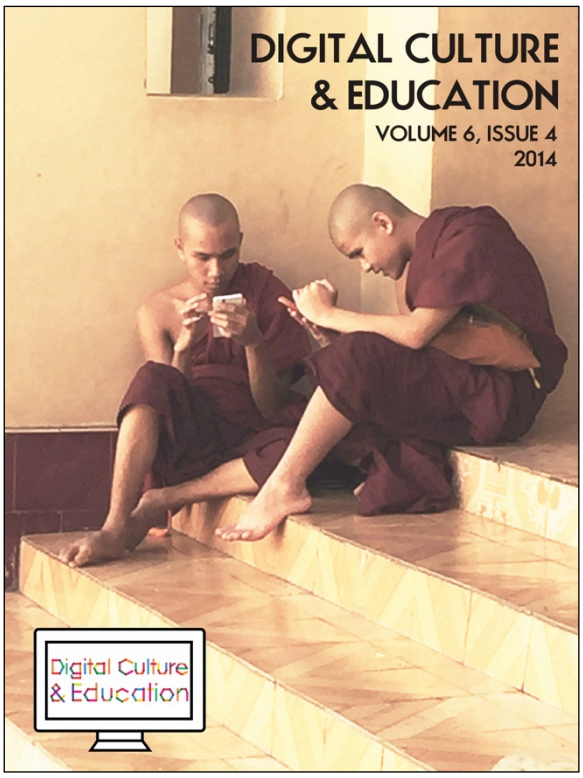

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Digital Culture and neuroscience: A conversation with learning and curriculum

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DIGITAL CULTURE AND NEUROSCIENCE: A CONVERSATION WITH LEARNING AND CURRICULUM

Kathryn Grushka, Debra Donnelly & Neville Clement

Abstract: *Multimedia digital technologies mirror neural processes and capacities and their proliferation introduce new possibilities for learning. Not only does the new digital media have the capacity to instantly record and communicate lifeworld experiences unimpeded by the distance or size of the targeted audience, but offers the means to construct virtual reality environments which were previously beyond human experience. This finds the teacher confronted with a new array of modes and an extended concept of literacy through which to engage the student in learning and meaning making. Digital culture and its multiliteracies now present challenges for the curriculum work of teachers, both in terms of the integration of appropriate technologies and the capitalization of the sensory and memory capacities of students. This article outlines the challenges faced by teachers as they engage in curriculum work that seeks to integrate the capabilities of our new digital culture in the design of learning experiences. It also highlights insights into human capacities for learning offered by neuroscience regarding the interplay of experience, memory, cognition, emotion and reflection in learning. By aligning these strands, teachers can develop curriculum that align with the capabilities of new digital technologies with the capacities of students.*

Keywords digital culture and learning, multiliteracies; neuroscience; digital technologies; curriculum; experiential and affective learning

Introduction

New digital technologies, with their multimedia capabilities, are now our social reality. These multimodal devices now shape the ways in which contemporary society makes meaning and communicates. This poses challenges for our conventional understanding of "literacy" as we attempt to incorporate them into curriculum design and practice. In addition, neuroscience provides educators with new insights regarding the role of learning in the formation of brain structures and the role of the classroom experience (Szűcs and Goswami, 2007). Together, these challenges and new discoveries will require the re-examination of curriculum and pedagogical content knowledge.

Not only does new media have the capacity to instantly record and communicate lifeworld experiences unimpeded by the distance or size of the targeted audience, it offers the means to construct virtual reality environments which were previously beyond human experience. Communication, entertainment and availability of information, the emergence of techno-social objects or multi-media devices within communicative practice make possible the emergence of the 'low-tech cyborg' (Escobar et al., 1994). The cyborg is defined as 'hybrid of machine and organism, a creature of social reality' (Haraway, 1991, p. 141), and student cyborg learning is firmly located in the lived social reality of the learners' life world and is increasingly gaining a presence in the classroom. The popularity of these multimedia devices has profound implications for our understanding of experience, learning and literacy because of the new possibilities presented by this digital culture. Any expansion in the repertoire of modes

and their 'affordances' are active in representation practices and shape 'knowledge' (see Kress, 2009). This presents new challenges for curriculum design in a digital culture.

Concurrent with this burgeoning of digital culture is the enhanced understanding of the nature of human perception learning and memory provided by the availability neuro-scanning technology. This expanded knowledge of brain functioning provides a further resource on which educators can draw in designing curriculum (Clement & Lovat, 2012; Lovat & Smith, 2003). Of particular interest, in light of the ubiquity of new media with its multimodal capacities, is that human perception and memory are multimodal with memory being a composite "*of the sensory and motor activities related to the interaction between the organism and the object* during a certain period of time" (Damasio, 2012, p. 133). This reinforces the notion that curriculum work is more than just selecting content to be taught and learned, but entails the careful and intentional design of learning experiences (Lovat & Smith, 2013). Given the nature and reality of an expanding digital culture in learning, this paper explores challenges presented for teachers enacting curriculum as they grapple with the impacts and implication for digital literacy, the emergence of concepts such as edusemiotics (Danesi, 2010) and their impact on teaching and learning. Through an examination of associated literature, it challenges normative assumptions as to what now needs to be regarded as "literacy" in the wake of current technological innovations and capabilities.

Digital technologies and curriculum

The availability and widespread use of small digital devices like smart phones and computer tablets raises issues for teachers designing curriculum as this technology is a new sociocultural phenomenon, able "to combine the material, the social and the symbolic in an associative web" (Budka, 2011, p. 4). Digitization has meant that image, sound and text are now processed similarly by a computer chip. This is unlike the previous analogue systems where each different mode required different rendering processes as in the case of printed text and images (Cope & Kalantzis, 2004) or even other media types as in the case of sound. Jewitt (2008b) proposes that this altered relationship between production and dissemination disrupts the conventions of the relationship between audience and author, as different types of texts proliferate and multiple literacies or different semiotic systems come into play. Furthermore, Jewitt points out that the corollary of these multiliteracies is the multimodal nature of social communication (see Kress, 2013) and argues that communication and meaning making call on a diversity of modes including sound, movement and image, each with its own repertoire of semiotics.

Given the increasing presence and use of multimedia communication devices, literacy is presented as more than learning to read and write in the traditional sense, and now extends to the manipulation, mastery and use of multimedia technologies (Mills, 2010). In addition, these different modes of communication are shaping new sensory capabilities and operate as a personal meaning making apparatus (Buckingham, 2012). As a result, there is an urgent need for teachers to understand how the different perceptual modalities function in relation to learning and memory and how each modality is socially and culturally represented.

Concurrently, technological innovation has seen the development of sophisticated neuroimaging technologies that afford unprecedented knowledge of the architecture and functioning of the brain coinciding with the proliferation of multimedia devices. For example, Gross (2008) points to the coevolution of neuroimaging and the increasing need to draw on the semiotic language of images to create and communicate meaning. Digital imaging technologies now allow opportunities to examine and understand the

role and functioning of the sensory modalities in relation to perception and the processing and storage of data at the neuronal level. Any new insights provided by neuroscience regarding the nature of learning, memory and recall have important repercussions for curriculum design in the new digital world. Thus, a trilogy of elements will need to be taken into account to achieve authentic curriculum design for the contemporary educational context, particularly in relation to literacy. The elements include: multimodal media; the expanded repertoire of semiotics potentiated in the use of multimedia; and insights into human perception, learning and memory made possible by neuroscience in dialogue with cognitive science. Using new media in curriculum practice is therefore more than replacing one set of technologies with another. It involves understanding the capacities of the new technologies and matching them to the learner.

New media and curriculum problematized

The evolution of digital literacy curriculum for the 21st century and the incorporation of new media and multiliteracies into curriculum design is a complex task and not just a process of substituting redundant technology with the more recent, for example the replacement of the typewriter with the keypad. Rather teachers' curriculum planning needs to take account of a divergent range of possibilities introduced by the new technologies and the new knowledge provided by neuroscience. A further problematic presented for curriculum development is the little known influence of the experience of using mobile digital devices on the cognitive development of individual students (See Mann, 2006).

As Lovat and Smith (2003) propose, a curriculum comprises a particular selection of knowledge, activities and experiences chosen and blended by the teacher in order to advance the learning of students. Curriculum development necessarily involves teachers in "selecting, sequencing, organizing and structuring knowledge, resources and activities" (p. 26). According to Lovat and Smith, this process of choosing and combining knowledge, resources and activities in a meaningful way is curriculum work or action and is informed by curriculum theory. Curriculum theory serves as a "linchpin" between the foundational educational disciplines such as psychology, sociology and philosophy, and curriculum practice. Curriculum theory, then, is a synthesis of knowledge derived from the foundational educational disciplines and experience of curriculum in practice as applied in actual learning and teaching situations. Experiences encountered in the practical implementation of teaching may provoke reflection on the adequacy of curriculum theory, which in turn asks questions of the educational disciplines.

New digital technologies challenge the manner in which curriculum work has been done in the recent past. Several key challenges include:

- The identity and agency of the learner, the explicit link to their cyborg identity (Boyd & Ellison, 2007) represented as individual interactive and communicative technological potential.
- Digital devices and the media they display extend the resource base of curriculum work.
- Multimodal learning, or the flexible mixing of verbal and visual text, animation and sound, afforded by contemporary technology impact in unprecedented ways on knowledge representation and a widening of semiotic practices.

- Digital technologies present an artificial adjunct to memory and can function as a learning prosthesis given their capacity to record experiences in multimedia format in a like manner the human brain.

It was Vygotsky (1978) who observed that humans employ a range of tools to support and extend cognition and memory. Now the capacity of multimedia digital devices to extend human cognitive and memory capacities is beginning to be understood and potentiated. Mills (2010) argues that students generally learn to use multimedia devices in informal situations, but they can benefit from expert scaffolding in their mastery of the media that will extend their knowledge and understanding of "multimodal practice". It may then be possible to consider how the long-term use of these technologies alters and adapts the mind as part of the very being of the user (Mann, 2006), or builds their preferences and skills in some semiotic systems over others, such as animation over writing.

The dissonance introduced into curriculum work for teachers by the new digital technologies is further informed by the rise of neuroeducation (the considered application of the findings of neuroscience to education, see Geake[2009] and Goswami [2008]). There are several ways in which the influence of neuroscience might be brought to bear on curriculum theory and practice (Clement & Lovat, 2012). One is that neuroscience contributes to the understanding in disciplines like developmental, social and cognitive psychology (e.g., Cacioppo, Berntson, & Decety, 2010; Hruby, 2011; Willingham & Lloyd, 2007) and thereby indirectly contributes to curriculum theory. Another consideration is that neuroscience can be used to inform and modify the cognitive models which are adapted in theories of learning, and so contribute to the interpretation of behavioural data (e.g., Bruer, 2008; De Smedt et al., 2011; De Smedt et al., 2010; Hruby, 2011). Szűcs and Goswami (2007) believe that "mental representations can best be understood by combining behavioural and mental measures" (p. 120). In turn, these cognitive models or mental representations inform curriculum theory and this leads to modified curriculum practice (Butterworth & Laurillard, 2010). This dynamic interdisciplinary interaction portrayed by Butterworth & Laurillard renders the process of delineating the individual contribution of each discipline to curriculum work difficult, if not impossible.

Moreover, the interaction between experience and the neuroplasticity of the brain is of particular interest for curriculum work. Neuroscience has demonstrated that the plasticity of the brain continues throughout the course of a person's life and that all learning involves, and is made possible through changes in the brain's neuronal structure (Blakemore & Frith, 2005; Doige, 2008). Willis (2010) describes plasticity as "the ability of neural networks to extend, prune, reorganize, correct or strengthen themselves based on acquiring new information, obtaining corrective feedback, and recognizing associations between new and prior knowledge" (p. 55). It is this adaptability of the brain that makes learning and teaching possible. Neuroeducationalist, John Geake (2009) comments: "Our brains did not evolve to go to school" (p. 12). Furthermore, Goswami (2008) points out that the ability to read is a constructed rather than an innate capacity. Therefore, learning is actuated because of the plasticity of the brain and this is "experience induced" (Diamond & Amso, 2008, p. 136). Neuroplasticity underlies both development (which is experience expectant, where certain experiences are endemic to typical development) and learning (which is experience dependant, Galván, 2010). Thus, memory formation is a function of neuroplasticity.

Having outlined the challenges for curriculum work to teachers presented by (a) the emergence of new multiliteracies, a phenomenon accompanying the proliferation of

digital technologies, and (b) the insights into the functioning of the human brain provided by neuroscience, attention now shifts to consider ways by which these challenges are being met in teachers' curriculum work. What follows is the argument for the need to re-evaluate the nature of teaching and learning given that new media learning experiences and how the student brain has now been significantly shaped by the use of digital devices, and their preferences for and engagement with particular kinds of multimodal learning. This discussion now considers three aspects related to the incorporation of multiliteracies into curriculum work: the evolution of multiliteracies in the current century with the attendant implications for semiotics and knowing; the foregrounding and limitations of attempts to embed technology in curriculum design; and the insights offered by neuroscience into the experiential nature of learning.

The evolution of digital literacy curriculum for the 21st century

Digital technologies and contemporary cultural behaviours have shifted the notion of literacy and expanded the concept beyond the printed text. Added to competency in reading and writing paper text is a set of technological and semiotic understandings and skills (Anstey & Bull, 2004; Cope & Kalantzis, 2009; Kalantzis & Cope, 2012; Knobel & Lankshear, 2007; Kress & Van Leeuween, 2001; Moore, 2011). The term "multiliteracies" conveys the notion that today's literacy calls for functionality across multiple forms of knowledge and discernment to identify the appropriate social context. As individuals are now deluged with vast quantities of information, an understanding of the constructed nature of texts has become vital as a broad range of platforms need to be evaluated in terms of veracity and reliability (Cazden, Cope, Fairclough, & Gee, 1996). The multiliterate student is able to seamlessly navigate between paper, electronic and live texts and their semiotic systems (Anstey & Bull, 2006; Kress, 2003; Luke, 2003) and they decode, communicate and collaborate to create across platforms.

Print-based models of literacy have been adapted to models of multiliteracies that have merit in that they provide a framework for analysis. However, the approach is a traditional one that sees the learner as interpreting and analysing rather than creating new meanings through new media. A consideration of Four Resource Model (Anstey & Bull, 2006; Muspratt, Luke, & Freebody, 1997) is useful here to illustrate the process is one of decoding, critical and semiotic image analysis as opposed to encoding, or creating new meaning through text production. This model proposes a continuum of four interdependent skills - code breaker, meaning maker, text user and text analysis. Code breaking, is defined as the ability to identify and use the semiotic systems of the electronic, print and live texts and understand how they collaborate. The reader then brings the broad range of literary, cultural, social and technological experiences to interpret and understand the text. The meaning making skill is not the creation of new meaning, but understanding the possible levels of meaning. The text user is able to transfer these skills to real-life situations. By understanding the structure, intent and meaning of texts the text analyst can make judgements about the reliability of the text and come to an understanding of it. This model is a demonstration of the essential initial stage of multiteracies, that of understanding and evaluating text. However, as a model of multiliteracies it is caught in the "physical-industrial mindset" (Gibbons, 2012; Lankshear & Knobel, 2003, 2004), one that views the contemporary world as much the same as the past, except for the addition of technology. This view constructs learning as teacher-directed and "curricular," that is the learning is pre-determined and officially sanctioned, and learner as consumer rather than producer. As observed by Carrington and Marsh (2005), digitextual practices are blurring these traditional distinctions between writer, reader, producer and consumer and require a complex and sophisticated

range of skills, knowledge and understanding. Lankshear and Knobel (2004, p. 16) have defined this "new literacies" as skills of accessing and using technology on various platforms "using and constructing hyperlinks between documents and/or images, sounds, movies, semiotic languages...producing non-linear texts, navigating three-dimensional works online and so on." New literacies, they argue, require "new learning," and a "post-physical and post-industrial mindset," which acknowledges that cyberspace operates on a basis of different assumptions and values from physical space. The student as cyborg employs external prosthetic devices or techno-social objects to communicate with other users on a network of information exchange centred on connectivity (Escobar et al., 1994).

Literacy, and what is to be literate has now become a dynamic concept in the 21st century. It challenges educational systems and teachers to remain relevant to their clients (Kalantzis & Cope, 2012; Leu, Kinzer, Coiro, & Cammack, 2004; Provenzo, Goodwin, & Lipsk, 2011). Kalantzis (2006) has extended the pedagogy of multiliteracies while calling for a reflective epistemology in which agency is re-balanced to empower the learner and teacher/student relationships. This learning is re-configured to construct learning as "a dialogue of difference" (Kalantzis, 2006, p. 31). A transformative approach, where learning is negotiated and co-constructed in a "bottom up" methodology, centred on an enquiry based learning model. Knowledge is understood to be contested, complex and negotiated and values the personalization of learning journey (Deakin Crick, 2009). It encourages critical and self-reflectively understandings achieved through historical, cultural and personal insights. Learners require interactive thinking skills, material experiences and performative practices. "Each meaning maker designs the world afresh…then leaves a representational trace to be found by others and transformed once again" (Kalantzis, 2006, p. 20).

New media and curriculum design

Incorporating new media into curriculum design and practice ushers in a changed paradigm as traditional written texts are now in battle for dominance with the possibilities afforded by new media. The conceptualization of curriculum and literacy as a top down or the reproduction model in western curriculum is no longer appropriate. The living reality is that we have an altered range of semiotic communicative practices and these practices are fluid, co-constructed, mobile, and transnational. They range across epistemological fields and herald the brink of initiating new creative futures where students can initiate authentic learning opportunities that can respond to this new extra-linguistic field of semiotics or edusemiotics (Danesi, 2010). This field includes sign signification, such as aesthetic products, visual communication, new media, advertising, narratives, material culture, film and gaming or other performance based acts such as dance, body movement or drama, anything that is underpinned by sign based activity.

Jewitt (2008a, 2008b) has identified that the representation of knowledge as well as the mode and media are integral to learning. The New Media Consortium (2005) has placed emphasis on the development of 21st century literacy as, "a set of abilities and skills where aural, visual and digital literacy overlap … the ability to understand the power of images and sounds, to recognise and use that power to manipulate and transform digital media, to distribute them pervasively and to easily adapt them to new forms" (p. 2). This will require the development of a much wider range of ways of thinking by teachers about: how students learn; how student brains have already been shaped by new media learning and the significance and power of their individual communication prostheses which equip every student with the capacity to represent meaning using multiple representational forms.

The power of personal mobile digital devices or learning prostheses corresponds to the call for learner-centred pedagogies that move beyond offering simply new technologies. It requires pedagogies that offer students greater levels of agency, social connectedness and autonomy driven by each student's access and experience of digital technologies. Students as knowledge producers take their digital prostheses into the rich world of daily experience and have already developed knowledge of working in digital communities of inquiry well before formal school. It therefore flows they will reject the learning metaphor of acquisition, as they have already gained insight into the richness of learning through participation, collaboration and/or production (Lloyd, 2013). Curriculum design will need to be underpinned by a range of transformative pedagogies that draw across different disciplines, modes and media to harness the existing multimodal brain development of students. These pedagogies will need to see a focus on creative inquiry and performance; learner-designed learning; inductive and creative modes of reasoning and collaborative problem solving through the iterative stages of inquiry, analysis, production and presentation.

Modern technology tools are driving teaching and learning to an understanding that the generation of new knowledge is grounded in the development of the brain and its inherent plasticity, its cognitive tools and imaginative endeavours. These have added a significant re-emphasis on "trans-disciplinary creativity". This rethinking of the relationship between technology and creativity (Mishra, 2012) shifts to a more intuitive engagement when learning. Mishra has identified a contradiction in thinking that creative problem solving occurs in-discipline. She argues that having the capacity to work creatively across varied domains implies multimodal learning and will require students to deal with contradictory knowledge and diverse semiotic systems and to develop the skill to break through these boundaries when learning.

With rapid advances and the uptake of the new digital technology the vision of curriculum has lagged (Mishra & Koehler, 2006). Buckingham (2012) argues that teaching and learning has remained relatively untouched by technology while the lives of young people have increasingly become filled with digital devices, asking us to consider a re-emphasis on the significance of situated cognition. In situated cognition, the learning context is perceived as meaningful to the learner and the inquiry is grounded in their lived experiences. Buckingham (2012) advocates for a learning-technology-by-design approach, where the emphasis is placed on becoming a technological practitioner through creating artefacts. This approach applies both to the teacher designer and to the student designer. Creating through design involves critical reflection, problem solving, dialogue, application of technological processes and iterative creative acts. Both teachers and students need to learn through creative use of the technology (Mishra & Yadav, 2013) rather than be just trained in the technologies. As multimodal practitioners, students wishing to work with visual technologies require a repertoire of visual language and related visual digital technologies in addition to the knowledge of how images and other modalities work together in contemporary communication. The complexity of this new learning space may benefit from neuroscience insights.

Experience, learning and multimodality

Neuroscience has extended insights into the processes by which human knowledge is distilled from sensory experience received via the different sensory modalities. Neuroscience has contributed to the understanding of the innate capacities of the learner, the role of reflection in learning, the understanding of memory and the role of emotion in learning. From birth, children have the ability to extract patterns from the environment in their learning of causation and language (Meltzoff, Kuhl, Movellan, &

Sejnowski, 2009; also Goswami, 2008). Hence, learning is not simply the reproduction of what is perceived through the senses, but humans come with the capacity to extract concepts from the world they experience. Furthermore, constructive learning involves an alternating pattern between independent states of external focus where information is taken from the external environment, and "constructive internal reflection" where the personal significance of learning, or meaning making emerges (Immordino-Yang, Christodoulou, & Singh, 2012). The implication is that facilitation of learning by the teacher requires recognition of the need for students to alternate between engagement with the external world where the focus is on the information and the internal processes of reflection and meaning making. Curriculum needs to be designed to provide opportunities for critical and reflective thought when using digital technologies and so connect to the lifeworld of the learner.

As Squire and Stark (2008) comment, learning is a process by which neural systems are modified by experience: "Learning is the process by which new information is acquired about the world and memory is the process by which this information can persist across time." (p. 242). Likewise Sah (2013) observes that:

> All learning results from the observation, manipulation and storage of information, and the long-term impact of any learning clearly depends on the efficacy and accuracy of recall. (p. 113)

Additionally, Sah (2013) observes that memory formation is affected by the internal emotional state of an individual as well as the environment in which a person is located. Memory, like perception, is multimodal, rather than being amodal or unimodal (Arnold, 2013; Barsalou, Kyle Simmons, Barbey, & Wilson, 2003; Butler & James, 2011). Moreover, as important as cognition is for learning, it does not function in isolation from emotional and social supports:

> Modern biology reveals humans to be fundamentally emotional and social creatures. And yet those of us in the field of education often fail to consider that the high-level cognitive skills taught in schools, including reasoning, decision making, and processes related to language, reading and mathematics do not function as rational, disembodied systems, somehow influenced by but detached from emotion and the body. (Immordino-Yang & Damasio, 2007, p. 3)

According to Arnold (2013) memory is exhibited in two types: affective memory, which is to do with appraisal of good or bad experiences, and modality specific memory such as visual, auditory, sensory and motor memory. Additionally, Arnold explains that conceptual memory, or semantic memory, has to do with meaning, origin, usage and naming of experiences and supplements the other types of memory. Concepts formation is dependent on the other types of memory and is not found in a separate location of the brain, apart from modality specific stored memory. Moreover, as Duncan and Barrett (2007) explain, the separation of affective and cognitive phenomena has no basis on ontological grounds because the psychological distinction between cognition and affect is not reflected in brain architecture. Cognition can regulate and instantiate affect, and in turn, affect participates in cognition. Sensory processes are modulated by "core affect" which "plays a crucial role in all levels of cognitive processing, determining what people are conscious of, how they use and understand language, and what content is encoded and retrieved in memory" (p. 1186). Additionally, it is argued that confidence in facts regarding "the validity of experience… is rooted in core affect" (p. 1023, see also Storbeck & Clore, 2007).

The findings of neuroscience provide insight into the underlying neural structures that support human perception, the way in which experience is coded and stored for future recall and the capacity to assimilate new experience and learning into memory. Furthermore, the work of researchers such as Immordino-Yang and Damasio (2007), Duncan and Barrett (2007) and Sah (2013) emphasise that cognition and memory are not phenomena that can be isolated from affect and the social context. Additionally, both perception and memory are multimodal (Arnold, 2013; Barsalou et al., 2003; Butler & James, 2011). Memory recall involves both content and context and therefore includes the accompanying sensory and motor experiences (Damasio, 2012). It follows that the particular modalities foregrounded by multimedia will shape learner experiences and learner preferences, such as film or the moving image over written text.

Multimodality, then, is part of the way that humans perceive, make meaning from and store and recall knowledge relating to their experience and action in the world. Multiliteracies present a corollary to these aspects of human nature by asking how formal learning might be advanced by incorporating into curriculum practice the presentation of information in a variety of modes (to use the distinction between mode [the form of presentation] and modality [the senses that receive the information]) as proposed by Moreno and Mayer (2007). Hence, there are two aspects of multiliteracies relevant to the discussion of their use in a new digitally focused education. One is the appropriate and effective use of multiliteracies, that is, the combining of two or more modes of experiences in order to advance student knowledge in curriculum work (Moreno & Mayer, 2007). The other is to do with encouraging student agency by advancing their understanding and competence in their ability to deconstruct their everyday encounters with multimedia, and, in turn, increase their understanding, proficiency and creativity in their use of multimedia (Albers & Harste, 2007).

Discussion

Issues raised by the ever increasing presence of digital culture and multimedia literacies in education invite questions around the role of experience in education and the representation of knowledge, and such questions are by no means new. In 1938, Dewey published *Experience and Education* in which he argued that the quality of the design of learning experiences by teachers has implications for the quality of learning on the part of students. Dewey's argument was that high quality learning was most likely to occur when students intentionally interacted with their environment and were able to deconstruct, reconstruct and reflect upon what they encountered and observed (see also, Dewey, 1933).

High quality learning finds the active student engaging in experimenting with problem-solving strategies increasingly accessed via digital communication, rather than being a passive consumer of information. For Dewey, high-level cognitive engagement and motivation to learn could only arise from appropriately structured learning environments where the student was recognized as an active learner and meaning maker. Knowledge of the type that would underpin purposive action could not be gained though second-hand transmission. When Dewey spoke of experiential learning he had in mind a certain quality of learning experience, whether formal or informal, that becomes grist for learning. In other words, students are active learners and that learning is an active response to the digital culture with which they interact. As Mishra (2012) points out, technology must facilitate and not encumber the learning process.

Dewey's insights were the product of his own observation and reflection of learning behaviour, and are remarkably perceptive especially in the light of recent advances in neuroscience that have observed the impact of the environment (both physical and

social) on brain plasticity and development (Diamond, 2007, 2009; Diamond & Amso, 2008; Goswami, 2008). Work such as that of Diamond (2007, 2009; Diamond & Amso, 2008) emphasizes the reality of the gene-environment interaction in human development. The role of experience in learning and subsequently the multisensory nature of learning is reiterated by the neuroeducationalist Usha Goswami (2008). Szűcs and Goswami (2007) go so far as to suggest that: "education involves the shaping of individual brains via targeted experience in the classroom ('teaching')" (p.114). This insight accentuates the importance of teachers' work in designing curriculum that will be the reality encountered by students in their formal education (see Lovat & Smith, 2003). In line with Lovat and Smith teachers/educators need to be cognizant of the increasingly digital culture of the classroom, the complex nature of curriculum work and the need to factor in the innate and developed capacities of their cyborg students.

This article has sought to identify and explore issues related to the increasing pervasiveness of digital culture and the virtual world manifested through the increasing availability of multimedia technologies in small digital devices. It attempts to advance the discussion of the implications of these technologies and the use of multimedia in teachers' enactment of curriculum. Framing the curriculum implications is Lovat and Smith's (2003) notion of curriculum work which typifies it as a series of decisions that teachers/educators make regarding the content, processes and resources to be coalesced to produce engaging learning experiences. This requires teachers to have a level of mastery of the technology (Mishra, 2012) and to have an awareness of student capacities, interests and capabilities (Lovat & Smith, 2003) to aid student learning rather than these being solely used for entertainment purposes.

Curriculum design is not about the foregrounding of digital technologies but the pedagogical decisions about the interaction between modes, instructional method and sensory modalities in relation to solving problems, building concepts and selecting representational forms with which to communicate. The above can only be effective in action if there is acknowledgment of the role of the affect in cognition and in deconstructing and reconstructing ideas and information. This becomes increasingly more challenging when working with the digitally active and virtually stimulated learner who responds with the speed and complexity afforded by the digital experience. In the past these decisions have come second to content and teacher selected technologies. Furthermore, creativity and technology must be taught together and not in isolation, because creativity cannot function apart from mastery of the medium through which creativity finds expression (Mishra, 2012; Mishra & Yadav, 2013). Mishra (2012), citing the work of Root-Bernstein (1996), points out that although creativity is manifested within the discipline areas, the thinking or cognitive skills that underlie creative thinking are similar across disciplines. According to Root-Bernstein (1996) creativity is at the basis of cross-discipline thinking, with imaginative thinkers being able to translate ideas from one discipline to another. Additionally, recent psychological and neurological research affirms the place of creativity in education and its essential role in the preservation of future generations. Creativity underpins the capacities of individuals to adapt and invent for survival and the enrichment of our cultures and society (Zeki, 2001). The new digital and multimedia technologies present challenges to conventional boundaries between the various discipline areas and point to the fact that knowledge is seamless and transcends artificial boundaries. Hence, the question is raised: What influences do these prosthetic devices have on cognitive development, memory systems and mind modification (Mann, 2006) as well as personal meaning making?

Coinciding with the challenge accompanying the emergence of contemporary multimedia technology is the exponential increase in the knowledge of and understanding of the functioning of the human brain. In particular, brain plasticity and

its inherent ability to restructure itself in development and learning. This restructuring is in response to experience, the synergy between cognition and emotion, and the nature and functioning of memory. All of the above are of interest because they add to the understanding of the use of multiliteracies and multimedia as they are applied in curriculum.

Curriculum work needs to be cognizant of an array of factors in relation to the design of learning environments and experiences. Teachers need to design lessons being aware of the interaction of modes or media, the instructional method and multimodality (Moreno, 2006; Moreno & Mayer, 2007). Multimodal learning is not a recent phenomenon but is used by civilizations both ancient and modern; however the media or mode of presentation varies according to the technologies used (Spivey, 2005). Moreover, it is obvious from Spivey's commentary that these multimodal presentations, regardless of the technology involved, engage multiple senses, perception, affect, memory, problem solving, communicative purpose and performative acts. The benefits of an expanding digital learning culture and multimodal learning is that it strengthens the neural fibres between the different areas of the brain and stimulus of a single modality activates stored information of multiple modalities, but further research is needed to establish whether this represents "stronger learning" (Goswami, 2008, p. 390). Nevertheless, the evidence Goswami cites indicates that multimodal learning does influence brain structure, strengthening connections between various areas of the brain. Further research will need to address the impact of the digital memory prosthesis on the brain development of the learner. Consequently, if multimodal learning stimulates brain plasticity in different ways, then, what are the implications for curriculum?

Motivation, engagement and learning are dependent on the interplay between affect and cognition. The fine line between real world digital practices, entertainment, engagement and active constructed learning is present in the decision making of all teachers. To reduce the function of multimedia in curriculum work to that of entertainment is to miss the observation of Dewey (1938/1963) that learning requires the active engagement of learners in problem solving. One question that teachers need to hold in mind in curriculum design is: How do we actively design problem creating and problem solving learning in a digitally driven curriculum? Research needs to be carried out into the epistemological outcomes of working across modalities. In addition, are there benefits for learners when they engage in problem-solving and production via their preferred modality?

Conclusion

Given the nature and reality of digital culture with new media pervading daily life, this paper has explored some of the challenges presented for teachers' designing and enacting curriculum as they grapple with the impacts and implications for digital literacy and hence teaching and learning in contemporary educational settings. It has plotted the trilogy of elements that need to be taken into account in curriculum design. Learning in a digital culture with and through new multiliteracies requires: multimodal media; the expanded repertoire of semiotics that accompany the new digital devices; and insights into human perception, learning and memory afforded by cognitive science and neuroscience. Additionally, it has argued that curriculum design is not about the foregrounding of technologies but the pedagogical decisions about the interaction between modes, instructional method and sensory modalities in relation to solving problems, building concepts and selecting representational forms with which to communicate. This is affirmed by the research that clearly articulates that human perception is multisensory as is the encoding, storage and recall of this experience. In

other words, human perception and memory are by their very nature multimodal and digital prostheses replicate human functioning.

Multimedia technologies continue to have uptake across all generations and proliferate society. They have become more intuitive, sophisticated and developed in ways that mirror the neural processes and capacities that constitute learning. Hence, the teacher is confronted with a new array of modes through which to engage the student in learning and meaning making. Learners require interactive thinking skills, material experiences and performative practices (Kalantzis, 2006; Kalantzis & Cope, 2012). This interactive thinking encourages critical and self-reflective understandings achieved through historical, cultural and personal insights. Creating through digital design is a student-centred learning by doing approach. Such an approach supports the constructivist ideas about learning and communicating knowledge over the traditional transmission model. It concludes that pedagogies that have the most chance of success are those that take into account the synergy between cognition and affect, and are aware of the strengths, limitations of the complex nature of memory. The research favours attention to the affective and collaborative aspects of learning, capacities scaffolded by digital devices. In the classroom this would see students orientating their inquiry from a personal perspective, sharing and collaborating with others in order to discover the relational aspects of the learning and selecting and building fluency in a range of semiotic systems. In the end, engaging students through multimodal learning comes back to the teacher's depth of discipline knowledge, and their expertise, creativity and fluency in the use of media devices to represent knowledge and the ability to explicitly teach these skills and insights to their students. Furthermore, the teachers' ability to utilize their adaptive capacity to shift their pedagogies for their learners and scaffold skill development in new technologies through observation of student skills and interests is important to successful learning.

Contemporary learning situations see teachers faced with the question of how to deal with the rapid shift to a digital learning culture and the creation and implementation of curriculum that harnesses and incorporates the potential of the new technologies. A conversation with neuroscience regarding the interplay of experience, memory, cognition, emotion and reflection in learning may support the development of curriculum that matches the capabilities of the new technologies with the capacities of students.

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