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Future Directions for Digital Literacy Fluency using Cognitive Flexibility Research: A Review of Selected Digital Literacy Paradigms and Theoretical Frameworks

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Abstract: As learners engage, test, and apply new subject knowledge, they often expend their cognitive capacity on the technological tools designed to capture their learning progress and outcomes. The energy and attention spent on these tools reduces their capacity to engage deeply with new learning concepts. Digital literacy skills require both cognitive and technical skills to develop a learner's ability to locate, use, and communicate information. Increasingly complex information environments create various barriers for student learning, and as our learning and working industries continue to evolve and integrate technologies, students must overcome these barriers by bridging learning needs and technology expectations. This research explores the value of developing digital literacy to improve learners' cognitive flexibility by decreasing technological cognitive load and increasing learning fluency. The findings highlight the need for establishing scaffolded digital literacy skills and digital tool selection, and expand college readiness requirements to include digital literacy as a prerequisite skill for learners.

Keywords: cognitive, digital literacy, technology.

Introduction

Students are accustomed to and comfortable with engaging diverse digital tools for socialising, playing and shopping but there is a gap and even resistance to using digital tools to discover, design, or create in digital learning environments, and an even wider gap in ability to transfer digital knowledge across education and industry. Educators have similar challenges but also have the additional challenge of being leaders setting expectations and modeling usage of digital tools in diverse learning environments. In this context, the definition for digital literacy fluency includes both students and educators as learners.

Learners need fluency across diverse skill sets to vacillate between primary and secondary knowledge generation, and surface and deep problem solving (Paas & Sweller, 2011; Sweller, 2021). We identify three learning barriers, including digital tool adoption, digital fluency, and transfer of digital knowledge to help learners solve complex and ill-structured problems; to deal with uncertainty; and, to adapt emotionally and culturally (Pulakos et al., 2000). The aim of this research is to develop the concept of digital literacy fluency as a solution to the established barriers.

In order to help learners overcome barriers, established frameworks for digital learning need to be explored in conjunction with cognitive learning practices. For example, Bloom's digital taxonomy creates a framework of levels of cognitive learning in a hierarchical pattern from simplest to higher and more complex learning to engage, test, and apply new subject knowledge. Bloom's digital taxonomy provides "foundational action terms to describe the learning outcomes of users' interaction" in digital learning environments (Piskurich, 2015, p. 134).

Fluency in digital tool use reduces cognitive load and enables learners to become flexible and adaptable in digital environments. As learners have limited cognitive capacity, energy and attention, cognitive flexibility has been recognised as a key indicator of learning behavior in complex tasks (Alexopoulou et al., 2020). Building from learners' development toward cognitive flexibility, the aim is then to improve learners' cognitive adaptability in transferring knowledge across diverse disciplines and digital environments.

Digital literacy skills require both cognitive and technical skills to develop a learner's ability to locate, use, and communicate information in complex learning environments. Digital literacies are multifaceted, often combining diverse seemingly simple literacies to form complex skill sets aimed to address deep problem solving in digital learning environments.

Theoretical Approach

Connectivism (Siemens, 2017) is an important learning theory and the underlying theoretical approach that is used to ground the premises of this research. This theory "is positioned as a new philosophy of education for the digital age" and includes "learning that lies outside the learner, in social networks and technological tools" (Mattar, 2018, p. 201). Connectivism is formed from the fundamental ideas in constructivism, behaviorism, and cognitivism and relies heavily on the works from three foundational psychologists: Jean Piaget, John Dewey, and Lev Vygotsky. Jean Piaget's theories center learning on the individual through interactions between ideas and experiences and is evidenced through his theory of cognitive development as a progressive process through four stages. John Dewey's theories on education builds on Piaget's cognitivism by including learning through real world activities and inquiry sustaining learning. Lev Vygotsky similarly focused his theories on individual ideas and experiences but also includes the social aspects of learning through experiences. His concept of zone of proximal development (ZPD) (Vygotsky, 1978) identifies a virtual space between what a learner already knows and what they cannot know without an instructor. The common beliefs among these theorists is that "learning is active, not passive; language is an important element in the learning process; and learning environments should be focused on the learner" (Mattar, 2018, pg. 205). These theorists founded constructivism before learning environments became deeply integrated with technology and hyper-social environments. Both of these elements have altered our approach to learning formally and informally.

This research uses connectivism to account for the incorporation of learners' cognitive capacity and digital literacy and the flexibility between these abilities. Learners' cognitive capacities are by nature dynamic and influenced by diverse learning environments (Adam-Turner & Burnett, 2018), and connectivism is the preferred theory for a digital age. Connectivism supports learners' ability to actively acquire knowledge and appropriately communicate across various culturally and socially diverse digital platforms.

Cognitive Adaptability

Our society and learning environments dynamically change and are influenced by rapid increases in scientific knowledge and workplace demands for twenty-first century skills. At every stage of learning, we are faced with competing demands for attention when learning with technology and cope by developing diverse learning strategies. The "ability to adapt our thinking, drive, and emotions to changing and novel problem situations has become essential (Scherer, 2015, p. 1). VandenBos (2007) defined adaptability as the "capacity to make appropriate responses to changed or changing situations; the ability to modify or adjust one's behavior in meeting different circumstances or different people" (p. 17).

Cognitive Capacity

Creation of new knowledge in complex learning environments requires access to both working memory and reasoning. Humans are adapted to making optimal use of available information but we have natural limits to our cognitive capacity and are cognitively affected by the level of complexity for diverse activities. Overwhelmingly complex tasks, as in learning new technology or problem solving, can harvest negative feelings toward educational digital technology use, which decreases working memory capacity and cognitive capacity, ultimately decreasing cognitive flexibility for engaging in new learning concepts (Ou et al., 2018).

Cognitive Flexibility

Cognitive flexibility is the human ability to adapt the cognitive processing strategies to face new and unexpected conditions in the environment (Cañas et al., 2003). It is also defined as "the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands" (Spiro & Jehng, 1990, p. 165). This definition involves three important concept characteristics. Firstly, cognitive flexibility is an ability that could imply a process of learning, that is, it could be acquired with experience. Secondly, cognitive flexibility involves the adaptation of cognitive processing strategies. The principle of cognitive flexibility refers to the working system of the human brain, wherein all the information obtained is stored in memory which can then be recalled when needed to be rebuilt into new knowledge under different conditions (Jones & Day, 1997; Cloonan & Fingeret, 2020). So, it can be concluded that cognitive flexibility is the ability to think about things in different ways, and relation to the learning process should be able to improve cognitive flexibility.

To improve and/or enhance a learner's cognitive flexibility in today's diverse learning environments immersed with learning technological tools, studies have shown that regular and repetitive mental stimulation using technology is a reasonable tool that results in improved cognition, focus, and task-switching (Alexopoulou et al., 2020). At the same time, today's learners are overwhelmed with the task of learning new technologies, which can be discouraging thus decreasing cognitive capacity for engaging in learning new concepts. Ou et al. (2018) describe that positive (activating) moods can "increase working memory capacity, thereby facilitating cognitive flexibility and restructuring, as well as more deliberate, analytical, and focused processing and combining of information" (p. 741). On the contrary, negative factors that affect mood, such as fear and anxiety in learning a new technological tool, can lead to decreased ability to shift attention, limited cognitive categories (cognitive capacity), and reduced cognitive flexibility (Ou et al., 2018). That is, when engaging in learning new

technological tools, learners' experience with their task can directly impact cognitive capacity ultimately affecting cognitive flexibility.

Digital Literacy

Our global society is learning to adapt to rapid technological changes from print to digital information sources which is altering our digital information seeking behavior. As information is presented in many forms across a growing plethora of sources, most learners must be taught how to find, sort, evaluate, integrate, and share digital information for different audiences. While most learners, regardless of age, are competent at navigating the internet for general information, asking them to use the same tool for educational purposes such as analysing, evaluating, and creating with digital information exposes learning barriers.

Digital Literacy continues to be the keystone literacy for learners navigating blended formal and informal learning environments. It was defined by Paul Glister in 1997 as "the ability to understand and use information in multiple formats from a wide range of sources when it is presented via computers" (Glister, 1997, p. 1). Since then, the definition has dynamically shifted based on the innovations of the platforms of retrieving, processing and using information (Jantijes, 2019). The American Library Association currently defines digital literacy as "the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills" (ALA, 2022, para. 1). Researchers are beginning to also include social elements in addition to cognitive and technical, such as Stordy's (2015) definition of digital literacy as "the abilities a person or social group draws upon when interacting with digital technologies to derive or produce meaning, and the social, learning and work-related practices that these abilities are applied to" (p. 472).

Digital literacy is a "much-needed prerequisite for students to excel in a blended learning environment" (Tang & Chaw 2016; Techataweewan & Prasertsin 2017; Anthonysamy et al., 2020, p. 2394) and imperative for educators and students alike, to be efficient in digital societies (Al-Qallaf & Al-Mutairi, 2016). Students enjoy focusing on technologies that they are already comfortable using in their personal life and the interactive aspects of digital tools, yet they are not quite sure how they contribute to their learning (Duffy & Ney, 2015; Neier & Zayer, 2015; Tovin, 2017). Nearly 80% of young individuals use the internet only for social activities, but use of technologies for education purposes has been very low (Abbas, Hussain, & Rasool, 2019).

Colleges and universities are seeing gaps in perceived digital literacy readiness expectations among faculty and students. While students are perceived as engaged with digital technologies and presumed proficient, they lack the digital literacy skills necessary to meet the learning objectives in digital tools equipped learning environments (Muresan & Gogu, 2013).

Digital literacy requires both cognitive and technical skills "to make effective use of technology for learning, one needs to have a certain level of digital literacy (Tang & Chaw, 2016, p. 1). The characteristic of being digitally literate extends beyond digital skills with hardware and software and includes a broader mastery of competencies including cognitive, technical and socioemotional learning in diverse learning environments (Ng, 2012). To be considered digitally literate, an individual needs to develop multiple literacies which then shape functional skills, values, attitudes, and

behaviors around information discovery, integration, creation, and dissemination (Mohammadyari & Singh, 2015).

Digital Literacy as a Complex Skill

Perceptions of digital literacy are inconsistent due to a wide diversity of definitions and relationships among adjacent literacies. The way we discover, share, and apply information has fundamentally changed as we continue to develop diverse media sources, rely on the abundance and immediacy of information, and practice social filtering (Storksdieck, 2016). Diverse organisational systems exist throughout the research to establish boundaries for literacies that are directly and adjacently related to digital literacy including but not limited to Hague and Payton (2011), Belshaw (2011), Ng (2012), and Spires and Bartlett (2012). Common adjacent literacies include computer and technology, media and new media, and information literacy. Digital literacy models can be categorised into two areas, government policies for broad societal change and higher education andragogy and praxis. The theme across digital literacy models is the inclusion of literacies adapted to and generated from digital learning environments at the intersection of critical technical and reasoning skills. While scholars focus on different dimensions of digital literacy, "individual differences in cognitive ability may well explain different types of digital media skills [. . .] for expressing the technological, social, and cognitive skills required in digital environments" (Atoy et al., 2020, p. 1016).

While digital literacy is becoming recognised as a central gateway and empowering agent in academia (Radovanović et al., 2015). a major barrier to improving digital literacy is the digital divide. Access to technology as well as training on digital tools also create a divide of literacy and skills (Haythornthwaite & Andrews, 2007; Radovanović et al., 2013; Van Dijk, 2005). Students as future global citizens will require interaction and training with digital tools to communicate in an efficient and ethical manner. According to Atoy et al. (2020), "people with high levels of digital literacy are more active in social affairs; are better able to express their opinions; and are able to search and understand desired information, express, share opinions or thoughts freely, and have a better understanding of those of others" (p. 1016). Higher education plays a key role in acquiring the skills necessary for students to be properly integrated into the professional context; however, despite the constant adaptation of new technologies and methods of social interaction across industries and academic disciplines, many higher education institutions have not yet fully embraced digital literacy as a fundamental literacy (Caldevilla-Domínguez et al., 2021). The guiding motivation for changing the way students learn is that they should be better prepared for college, career, and civic engagement in a pluralistic and democratic society that puts considerable emphasis and trust into the notion of ''informed decision-making'' by all. To do this, higher education institutions must rethink ways to speed up the quality of learning by fostering digital literacy (Abrosimova, 2020).

Complex Information Environments

The information environment is becoming more complex with the growth of access to information sources, expanding media and technologies, and responses to diverse information presentation strategies (Thompson, 2013). The development of increasingly complex information environments reshapes our approach to diverse literacies, going so far as to evolve the initial concept of literacy from a simple ability to read and write to requiring mastery of diverse `skill-based literacies'. Digital literacy is evolving from the plethora of new technologies and a wider variety of media and services

"showing that, as with literacy itself, these seemingly simple forms of literacy require a wide spectrum of skills, knowledge, understanding and attitudes" (Bawden, 2001, p. 226). Digital Literacy as a threshold concept is troublesome as mastery requires a complex combination of skills through a non-intuitive process, "reveal[ing] the true complexity of the information environment in which students find themselves" (Bingham et. al., 2017, p. 438). Current learners are the first generation to grow up in a digital world using digital tools primarily for social and collaborating purposes and "in this highly interconnected and technologically rich world, university students need to acquire more skills, adaptability, and flexibility to prepare themselves for the future workplace" (Anthonysamy et al., 2020, p. 2394). Increasingly complex information environments create the cascading barriers for student learning, as discussed in the next sections.

Digital Tool Adoption

Technology, as the driving force of educational processes, has transformed the teaching–learning landscape and changed the ways students and teachers think, perform, interact and process information (Raymundo, 2020, p. 224). Digital technologies are pervasive and students are "exposed to a plethora of information, yet they lack the ability to incorporate those in academics" (p. 237) yet failing to gain meaningful and constructive learning experiences that can be acquired with the use of digital tools in conjunction with traditional pedagogies (Amin & Mirza, 2020). In conjunction with increased use of technologies in learning spaces, a number of challenges with digital tool adoption have emerged. This research has focused on few of them, namely scarcity of time, attitude towards digital tool use, and the dual information technology (IT) roles of instructors (with limited institutional support).

Technology-aware learners in both virtual and physical learning environments demonstrate strong task switching skills but are challenged by scarcity of time. Digital tool adoption requires keeping up with constant change, and applying new teaching strategies linked to technology, pedagogy, and instructional plan (Kundu & Bei, 2021). This forces teachers and students to shift their routines, including concentration, focus, and attention span while learning, and implementing and operating digital technologies. Blended learning environments require learners to become proficient in digital literacy but as this is a complex skill, learners often adopt digital tools without considering the time commitment through proper vetting. Inadequate preparation can lead to reinforcing established negative or positive attitudes about digital tool adoption.

Attitude among learners about digital tool use and the desire to modify current teaching and learning practices directly affect the integration and implementation of digital tools in the digital learning environments (Wohlfart et al., 2021). The correlation between positive attitude and digital tool adoption is a common theme in the research. A positive attitude among learners fosters an increase in available cognitive capacity, and assists in expanding cognitive flexibility to afford restructuring processes that are deliberate, analytical, and focused (Ou et al., 2018). On the contrary, a negative attitude toward digital tool use and adoption hinders the integration process. Heterogeneity among the learning population also has impact in terms of divergent attitudes towards digital tool application, understanding, and integration in learning environments (Wohlfart et al., 2021). While instructors are aware of the diversity of learners' limitations, few consider these limitations in digital

tool adoption. Positive attitude towards digital tool use combined with fully functional infrastructure for schools, students, and teachers alike can strengthen digital tool integration (Wohlfart et al., 2021).

Instructors' are challenged by the use and integration of digital tools that are considerate of the diversity of accessibility among students. Further, crisis-induced changes influence instructors to evaluate their role using digital tools for distance learning, and reconsidering and challenging educational norms (Lockton & Fargason, 2019; Wohlfart et al., 2021). Instructor and learner support and training are important in influencing technology adoption and to "broaden students' conceptualisations of and approaches to learning" (Lai et al., 2012, p. 577). The assistance of associated infrastructure and digital support teams affect the adoption, integration, and acceptance of digital tools.

Digital Fluency

While digital technologies are is easily accessed by people everywhere, lthe iterature has long identified the risk of a 'fluency gap' due to learners' inability to use the technology fluently (Resnick, 2001). Digital fluency is defined as the ability to leverage technology to create new knowledge, new challenges, and new problems and to complement these with critical thinking, complex problem solving, and social intelligence to solve the new challenges (Wang et al., 2013). Therefore, learners must diligently engage in the use of technologies educationally and personally to fully maximise the potential of technologies for education (Lai et al., 2012) and close the fluency gap (Wang et al., 2010). Competency, perceived correlation between technology use and study demands, educational technology resource potentials, and available support in digital tool learning environments influence learners' use of technology for learning and digital fluency. Therefore, digital fluency requires excellent "communication skills, new media literacy, and cognitive load management to address the issues, and concerns we face today and in the future" (Peacock, 2020, para. 1).

Learners need to develop media literacy skills as a component of digital literacy to be prepared for a world that expects them to be digital citizens, which includes the ability to use technology safely, responsibly, critically, productively and civically (Takavarasha et al., 2018). Media awareness, or media literacy, is a multidimensional critical thinking skill (Leaning, 2017; Potter, 2010) and is defined as a "movement, designed to help to understand, to produce and negotiate meanings in a culture of images, words and sounds [...] a critical autonomy relationship to all media". (Koltay, 2011, p. 212). The cultivation of media literacy is necessary for learners' communication and navigation in digital environments. Learners with higher levels of media literacy are better equipped to analyse media using critical thinking (Luo et al., 2022). Therefore, new media literacy education enables learners to build media awareness, approach media in a more critical manner while mitigating the negative effects of misinformation in media (Al-Zou'bi, 2021; Luo et al., 2022). As learners become more engaged with media (digital technologies), they take on a "more active construction, creation and sharing in media participation" (Luo et al., 2022, p. 2).

Another component for achieving digital fluency is cognitive load, which refers to the demand of complex tasks, such as navigating digital tools and technology in learning spaces, on working memory (Sweller et al., 1998). Learners seeking solutions to a learning problem often begin problem solving by analysing surface structures for commonalities and use general means-end problem solving strategies. Primary information, knowledge, skills, and processing provides learners surface-

level problem solving abilities that progressively shift to enhance secondary knowledge and skills for deeper problem-solving (Paas & Sweller, 2011; Sweller, 2021). However, situations that induce high levels of cognitive load, such as deep problem-solving, can impede learning and efficient performance on designated tasks (Chen, et al., 2012). The natural information processing system established that learners "acquire novel information, process and store it before retrieving it from storage to govern action that is appropriate for the environment" (Sweller, 2020, p. 4). Digital fluency is the ability to reformulate knowledge and produce information to express oneself creatively and appropriately in a digital environment (Wabg, Myers, & Sundaram, 2013). The establishment of positive attitudes toward digital tool use and integration increases cognitive capacity and enhances cognitive flexibility among digital learners. Learner training, institutional infrastructure, and repetitive mental preparation promotes an increase in cognitive capacity and cognitive flexibility which can lower cognitive load to foster digital fluency (Ou et al., 2018; Alexopoulou et al., 2020).

Digital Literacy Fluency

For learners to be successful in today's increasingly complex information environments, they must master the ability to navigate digital technologies and work toward addressing complex problems. Critical thinking, problem solving, and social intelligence are new skills required of future learners. Teaching learners to manage cognitive capacity and cognitive flexibility creates opportunity to develop mastery in their domain knowledge and competency as global citizens. However, learners have limited cognitive capacity for navigating, retaining, and developing new knowledge using educational digital tools. At the same time, learners show decreased cognitive flexibility due to reduced efficiency of working memory toward complex tasks and increased complexity of task-switching. To address the concerns we face today and in the future, educators and students need to develop greater digital fluency to become informed global citizens who can utilise digital educational technologies, navigate within digital learning environments, and display communication competencies.

Learners are immersed in technologies daily for personal use. Interaction with smartphones and personalised virtual assistance technologies, such as Alexa and Siri, are common practices when seeking digital information. Learners of all ages are comfortable and proficient in steering through the internet for basic information. However, learners often lack the skills to utilise the same tool to find, sort, analyse, evaluate, create, and share digital information. Learners use technologies for entertainment and social interaction, yet the use of digital tools and proper use of educational technologies is unclear (Shopova 2014; Anthonysamy et al., 2020; Tovin, 2017). As learners blend personal and educational use of digital technologies, the ability to understand and use acquired digital information is necessary (Glister, 1997). Learners must also understand how both malicious and benevolent information architecture manipulates their behavior in online spaces. Disinformation and manipulation through technology architecture can be mitigated through increased digital literacy as a means of cognitive resistance to manipulation (Kozyreva et al., 2020). Therefore, digital literacy is a prerequisite for learners to efficiently navigate these blended learning environments (Techataweewan & Prasertsin 2017; Anthonysamy et al., 2020).

To navigate constantly evolving digital environments, learners must be fluent in digital technologies which is a cumulation of information literacy, technology literacy, media literacy, and digital literacy.

The digital world has created a shift in traditional definitions of literacy, prompting "new" forms of literacies to evolve (Buschman, 2009). However, "there is no single literacy that is appropriate for all people or for one person over their lifetime and that would not require a constant updating of concepts and competences in accordance with the changing circumstances of the information (digital) environment" (Koltay, 2011, p. 219).

Conclusion

This research explored digital literacy as a catalyst for increasing learner's adaptive cognitive flexibility. This research explored the value of developing digital literacy fluency using digital educational tools. Learning environments both online and offline require learners to develop fluency in complex literacy skills. The learners' relationships among new literacies is dynamic and dependent on the learner's application and skill level of each literacy in order to create meaning through a combination of literacies. The ability to learn with these complex literacies is complicated by rapid diversification of online information presentation strategies. Digital information is not presented in a consistent manner and learners must constantly task their working memory to sort the information and simultaneously work toward mastery of highly related but diverse literacies. Mastering multiple literacies is complicated first by complex information architecture and second by the spectrum of individuals' knowledge and attitudes toward learning and technology. The goals are for the learners to develop beyond surface knowledge into deep knowledge and discover their path through the non-intuitive processes for navigating, selecting, and incorporating new information into new knowledge. Digital Literacy is a culmination of complex relationships among literacies and complex learning attitudes and environments.

Learners' ability to transfer knowledge technically, socially, and cognitively across disciplines and industries using digital literacies is the culmination of skills needed for digital literacy fluency. Learners' ability to transfer personal digital technology use skills to educational practice is often lacking. Lifelong learners need to be able to apply, deconstruct, and synthesise new knowledge throughout their lifetimes to become culturally informed and ethical global citizens.

Future research into cognitive flexibility could establish digital literacy as a core skill for learners in the digital age and provide additional tools for educators to understand how we can increase learning efficiency. The findings highlight the need for future research to develop assessment tools determining the relationship among digital literacy fluency and cognitive flexibility. These studies could develop this research further by exploring how we 1) curate positive attitudes toward technology and digital learning environments; 2) measure cognitive flexibility and adaptability; 3) deep problem solve using digital literacy skills; and, 4) develop a sense of global citizenship. As our learning and working industries continue to evolve and integrate digital technologies, students must overcome learning barriers to become discerning citizens and scholars by bridging learning needs and technology expectations with disciplinary content in order to achieve educational and career success.

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