

Investigating Working Memory in Educational Research

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Abstract

The twenty-first century higher education students are expected to possess requisite generic skills and competencies and proffer solutions to everyday challenges within the shortest time frame. These generic skills such as problem-solving skills, communication skills, and interpersonal skills are required in the workforce in order to be relevant in global decision making. Students, in turn, must develop their cognitive processing skills in order manifest these generic skills. Additionally, the recent introduction of neuroscience in the psychology parlance has application transcending across clinical, social, developmental, and educational psychology. Within educational psychology, centrally sits a cognitive information processing system termed working memory which is still evolving and better explaining human behaviour and learning. Working memory can be broadly defined as a multi-component system responsible for active maintenance of information in the face of ongoing processing and/or distraction. The main objective of this conceptual paper is therefore to elucidate the importance of this essential construct in educational research.

Keywords : Working Memory, Higher Education, Twenty-First Century Expectations, Generic Skills

INTRODUCTION

The primary aim of higher education (HE) is to educate (Barnett, 2007; Altbach, 2011; Boud & Falchikov, 2006; Astin, 1985) including a progression to higher order domains of cognitive learning (Altbach & Knight, 2007); inculcation of interpersonal and intrapersonal qualities otherwise referred to as generic skills (Barnett, 2007) and service to the society (Boud & Falchikov, 2006). The Malaysian national policy on education is in line with this aims as it is stated as “the holistic development of character and capabilities, the acquisition of specific skills, the realization of intellectual, physical and spiritual potential, and the training of human capital” (MOHE, 2009) as well as having her second objective for Malaysia HE being producing marketable students (MOHE, 2010). It is evident from these aims that higher education concerns itself not only with professionalization but also producing globally relevant employable graduates that can advance the economic and technological competitive edge of their nations. This is by preparing her students for a largely unknown future through the application of generic skills to novel situations.

Generic skills otherwise known as soft, transferable, key or core skills encompass varied skills and competencies such as time and environmental management (Biggs, 2003), problem-solving skills, communication skills, information gathering skills and interpersonal skills (Mosaku & Mohd. Najib, 2010) to mention a few. These skills are evident in attributes such as, team working, networking, self-confidence, coping with unexpected challenges that the twenty first century workforce requires in addition to academic qualification. Its underlying assumption is that they may be developed independent of context, hence ensuring its transferability and applicability across events and tasks.

These generic skills, believed to aid students’ ability to take ownership of their own learning, resulting to independent and life-long learners and higher employability rate, are mostly derived from psychological factors. Moreover, when compared with the traditional academic measures used in the admission process (i.e., standardized test scores and high school academic performance) with respect to their ability to increase minority admissions; to predict academic problems and performance; and also reduce attrition of all students, these psychological predictors, that generic skills emanates from, resulted in higher “hit” rates meaning accurate predictions of academic or retention problems.

From the premises of learning theories, cognitivism explains the psychological nature of learning that supports generic skills inculcation. Learning from this point of view is asserted as an information-processing system that is likened to a computer with short-term memory, long-term memory and working memory as the three storage systems. Learning from this paradigm is determined by the beliefs, expectations, and anticipations individuals have about future events while their actions is believed to be purposeful, goal-directed, and based on conscious intentions. New learning is attained by the reorganization of the cognitive structures (schemata). Piaget (1971) approach has most influenced this learning theory as it explains that information from the environment is acted upon, actively reconstructed through assimilation and accommodation after cognitive dissonance before equilibrium is reached. Vygotsky added two important elements which are zone of proximal development and scaffolding.

Furthermore, WM representing neurological concept from the branch of cognitive educational psychology is gaining prominence (Baddeley, 2000), especially as its impact on learning. Only few studies have however linked it to general students as most discussion is centred on attention deficiency/ hyperactive cases and even fewer to post-secondary students.

WORKING MEMORY

Working memory (WM), being one of the three storage system, is a system that simultaneously stores and manipulates information temporary for brief periods of time, which is what is essentially required in many real-world and high-level cognitive activities (Davis, 2011; Jarrold & Towse, 2006; Schweitzer, Hanford & Medaoff (2006; Alloway, Gathercole, Kirkwood & Elliot, 2009; Baddeley, 1992). It is conceived as one of the executive functions responsible for goal-directed and problem-solving behavior (Pennington & Ozonoff, 1996). Although working memory shares a neuroanatomical association with the frontal lobes, current evidence suggests that in cognitive terms at least, it is distinct from other executive functions such as inhibition (Oberauer, 2005; St. Clair Thompson & Gathercole, 2006) and has a separate link with learning. Barch, Carter, Arnsten, Buchanan, Cohen, Geyer, Green, Krystal, Nuechterlein and Robbins (Barch, Carter, Arnsten, Buchanan, Cohen, Geyer, Green, Krystal, Nuechterlein & Robbins, 2009) also added that WM is the building block of all higher cognitive functions, underlying things like abstract thought and executive functions including multitasking - juggling several activities at once situated in a highly-evolved area of the brain called the pre-frontal cortex.

WM has proved to be a very useful, scientifically sound construct (Cowan, Elliot, Scott Saults, Morey, Mattox, Hismajatullina & Conway, 2005) explaining twenty first century cognition models (Anderson, Costa & Kallick, 2008) of cognitive behaviours, such as problem solving, reasoning and comprehension (Engle & Kane, 2004). Its capacity also accounts for differences across individuals (Cowan, Elliot, Scott Saults, Morey, Mattox, Hismajatullina & Conway, 2005). Poor working memory leads to failures in simple tasks such as remembering classroom instructions (Engle, Carullo & Collins, 1991) to more complex activities involving storage and processing of information and keeping track of progress in difficult tasks (Alloway, Gathercole, Kirkwood & Elliot, 2009; Gathercole, Alloway, Willis & Adams, 2006).

Everyday mundane activities that demand WM include among others following directions, mentally adding up the total amount spent while selecting items from the supermarket shelves and remembering to measure and combine the correct ingredients when the recipe is no longer in sight (Davis, 2011). In the academic setting, it is termed the "workbench of cognition"¹⁷ as it aids solving mathematical questions at times requiring multiple operations and withholding certain information required in comprehension of passages.

DIFFERENCES BETWEEN WM, SHORT TERM MEMORY (STM) AND LONG TERM MEMORY

In literature, both short term memory and working memory are often used interchangeably, but the main difference lies in their varied ability to manipulate and integrate information to achieve a cognitive goal (Davis, 2011). WM can predict cognitive behaviours needed for reading comprehension, problem solving, and reasoning, primarily because of its general executive function ((Cowan, Elliot, Scott Saults, Morey, Mattox, Hismajatullina & Conway, 2005). General executive function implies withholding information in a high active phase especially during interference whereas STM is meant for domain-specific temporary storage. Additionally, WM tasks involve complex span tasks while simple span tasks are administered in STM tasks. Alternatively, Researchers such as Runckin, Grafman, Cameron & Berndt (2003) describe WM as activated long term memory.

THEORETICAL MODELS OF WORKING MEMORY

i. Baddeley's Model of Working Memory

The most commonly accepted WM model is the Baddeley's model which was revised by the same proponents twenty years after the initial formulation in 1994 (Baddeley & Hitch, 1994) and further refined by Baddeley at the onset of the twenty first century (Baddeley, 2000). He postulates that WM as a hypothetical limited capacity system that provides the temporary storage and manipulation of information that is necessary for performing a wide range of cognitive activities. A second assumption is that this system is not unitary but can be split into an executive component and at least two temporary storage systems, one concerning speech and sound while the other is visuo-spatial. Both executive components are tightly interlinked within the WM and loosely linked to other systems such as the long term memory (Baddeley, 2012).

The model consists of a central executive that control attention, processing, and phonological loop; the visual-spatial sketchpad; and the episodic buffer as subsystems (Alloway, Gathercole, Willis & Adams, 2004). The functions of the central executive are numerous and these are:

- a. Selective attention in which the ability to focus on the relevant information while inhibiting disruptions is manifested.
- b. Switching, portrayed as the capacity to coordinate several cognitive activities at once.
- c. Allocating resources to other parts of the working memory.
- d. Temporarily retrieving, storing and manipulating information from long-term memory.

The central executive is the most complex component of WM capable of attentional focus, storage, and decision making (Baddeley, 2012) while the phonological loop is a limited-capacity verbal storage system which needs further rehearsal or storage in long-term memory. The visual-spatial sketchpad is responsible for processing and maintaining visual or spatial information especially in reading and while imagining. Like both the phonological loop and visual-spatial sketchpad, the episodic buffer is a temporary storage system but encodes the information processed from other sources such as the phonological loop and visual-spatial sketchpad into the long-term memory (Baddeley, 2004; Dehn, 2008).

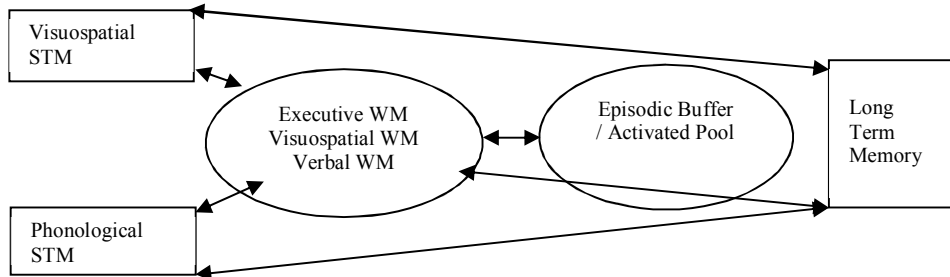


Figure 1.1 Assessment Model for Working Memory adapted from Dehn, 2008

The central executive is the most complex component of WM capable of attentional focus, fluid reasoning, decision making, and storage (Baddeley, 2012) while the phonological loop is a limited-capacity verbal storage system which needs further rehearsal or storage in long-term memory. The visual-spatial sketchpad is responsible for processing and maintaining visual or spatial information especially in reading and while imagining. Like both the phonological loop and visual-spatial sketchpad, the episodic buffer is a temporary storage system but encodes the information processed from other sources such as the phonological loop and visual-spatial sketchpad into the long-term memory (Baddeley, 2004; Dehn, 2008).

ii. Cowan's Embedded Processes Theory

Cowan's Embedded Processes Theory (Cowan, 1995) defines WM as "cognitive processes that are maintained in an unusually accessible state". His theory involves a limited-capacity attentional focus of four chunks or episodes, with each having more than a single item (Cowan, 1995). He stresses the link between the Central Executive and the episodic buffer.

iii. Daneman and Carpenter (1980) WM Theory

They stress features of complex span measures as it explains the differences across students in order to predict cognitive performance so effectively but in correlational studies. Research focus of this theory borders on investigating complex span measures including utilization of gaps between processing operations (Barrouillet, 1996) efficiency at switching between the various tasks in order to undermine time based decay or emphasis on interference rather than on decay (Saito, 2004; Towse, Redbond, Houston-Price & Cook, 2000).

iv. Engle's WM Model (1991)

Emphasis is placed on inhibitory processes as they argue that it shields the memory content from potential disruption in both experimental and quasi experimental studies (Engle, Tuholski, Laughlin & Conway, 1999). Researchers like Kane, Hambrick, Tuholski, Wilhelm, Payne & Engle (2004) also undertook quasi experimental studies before streamlining the participants for experimental study. Argument that the scope of the theory (inhibitory processes) is too narrow to explain executive processing was made by Baddeley (Baddeley, 2012).

Summarily, Baddeley (2010) asserts that most theories focus on executive control in individual processes but personally acknowledge the contributions of separate visual and verbal STM components as well as most theories have similar concepts obscured by terminologies.

EMPIRICAL STUDIES LINKING WORKING MEMORY TO EDUCATION

With its origin in psychology, empirical studies based on WM is evolving and cutting across not only clinical (neurobiological) but also on behavioural studies encompassing developmental, cognitive and educational psychology (Baddeley, 2012). Table 1.1 illustrates some researches of clinical and developmental disciplines.

Table1.1 : Research on WM

Discipline	Research area and author
Clinical	<ul style="list-style-type: none"> • Depression [32] • Stress [33] • Alcohol consumption [34]
Developmental	<ul style="list-style-type: none"> • Development of cognitive abilities in general [35] • Cognitive-aging effects [36]

As this paper is primarily educationally oriented, review of behavioural literature alone concerning WM investigation will be reported in areas such as fluent reading, the development of WM in children, and the effects of aging. WM in a correlational study between WM measures and capacity for prose comprehension necessitated the combination of temporary storage and processing in predicting performance on cognitive tasks ranging from comprehension to complex reasoning and from learning a programming language to resisting distraction (Engle, Tuholski, Laughlin & Conway, 1999; Daneman & Merikle, 1996) WM capacity was also found to be independent of environmental factors or learned skills (Gathercole, Pickering, Knight & Stegman, 2004). Researchers has also found WM to predict future academic success even than IQ as a direct correlation existed among students' scores on working memory assessments and national curriculum tests (Gathercole, Pickering, Knight & Stegman, 2004); WM was likewise found to explain the variance in reading comprehension better than verbal ability, vocabulary knowledge and word reading skill (Cain, 2006). However, as highlighted before, most research is primarily on children and up to secondary education.

The factors inhibiting WM operation include distractions and doing something else while trying to hold information in working memory (Gathercole & Alloway, 2008) as information lost cannot be retrieved but will have to start the task afresh. Similarly, normal cognitive development of individuals can affect their WM capacity (Gathercole & Alloway, 2008). WM capacity, in turn, is directly significant to performance on cognitive tasks. Another factor is individual differences in processing information as speedy and efficient processing reduces storage time and vice versa.

WM IN LEARNING DISABILITIES

Students identified as having low WM capacity forget instructions, showed inability to combine store and process tasks simultaneously; occasionally losing track in complex tasks (Gathercole & Alloway, 2008) which eventually has effect on the academic progress of these students. Comparative study of Cornish, Wilding and Grant (Cornish, Wilding & Grant, 2006) also affirm that attention exhibits differences in working memory function which is also attested by Dehn (2008) that a principal operation of working memory is maintaining attention on the task at hand. The same effect was established especially when the WM was overloaded though in young adults' sample population.⁴¹

CONCLUSION

Individual student's working memory capacity directly impacts an individual's performance on cognitive tasks and, consequently, influences a student's performance in HE. As HE's purpose comprise an amalgamation of connective interdisciplinary knowledge areas and a generic core of knowledge, skills and processes which is strongly promoted from the business, industrial as well as educational stakeholders (CBI, 1993) it refers, at the individual level, to the need for an understanding of the social, cultural, political and economic implications of any knowledge or skill in its context, and how, through such a concept of education, an individual can learn knowledge, specific skills expected, and the capacity to take initiatives, whatever their specific occupation or position. It also promotes democracy, creating active citizens who can solve all kinds of social and economic problems in heterogeneous contexts. All these demands more from students in terms of competence and skills especially as they are confronted with more information, facts, evidence, arguments and tasks than they need. Cognitive processes of which working memory plays a central role is thus a sine qua non. Further delineation of this construct, its operationalization, measurement and evaluation will be addressed in future publications.

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