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# Visualization, inductive reasoning, and memory span as components of fluid intelligence: Implications for technology education

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ABSTRACT

The philosophy and epistemology of technology education are relatively unique as the subject largely focusses on acquiring task specific relevant knowledge rather than having an explicit epistemological discipline boundary. Additionally, there is a paucity of intelligence research in technology education. To support research on learning in technology education, this paper describes two studies which aimed to identify cognitive factors which are components of fluid intelligence. The results identify that a synthesis of visualization, short-term memory span and inductive reasoning can account for approximately 28% to 43% of the variance in fluid intelligence. A theoretical rationale for the importance of these factors in technology education is provided with a discussion for their future consideration in cognitive interventions.

## 1. Introduction

Considering learning as "a change in long-term memory" (Kirschner, Sweller, & Clark, 2006, p. 75) which "involves the acquisition of knowledge" (Mayer, 2002, p. 226), it is important, within specific educational contexts, that appropriate pedagogical strategies are identified which can support knowledge acquisition. In adopting this view of learning it is also important that knowledge is considered broadly to describe multiple types of knowledge including, for example, declarative knowledge, procedural knowledge, strategic knowledge, and wisdom (Gorman, 2002). Furthermore, knowledge can be both tacit and explicit (Collins, 2010). In relation to learning, the Organisation for Economic Co-operation and Development (OECD) noted how, for more than a century, approximately one in six students reportedly dislike school, don't attain sufficient levels of literacy and numeracy to become securely employable, and have disrupted or withdrawn from lessons (OECD, 2002, 2007). From this they speculate that the traditional education system may be "brain-unfriendly" and may be offending one in six learners (OECD, 2007, p. 156).

While the OECD's report predominantly focuses on an agenda to translate and apply neuroscientific evidence within education, it acknowledges the capacity of cognitive psychology to contribute to understanding learning processes. One area of cognitive psychology which is often contextualised in understanding learning is the area of individual differences. Individual differences in learners can describe cognitive, conative, physical or physiological differences (Manichander, 2016). Individual cognitive differences have long been acknowledged as critical within education (Cronbach, 1957; Paterson, 1957) and now typically describe differences in relation to cognitive factors (Carroll, 1993; Kvist & Gustafsson, 2008; Schneider & McGrew, 2012). This paper focusses predominantly

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on one such factor, fluid intelligence, and its relationship with other cognitive factors, with the aim of contributing empirical evidence to support technology education research and practices. Fluid intelligence can be defined as "the use of deliberate mental operations to solve novel problems (i.e., tasks that cannot be performed as a function of simple memorization or routine)" (Primi, Ferrão, & Almeida, 2010, p. 446). These include drawing inferences, concept formation, classification, generating and testing hypotheses, identifying relations, comprehending implications, problem solving, extrapolating, and transforming information (Kane, 2005; McGrew, 2009; Primi et al., 2010). Along with crystallised intelligence, defined as "accessible stores of knowledge and the ability to acquire further knowledge via familiar learning strategies" (Wasserman & Tulsky, 2005, p. 18), it is one of the two general factors of intelligence posited in the Gf-Gc theory (Cattell, 1941, 1943).

Technology education is a relatively unique discipline due to its epistemological fluidity (Norman, 2013). Contemporary technology education is acknowledged to have the potential to develop and deliver outcomes of autonomy, creativity, problem solving, self-actualization, critical reflection/appraisal and communication skills (Barlex, 2007; Kimbell, 2000; Williams, 2009). A characteristic of technology education which is considered integral to the achievement of these outcomes is its emphasis on applied problem solving whereby the knowledge needed to solve a problem may not be necessary to solving future problems. As such, compared to many other subject areas such as Mathematics, Science and Engineering, there is less of an emphasis on the acquisition of large quantities explicit content knowledge. Instead, "the domain of knowledge as a separate entity [in technology education] is irrelevant; the relevance of knowledge is determined by its application to the technological issue at hand" (Williams, 2009, pp. 248–249). Knowledge is still valued in technology education but it is less transferable between problems than it is in many other subjects. In line with this, fluid intelligence has been identified as a causal factor in general learning as it supports the acquisition of knowledge and skills (Kvist & Gustafsson, 2008; Primi et al., 2010). Therefore, this paper focuses on fluid intelligence rather than crystallised intelligence as it aligns more closely with the philosophy and epistemology of technology education.

## 2. Theoretical framework

Prior to describing fluid intelligence and its potential relationship with technology education in more detail, a brief overview of cognitive factors is required. Within the pertinent literature there is much debate regarding the definition of intelligence and there are many different approaches taken to studying it. One way that intelligence has been conceptualised is as a group of discrete cognitive abilities or factors including for example, spatial ability, verbal ability and reasoning ability (Carroll, 1993; Guilford, 1967; Horn & Cattell, 1966; Johnson & Bouchard, 2005; Schneider & McGrew, 2012). It has also been considered in terms of mental processes such as planning, attention, and negotiating information in sequential or holistic approaches, rather than on discrete cognitive abilities (e.g. Das, Naglieri, & Kirby, 1994; Kaufman & Kaufman, 1983; Luria, 1980). Within the cognitive factor perspective there is disagreement relating specifically to the existence of factors and relationships between factors. For example, certain theories describe intelligence in terms of a hierarchical model (Carroll, 1993; Johnson & Bouchard, 2005; Schneider & McGrew, 2012) whereas other describe intelligence as a bifactor model (Gignac, 2016; Maccann, Joseph, Newman, & Roberts, 2014). The theoretical framework subscribed to in this study is the Cattell-Horn-Carroll (CHC) theory (McGrew, 2005, 2009; Schneider & McGrew, 2012). It was primarily selected as it contains the fluid intelligence factor which is posited to be a critical factor in technology education. Furthermore, it has strong empirical support and a comprehensive compilation of additional factors adding to its utility for education research. An illustration of the structure of this framework is presented in Fig. 1. It is a hierarchical factor model containing three

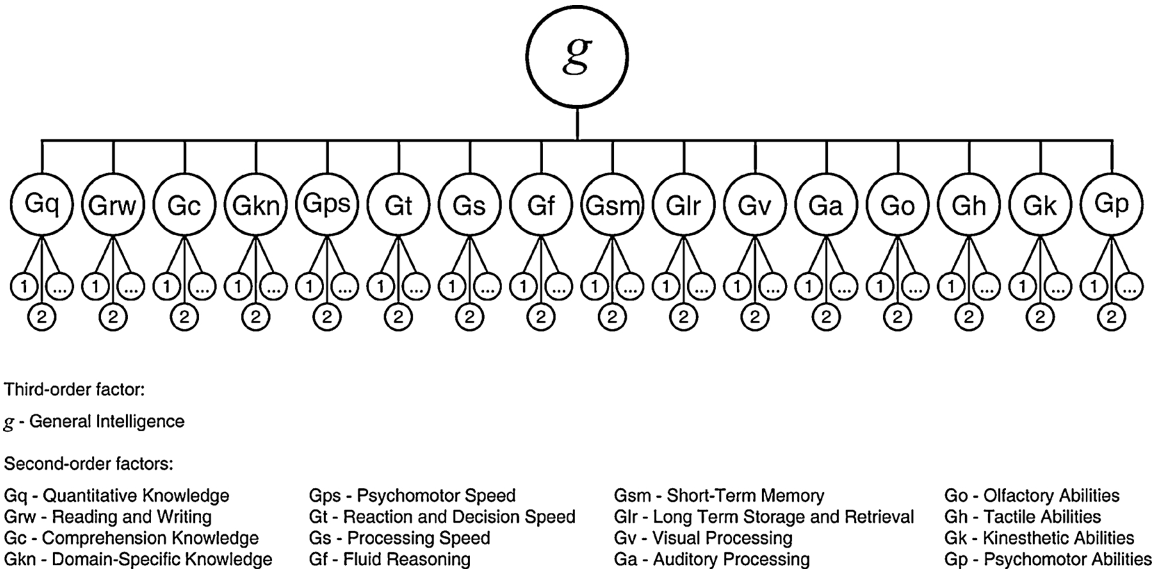


**Fig. 1.** The structure of the Cattell-Horn-Carroll (CHC) theory of intelligence (Schneider & McGrew, 2012). Figure originally published by Buckley, Seery, and Canty (2018) under a Creative Commons 4.0 International license (CC BY 4.0).