Thinking Skills and Creativity 22 (2016) 233–246

Contents lists available at ScienceDirect

Thinking Skills and Creativity

journal homepage: http://www.elsevier.com/locate/tsc

Combined working memory capacity and reasoning strategy training improves reasoning skills in secondary social studies education: Evidence from an experimental study

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ARTICLE INFO

Article history:
Received 11 May 2016
Received in revised form 17 October 2016
Accepted 18 October 2016
Available online 26 October 2016

Keywords:
Reasoning abilities
Secondary education
Social studies
Working memory
Critical thinking

ABSTRACT

Evidence suggests that working memory (WM) abilities and WM training correlate with deductive reasoning achievements. In this study, a combined WM-capacity and WM-reasoning strategy training is incorporated in secondary school social studies curricula to investigate its effects on reasoning achievements. Four secondary classes in three schools in the Netherlands participated in the present study with a total of 81 students in higher general secondary education. WM-capacity and reasoning achievements of the experimental groups improved significantly after 4 training weeks compared to control group results. The gain in reasoning abilities is demonstrated in both experimental subgroups, while control group results did not improve. The study supports the notion that deductive reasoning gains can be achieved through a combination of WM-capacity and strategy training in a content-based context.

1. Introduction

Reasoning in secondary social studies education requires higher thinking skills, which students often find difficult to master and implement in social studies school tests (Baildon & Sim, 2009). Frequently these tests contain a large number of reasoning questions (Sluijsmans, 2013). Neuropsychological research has provided evidence that training of working memory (WM) improves skills in both math and reading comprehension (Conway, Kane, & Engle, 2003; Cheshire, Ball, & Lewis, 2005; Holmes, Gathercole, & Dunning, 2009; Karbach, Strobach, & Schubert, 2014; Nevo & Breznitz 2014). However, little research has been conducted to show whether working memory training improves reasoning abilities in behavioral sciences education at secondary schools (e.g. history, geography, social studies, economics). In a systematic review of the literature on school-based WM training, Ariës, Ghysels, Groot, and Maassen van den Brink (2015) concluded that optimal working memory training consists of both a short term memory and a long term memory component. This paper adds to the literature by presenting the results of an evaluation of a two-component WM training method, including WM-capacity and reasoning strategy, implemented over a six week training period in secondary school social studies education.

Reasoning in behavioral studies in secondary education is the deductive process of reasoning from statements to reach a conclusion. While inductive reasoning becomes slightly more relevant in reasoning in pre-university education, deductive reasoning is the dominant form of reasoning in behavioral studies in the lower and medium tracks of Dutch secondary

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http://dx.doi.org/10.1016/j.tsc.2016.10.008
1871-1871/

education (SLO, 2011, p.53). Deductive reasoning starts with premises and yields a logically necessary conclusion that is not explicit in the premises. In deductive reasoning, one follows three fases: (1) the premise processing phase, (2) the premise integration phase, and (3) the validation phase (Fangmeier, Knauff, Ruff, & Sloutsky, 2006). Two theories have dominated the cognitive literature on deductive reasoning. Goel (2007) states that 'the major issue of contention between the two theories is whether deduction is underwritten by a system of (linguistic) rules sensitive to the logical form of the evidence (mental logic theory), or whether a visuospatial representation of the argument is constructed and evaluated (mental model theory) (p.435). Based on Neuroimaging studies, Goel concludes that "cognitive neuroscience data point away from a unitary system for logical reasoning and towards a fractioned system dynamically reconfigured in response to specific task and environmental cues" (p.435). Reasoning in history education is defined by Leinhardt, Stainton, Virji, & Odoroff, (1994, p. 134) as 'the process by which central facts and concepts are arranged to build a historical case'. According to Van Drie and Van Boxtel (2008), this requires analysis, synthesis, hypothesis, generalization and interpretation of questions, sources and retained knowledge. Based on a review of empirical literature, Van Drie and Van Boxtel (2008) concluded that the main reasons for students to underachieve are that students frequently are unable to (1) take into account alternative views, use sources extensively, (2) acquire detailed factual knowledge and a broader frame of reference, (3) judge the past by its own standards, (4) take into account the process of continuity and (5) understand many substantive concepts. Though research on the relevance of reasoning for social studies courses has not been found, we may expect that the analyses of both Leinhardt et al. (1994) and Van Drie and Van Boxtel (2008) on reasoning in history education can inform the results of the social studies courses because of the similarities between history and social studies education (SLO, 2011). Both history and social studies are courses of the humanities. Students have to (1) develop both general and domain-specific thinking strategies that are used in all of the behavioral sciences education, (2) address reasoning questions that meet the criteria of reasoning as defined by Van Drie and Van Boxtel (2008) and (3) address similar subjects. For instance, the main subjects of the social studies course in Dutch secondary education are 1. parliamentary democracy, 2. the Dutch constitutional state, 3. multicultural societies, 4. the welfare state (College voor Examens [Commission for exam standards], 2013). The same subjects are addressed in secondary history courses, but in a historical context (College voor Examens [Commission for exam standards], 2012). The social studies course addresses the four main subjects in a contemporary context. In line with the generality of its subjects, the social studies course addresses historic, geographic, economic, philosophic and art historic subjects with which secondary education courses it is closely related.

WM, 'the cognitive system that provides temporary storage of information in the course of complex cognitive activities which appears to play a crucial role both in supporting learning and maintaining focused behavior in practical situations', monitors higher cognitive processes in the brain and plays a crucial role in developing reasoning skills (Holmes et al., 2009). It underlies several cognitive abilities, including logical reasoning and problem solving (Klingberg, 2009). WM is associated with specific higher cognitive abilities and underlies the frequent inability of children with poor WM to make progress in higher cognitive skills, such as reasoning (Alloway & Gathercole, 2009; Holmes & Gathercole, 2014; Süss, Oberauer, Wittmann, Wilhelm, & Schulze, 2002). WM needs to change its content constantly and rapidly in order to effectively address a problem state. Therefore, cognitive load seems to play a crucial role in higher cognitive abilities. In this regard, Sweller (1988) states that the capacity of WM could empower reasoning abilities. Also, Sweller (1988) states that novices, in contrast to experts, do not yet possess generic memories-developed schemas or patterns to solve problems and therefore endure a higher cognitive load. So, this process is affected by the two functions of the WM. First, the cognitive function, which stores and manipulates information during reasoning tasks, depends strongly on the capacity of information that can be stored in WM (Fuster, 2003; Goldberg, 2010). When more information can be stored and, subsequently, manipulated, reasoning abilities are improved (Olesen, Westerberg, & Klingberg, 2004). Short term storage and manipulation of information can be improved by training the cognitive WM function (Conway et al., 2003; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). Second, pattern recognition of reasoning structures is regulated by the meta-cognitive function of WM (Gazzaniga, Ivry, Mangun, & Steven, 2009). When frequently exposed to similar reasoning contexts, a student can develop and internalize matched response strategies (Gold, Berman, Randolph, Goldberg, & Weinberger, 1996). In this view WM will form blueprints and will plan for rational analysis and analytical methods more effectively when trained via reasoning strategy training. This also causes WM to develop memories of previous patterns that successfully lead to solutions of problems (Goldberg, 2010). Consequently, this can be used to solve new reasoning problems, making reasoning processes more efficient and more effective (Sweller, 1988; Kramarski & Mevarech, 2003; Cheshire et al., 2005). As such, we regard WM as being part of short term memory and extending to long-term memory as conceptualized by Cowan (e.g. 1998, 2008). Cowan views WM not as a separate system apart from short or long-term memory, but representations in WM are a subset of long-term memory representations. Therefore, WM consists of activated long-term memory representations and also of focusing attention, which resides in short-term memory and has a limited capacity.

A school-based training method which contains domain specific content of both cognitive WM and reasoning strategies integrates several general and domain-specific reasoning processes. Combined training may better address course-specific reasoning problems and thereby improve the efficiency of the training. In a study on secondary history courses (Ariës, Groot, & Maassen van den Brink, 2015), which integrated general and domain-specific reasoning processes, it was shown that significant improvements in reasoning were caused by a combined WM-training. This confirmed conclusions from comparable research in which WM-capacity and reasoning strategies were trained to benefit reasoning (Holmes et al., 2009; Mevarech & Kramarski, 2003; Olesen et al., 2004). Furthermore, it showed that reasoning structures were internalized and consequently improved achievements in reasoning tasks and strategies.