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Explicit Instruction and Executive Functioning Capacity: A New Direction in Cognitive Load Theory

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Abstract

Explicit instruction is a teaching strategy that aims to avoid cognitive overload experienced by students which aims to improve academic performance. Previous research has mentioned working memory as a cognitive capacity that processes information and cognitive control and supports the success of explicit teaching on student academic performance. The core components of the executive function consist of working memory, but also inhibitory control and shifting. This review of the article provides new directions for the development of cognitive load theory on explicit teaching and research on executive function-based information processing aimed at avoiding cognitive load.

Keywords

explicit instruction, working memory, inhibitory control, shifting, cognitive load theory

Introduction

The academic performance achieved by students is determined by external factors, for example, explicit instruction design (Heijitjes et al., 2014; Srikon et al., 2018) and internal factors, namely the capacity of executive functions (Bailey et al., 2018; Iglesias-Sarmiento et al., 2015; Viterbori et al., 2017). Explicit instruction combines cognitive and metacognitive strategies that aim to make it easier for students with learning difficulties to achieve academic performance (Hott et al., 2014; Leone et al., 2010; Moradi, 2013; Nguyen, 2013; Tavakoli & Koosha, 2016). However, executive functioning capacity is a cognitive process and control that serves the use of cognitive strategies, for example, reading comprehension (Butterfuss & Kendeou, 2018; Chang, 2019) and metacognitive strategies (Garcia et al., 2015; Meltzer, 2014). Students with learning difficulties have a lower capacity for executive function than students without learning difficulties. The use of explicit instruction based on the capacity of students "executive functions can change students" perceptions of learning to be more positive (Marulis, Baker, & Whitebread, 2020).

Previous research has reported that the limited capacity of executive functions to students with learning difficulties so that they are unable to process complex information is the reason why it is important to design explicit instruction (Kalyuga & Singh, 2016; Sweller, 2011). This is based on the cognitive load theory which aims to make executive function performance more efficient when students do academic tasks (Lindsey et al., 2017; Sweller, 2016). Working memory capacity is one of the core components of executive function which is often referred to as related to cognitive load theory (Leppink & Hanham, 2019; Paas & Ayres, 2014; Sepp et al., 2019). In fact, the core components of executive function consist of working memory, inhibitory control and shifting / cognitive flexibility, each of which contributes to student academic performance (Brookman-Byrne et al., 2018; Cartwright et al., 2017, 2019; Cragg et al., 2017). However, it is very rare to report involvement in inhibitory control and cognitive flexibility in terms of cognitive load theory. Although, implicitly, previous research has been carried out on the role of cognitive flexibility that supports problem-solving (Paas et al., 2010).

There are gaps in previous research findings regarding the role of working memory in ignoring irrelevant information (Fallon et al., 2018). Working memory performance is determined by the increasing number and variety of tasks and the presence of irrelevant information (Nasr et al., 2008; Oberauer, 2019; Zanto & Gazzaley, 2009). However, the increasingly complex nature of tasks with variations in irrelevant information requires the work of other cognitive mechanisms that support working memory performance (Mathy et al., 2018). The cognitive mechanism in question has the

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task of suppressing irrelevant information (Pimperton & Nation, 2010). Inhibitory control plays an important role in inhibiting irrelevant information and together with working memory to perform complex tasks and the role of inhibitory control to keep working memory performance better (Getzmann et al., 2017).

This literature review study aims to describe (a) the executive function model for irrelevant information; (b) the contribution of working memory, inhibitory control and shifting to explicit instructions; and (c) working memory, inhibitory control and shifting for the development of cognitive load theory.

Executive Function Model on Irrelevant Information

Executive function is a cognitive process involved in higher-order thinking which consists of core components: working memory, inhibitory control, and shifting / cognitive flexibility (Diamond, 2013; Friedman & Miyake, 2016; Miyake et al., 2000; Miyake & Friedman, 2012). Working memory is the speed of processing and manipulating relevant information through efforts to focus attention (Aben et al., 2012; Baddeley, 2012; Oberauer, 2019; Stepanov et al., 2020). Inhibitory control shows efforts to focus attention to inhibit responses and irrelevant information that competes with irrelevant information (Borragan et al., 2018; Perri, 2020; Tiego et al., 2018). Shifting is a skill to adapt and shift from one rule to another in a flexible manner which is supported by working memory and inhibitory control (Blakey et al., 2016; Diamond, 2014; Gabrys et al., 2018).

Working memory, inhibitory control and shifting / cognitive flexibility as predictors of solving math problems (Getzmann et al., 2017; Lubin et al., 2013; C. Yu et al., 2012). Working memory has been shown to play an important role in solving mathematical problems (de Weijer-Bergsma et al., 2015; Fung & Swanson, 2017; Raghubar et al., 2010; van den Bos et al., 2013; Wang et al., 2016). However, there are still few studies that report the respective roles of inhibitory control (Dooren & Inglis, 2015; Keller & Libertus, 2015; Lee & Lee, 2019; Ng et al., 2015) and cognitive flexibility (Decaro, 2016; Liu et al., 2018; Magelháes et al., 2020) on mathematical solving abilities. In fact, working memory performance in certain tasks requires the role of inhibitory control to inhibit irrelevant information (Getzmann et al., 2017; Roncadin et al., 2007). The same thing also happened to cognitive flexibility performance supported by working memory performance and inhibitory control (Ionescu, 2012) to perform complex tasks (Hall-McMaster et al., 2019).

Studies on the dynamics of working memory, inhibitory control, and shifting of irrelevant information are needed to understand how a complex task is carried out not only involving one component of the executive function (Ávila et al., 2015; Nweze & Nwani, 2020; Stavrovlaki et al., 2017). This is because the more complex a task is, there are variations in relevant information (Zamary et al., 2019) and irrelevant information that demands working memory performance. This can be done by high working memory capacity by independently ignoring irrelevant information (Linck & Weiss, 2015; Ortells et al., 2016). However, high working memory capacity can be a predictor of shifting performance (Pettigrew & Martin, 2016). However, when the working memory capacity is low, it affects the performance of the tasks performed and it is difficult to control irrelevant information (Lilienthal et al., 2015). Inhibitory control is needed to maintain working memory performance in performing tasks by blocking irrelevant information (Barbas et al., 2018; Verhoeven et al., 2011). This shows that under certain conditions the working memory can carry out tasks independently, but in very complex types of tasks, the performance of working memory is supported by inhibitory control, especially related to blocking irrelevant information. Working memory performance depends on individual differences and the variety of tasks performed by working memory (Miller & Unsworth, 2018; J.-C. Yu et al., 2014).

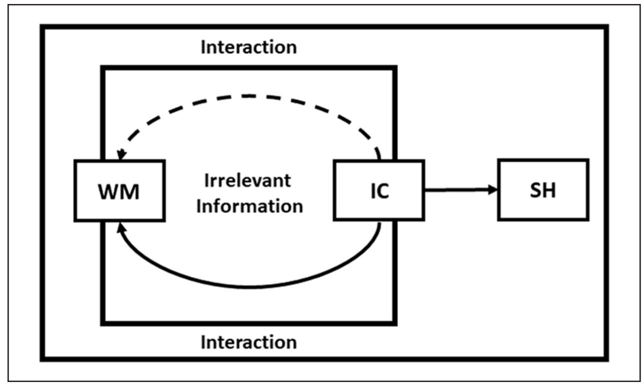

Figure 1. (Siregar, 2021) Dotted arrows from inhibitory control (IC) to working memory (WM) indicate that working memory performance ignores irrelevant information, which is an incomplete representation of inhibitory control function. A clear line shows the full function of the IC to inhibit irrelevant information which can reduce the performance of working memory in carrying out tasks. The interaction between working memory and inhibitory control supports shifting (Sh) performance.

The following is a dynamic framework of working memory performance, inhibitory control and shifting as well as the dynamics of working memory and inhibitory control response to irrelevant information.

This scheme provides information that the executive function is a cognitive control system (Sachs et al., 2017; Visu-Petra et al., 2011) to focus on relevant information. Working memory performance is impaired if irrelevant information is not ignored. However, the load of working memory is higher when the variation of relevant information increases as well as the presence of irrelevant information. This condition requires the role of inhibitory control to inhibit irrelevant information.

Contribution of the Executive Function to Explicit Teaching

Explicit instruction is a structured, systematic, and effective method of training academic skills in students having difficulty learning with teacher guidance and guidance in the classroom (Archer & Hughes, 2011; Doebler et al., 2012; Satsangi et al., 2018). Explicit instruction uses cognitive and metacognitive strategies that aim to control the use of cognitive strategies during academic tasks (Powell, 2011; Wischgoll, 2016). Students who have learning difficulties have the ability to use cognitive strategies and low monitoring, so it is advisable to use explicit instruction (Zhu, 2015).

Schema-based instruction (SBI) and cognitive strategy instruction (CSI) are two explicit instruction models that have been reported to play an important role in improving mathematical problem-solving skills (Cook et al., 2020; Jitendra et al., 2009; Krawec et al., 2013; Xin, 2008). However, the difference between the two lies in the number of stages of cognitive and metacognitive strategies that are fewer but complex in schema-based instruction compared to cognitive strategy instruction, which have more stages and are easier for students to do. Cognitive strategies and metacognitive monitoring of thinking processes do not lie in quantity but in the quality of monitoring tasks (Baars et al., 2018) so that they do not become an obstacle for students with low executive functioning capacity (Klepsch & Seufert, 2020). However, there are students with learning difficulties who have high executive functioning capacities (Swanson, 2014, 2015; Swanson et al., 2013) who become inefficient when the monitoring process of simple cognitive strategies (Jackson et al., 2014).

Performance of executive functions is realized through the main components, including working memory, inhibitory control, and shifting/cognitive flexibility. All three are cognitive processes that contribute to cognitive and metacognitive strategies (Bohn-Gettler & Kendeou, 2014; Gnaedinger et al., 2016; Jones et al., 2020). Collaboration between cognitive and metacognitive strategies contained in explicit instruction as well as with working memory, inhibitory control and shifting plays an important role in the transfer of knowledge in students (Bellon et al., 2019; Roebers & Feurer, 2016). Working memory, inhibitory control, and shifting each support the performance of cognitive and metacognitive strategies in carrying out academic tasks.

The following is a schematic model of how working memory (WM), inhibitory control (IC), and shifting (Sh) serve the performance of cognitive strategies and metacognitive control. However, explicit instruction shows how metacognitive control performs on cognitive strategy performance.

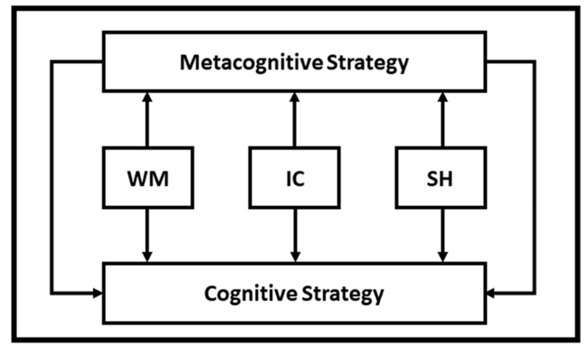

Figure 2. Working memory (WM), inhibitory control (IC), and shifting (Sh) support the performance of cognitive and metacognitive strategies where metacognitive strategies provide control over cognitive strategies.

The schematic model shows that when a cognitive strategy carries out an academic task, for example, reading comprehension, it is supported by the executive function. Working memory manipulates and processes relevant information and ignores irrelevant information (Simon et al., 2016). Increasingly complex tasks involve irrelevant information that cannot be executed by working memory so that inhibitory control performance is needed to inhibit irrelevant information (Hazan-Liran & Miller, 2017). Shifting performs the task of moving from using one cognitive strategy to another or moving from one metacognitive strategy to another metacognitive strategy.

Working Memory, Inhibitory Control, and Shifting for the Development of Cognitive Load Theory

Previous research has only focused on the performance of working memory capacity working on tasks with certain limitations that indicate cognitive density (Konstatinou et al., 2014; Redifer et al., 2019). However, cognitive processes do not only involve working memory performance, there are inhibitory control and shifting, each of which has a different function and supports working memory performance. Both working memory and inhibitory control have mental functions that are separate from one another (Robert et al., 2009; Wright & Diamond, 2014). Although under certain conditions when the performance of working memory is bad it can also be indicated by poor inhibitory control performance (Brocki et al., 2007).

The performance of working memory, inhibitory control, and shifting has similarities in the neural mechanism pathways when responding to irrelevant information

(Burhan et al., 2016; Jaeger, 2013; Yang et al., 2014). However, the anterior cingulate cortex (ACC) is a specific neural mechanism reported by experts regarding inhibitory control function (Borst et al., 2014; Brockett et al., 2020; Jhang et al., 2018; Starr, 2011). This indicates that when working memory only marks or ignores irrelevant information and passes through the anterior cingulate cortex (ACC) pathway, there is a role for "cryptic" inhibitory control. Irrelevant information remains side by side with relevant information as long as the working memory performs tasks (Janowich et al., 2015; Lv, 2015). When tasks vary, both relevant and irrelevant information that "threatens" working memory performance, inhibitory control displays the "real" performance inhibiting stimuli or irrelevant information and responses (Chamorro et al., 2017; Geng et al., 2005; Xu et al., 2019).

Working memory is a cognitive process that plays an important role in manipulating information. The performance of working memory capacity is not always stable, especially in relation to processing complex and varied tasks and the presence of irrelevant information. Excessive loads lead to depletion of working memory (Chen et al., 2018; Sweller et al., 2019), thus reducing the performance of working memory capacity. Training to increase working memory capacity is one solution; however, working memory will continue to experience fatigue while doing tasks. Inhibitory control capacity is another cognitive process that can support working memory tasks to improve performance.

Conclusion

Working memory performance aims to process relevant information that can be supported by inhibitory control performance to inhibit information and irrelevant responses. The shifting performance aims to produce new actions by switching flexibly from one task to another, where this condition can be supported by working memory and inhibitory control.

Explicit teaching that integrates cognitive strategies and metacognitive strategies is based on the perspective of cognitive load theory. This theory states that the explicit teaching design is made in such a way as to avoid overloading the working memory capacity. However, inhibitory control and shifting are involved in information processing which can reduce the load on working memory. Based on this, further research is needed to design explicit teaching that fulfills the role played by working memory, inhibitory control, and shifting as a development of cognitive load theory.

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