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Investigaciones y Experiencias

La relación de las habilidades metacognitivas de los alumnos con TDAH con su competencia matemática con el uso de las TIC's

The relationship of metacognitive abilities of students with ADHD with their mathematical competence with the use of ICT's

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Resumen:
La metacognición es la capacidad de los alumnos para tomar las medidas necesarias para planificar estrategias adecuadas para resolver los problemas que enfrentan, evaluar las consecuencias y los resultados y modificar el enfoque según sea necesario, en función del uso de su conocimiento previo. Los estudiantes son conscientes del proceso de aprendizaje y saber cómo aprenden es importante tanto para controlar su aprendizaje anterior como para construir su nuevo aprendizaje sobre los anteriores. Saber qué factores cognitivos subyacen a las diferencias individuales en las habilidades matemáticas es la clave para obtener una mayor comprensión del desarrollo matemático de los niños. En este artículo se conceptualizan niños con TDAH (Trastorno por Déficit de Atención e Hiperactividad) que experimentan dificultades para gestionar la atención en la escuela y se realiza un estudio exhaustivo que se centra en cómo la metacognición ayuda a los alumnos con TDAH a alcanzar con éxito un objetivo personal eligiendo la información cognitiva adecuada y Herramientas de las Tecnologías de la Comunicación (TIC) para este fin.
Este artículo, por lo tanto, aborda la relación y el impacto de la conciencia metacognitiva en el rendimiento académico de los estudiantes, especialmente de la competencia matemática y la competencia digital y tecnológica. Los estudiantes que reciben este tipo de aprendizaje de metacognición están más satisfechos y mejoran en sus resultados adquiriendo conocimientos profundos y perdurables.

Palabras clave: TDAH; Competencia Matemática; Metacognición;TIC.

Abstract:
Metacognition is the ability of learners to take necessary steps to plan suitable strategies for solving the problems they face, to evaluate consequences and outcomes and to modify the approach as needed, based on the use of their prior knowledge. Students are aware of the learning process and know how they learn is important in terms of both controlling their previous learning and building their new learning on the previous ones. Knowing which cognitive factors underlie individual differences in mathematical abilities is the key to gaining further insight into children's mathematical development. In this article are conceptualized children with ADHD (Attention Deficit Hyperactivity Disorder) who experience difficulty in managing attention in school and make a thorough study which is focused on how metacognition helps ADHD-learners to successfully achieve a personal goal by choosing the right cognitive Information and Communication Technologies (ICT) tools for this purpose.
This article, therefore, discusses the object of explaining the relationship and impact of metacognitive awareness on student's academic achievement, especially on their mathematical competence and makes the appropriate connections with the contemporary necessary technological equipment for educational use, in a way that students who receive metacognition-based education do enjoy learning and this method is sustainable.

Key Words:
ADHD; Mathematical Competence; Metacognition; ICT.

Introduction

Learning and development in the human capital context necessitates new ways leaning and critical thinking with active discussion beyond the classroom walls. The ability to think critically, reflect deeply and consider the scope impacts further into the future becomes essential, through content development rigorously and infuses the active deployment of ICT for teaching and learning. In this new context, metacognitive awareness is a pivotal part of the learning process whereby individuals understand their own resources, gather information about the task at hand, and come up with an appropriate strategy to achieve the task, while overseeing its accurate implementation (Dimmitt & McCormick, 2012). On the other hand, a lack of metacognitive skills is associated with a higher risk of poor student academic attainment (Laskey & Hetzel, 2010). The above situation of metacognitive awareness makes significant the metacognitive based training which helps students to develop, evaluate and organize their mathematical thinking and become aware of their own thinking (Lynch et al., 2013). The National Council of Teachers of Mathematics (National Council of Teachers of Mathematics NCTM, 2004) stated that students with advanced cognitive skills can be good problem solvers, as they can use skills such as controlling, verifying, goal setting and analogical reasoning better than other students in problem solving process. Previous studies have emphasized the importance of metacognition in mathematics education (Erdogan & Sengül, 2017). Studies in the literature have also reported that metacognition was effective in solving mathematical problems (Mevarech, 1999) and in mathematical thinking and proving (Dietz, 2016) as metacognition is based on the development, evaluation and organization of logical-mathematical thinking.

Over the last 25 years many reform efforts have had theoretical and/or research bases, as a concequence to focus on putting into practice the constructivist learning theories of Piaget (1953) and Vygotsky (1978) and helping students to develop an understanding of mathematics through active participation in their learning. However, evidence suggests that at the senior secondary school and undergraduate levels there has been little change to teaching practice; mathematics teaching at both levels still tends to be dominated by the transmission of knowledge approach (Radmehr, 2016).

Sufficient mathematical skills is a prerequisite to adequately function in society (Butterworth et al., 2011). Prior research shows that basic arithmetic skills are precursors to necessary mathematical skills (Hooper et al., 2010). However, children’s arithmetic skills vary already at an early age (Anders et al., 2013). General cognitive abilities have also been found to provide independent contributions to children’s arithmetic achievement (Martin et al., 2014).

Information and Communication Technology (ICT’s) provide with multiple ways of representing problem situations that allow students to develop problem-solving strategies and a better understanding of the mathematical concepts they are working on. The National Council of Teachers of Mathematics (NCTM, 2000) states that “when technological tools are available, students can focus on decision making, reflection, reasoning, and problem solving more” (p. 3).

Metacognition and ICT'S

Metacognition is defined as the one's reflection on his/her thoughts. Metacognition, on the other hand, can be expressed as thinking about the knowledge and skills that exist in the mind of the individual (Akın, 2013). Although many classifications have been made for the components of metacognition, the most widely accepted classification is the knowledge of cognition and the regulation of cognition (Schraw, 1998). Cognition can be explained as the knowledge and thoughts that exist in the human mind (Akpunar, 2011). There are many learning approaches that use metacognition as a learning tool. These approaches, which are based on questioning (Sonay-Ay & Bulut, 2017) or strategies (Ozdemir & Sarı, 2016), are generally called metacognitive training. The problem-solving approach based on metacognitive questioning, good strategy user model, cognitive awareness-based problem solving method and improve are some of the metacognitive training methods (Mevarech & Fridkin, 2006; Sonay-Ay & Bulut, 2017). And this is where ICTs play an important role in this process since allow students to be active agents of their learning, bringing those concepts that were once abstract and now they are part of their reality (Cruz & Puentes, 2012).

ICT is particularly useful for approaching such complex and unfamiliar problem-solving tasks because it enables the learner to search for information on the web, look for similar problems and sub-problems on-line, and use various computerized tools that can carry out the tedious work that is sometimes associated with solving mathematics problems (such as plotting graphs or doing computations) and hence release cognitive energy for higher-order cognitive processes (Mayer, 2010). Furthermore, search tools and online information sources may lead users to reflect on the given information, decide which piece of information is most applicable to the given problem. Computer supported collaborative learning (e.g., asynchronous learning networks, forums, even emails) can become a powerful reflection tool, enabling students to be aware of how and why a solution path was chosen. These advanced learning technologies also require learners to actively, deliberately, and critically consider and monitor the logical relations between various pieces of information, different kinds of representation, or the varied input from co-learners, in relation to the progression in their own learning process. For instance, gamification of learning can increase both the cognitive load and the levels of performance, and generally, the students have positive beliefs with respect to the gamification strategies (Marín-Díaz et al., 2020). Successfully navigating nonlinear information, integrating information from various representations of the same concept, or integrating input from a peer learner requires learners to actively regulate their own learning, and learners' inability to do so will undermine their learning success with these technologies (Verschaffel et al., 2019). Below are illustrated the three basic parameters that metacognition consists of, knowledge, skills and experience, as well as the relationship these have with the ICT's development in education.

2.1 Metacognitive knowledge and ICT's

Metacognitive knowledge is a declarative knowledge about cognition and derives from a person's long-term memory about himself, herself, or others and it includes explicit or implicit knowledge about persons, tasks, goals, and strategies (Efklides, 2008). In addition, it encompasses knowledge of the criteria of knowledge validity and beliefs that individuals have about people's minds (Bartsch, & Wellman, 1995). Monitoring others people's cognitive activities and self-monitoring, communicating with others, and awareness about personal metacognitive experiences could help individuals develop and revise their metacognitive knowledge (Kim et al., 2013). Here come ICT's that allow students with few symbolic and numerical skills to develop strategies to solve problem situations, using various tools that provide them with a better understanding (Cruz & Puentes, 2012). After all, there is consistent evidence that effective ICT's use requires changes in attitudes, values, and beliefs that develop confidence for ongoing learning and adaptability to change (Cadamuro et al., 2021), by designing new in-service training programmes in which alternative teaching methods and strategies are employed, to support the teaching process with ICT. It is expected that an effective professional development activity on the use of ICT will enable teachers, as well, to adapt to change, develop confidence in lifelong learning and create positive change in values and beliefs (Selen & Seferoglu, 2020).

2.2 Metacognitive skills and ICT's

Metacognitive skills are a form of procedural knowledge related to activities that individuals undertake to control their cognitive activities (e.g., learning) (Schraw, 1998). These deliberate activities include task orientating, planning, monitoring, regulating, and evaluating. Task orientating is understanding the task requirements, planning refers to identifying the steps needed to achieve a goal or complete a task, monitoring refers to the oversight of activities while implementing strategies, and evaluating and regulating correspond to checking the outcome of cognitive processing and modifying it when necessary (Rittle-Johnson & Schneider, 2014). Through integration of ICT's into math classes, math become more than using a resource or tool, implies redefining the way of learning and teaching mathematics (Hodges & Conner, 2011). For instance, within online and/or virtual learning environments, a community of inquiry requires experience and knowledge through critical analysis, questioning, challenging and being reflective, which is extremely valuable for higher-order learning, reflective discourse and for critical thinking skills (Kilis & Yildirim, 2018).

2.3 Metacognitive experience and ICT's

Metacognitive experience presents in working memory and is "what the person is aware of and what she or he feels when coming across a task and processing the information related on it" (Efklides, 2008, p. 279). Metacognitive experience includes feelings of knowing, familiarity, difficulty, confidence, and satisfaction (Efklides, 2008). It also includes judgments of learning, estimation about effort and time that is needed and spent on the task, as well as estimating the correctness of the solution (Schneider & Lockl, 2002). The proper use of the appropriate ICT's tools cannot replace the conceptualization or the processes that teaching entails of any stage of learning or correctness. On the contrary, they serve as support to achieve a better understanding of these. Taking these aspects into account, we have developed an empirical experience on the use of some resources provided by ICT's in the teaching-learning process of the Basic Mathematics subject (Cruz & Puentes, 2012).

Rosenzweig et al. (2011) investigated students' with and without Learning Disabilities metacognitive strategies, such as self-observation, self-instruction, self-monitoring, self-questioning, self-evaluation and self-control while being engaged in novel or challenging math problem solving tasks. The aforementioned set of metacognitive skills assessment was based on a think-aloud protocol, in which students were audio-taped as they processed their on-line textbook-type problems of increasing difficulty. Thus, such investigative method may be used in an attempt to verbalize and obtain information on the cognitive and metacognitive processes taking place in on-line activities. Productive verbalizations included self-monitoring, self-instruction, self-questioning and self-correction statements directly related to solving the problem. Students with learning disabilities produced significantly more overall metacognitive verbalizations than their average achieving peers, with their non-productive verbalizations increasing as the problems became more difficult. Therefore, students with learning disabilities exhibited frustration and lack in the implementation of metacognitive strategies. Moreover, students' problem-solving ability as well as their self-regulation and self-consciousness about their metacognitive skills are interrelated components of successful problem-solving processes, which should be taught and measured through complex, math problems (Karyotaki & Drigas, 2016).

Mathematical competence and use of ICT'S

Mathematical competence, in line with the Recommendation of the European Parliament and the Council of the European Union, is defined as "the ability to develop and apply mathematical thinking in order to solve a range of problems in situations of everyday life" (European Parliament and the Council of the European Union, p.9). There are large individual differences in the way children acquire mathematical abilities (Berch et al., 2015). When looking for cognitive explanations for these differences, research has investigated both domain-general cognitive factors (i.e., factors relevant for learning various academic skills) and domain-specific cognitive factors (i.e., factors specifically relevant for mathematics learning) (Geary & Moore, 2016; Vanbinst & De Smedt, 2016), such as numerical magnitude processing (i.e., children's elementary intuitions about quantity and the ability to understand the meaning of numbers), as a core factor of individual differences in mathematical abilities (Schneider et al., 2017). The association between metacognition and general academic performance has been extensively studied. Vo et al. (2014) found that children's metacognitive ability in the numerical domain predicted their general school-based mathematics knowledge and suggested that children's metacognition is a domain-dependent cognitive ability in children.

Mathematics as a cognitive subject is characterized by some peculiarities which, if taken into account in teaching, can evolve into causes of poor school performance or failure (Tshabalala & Ncube, 2016). Some of the most important peculiarities are: 1) the hierarchical nature of mathematics, 2) the mathematical code of communication, 3) the ways of representation of mathematical knowledge. The nature of these peculiarities and their possible relationship with the difficulties in the evolution of mathematical knowledge of children are then analyzed and examined.

3.1 The hierarchical nature of mathematics

Mathematical concepts and skills are structured in a strict hierarchical way and resolutely rely on their predecessors (Hoffmann, 2021). Any incomplete coverage of curriculum sections may lead to a collapse of the mathematical structure and failure in learning. Mathematics inherently requires particular consideration and assessment of learning difficulties, as the student moves to the next chapter of the subject, he must have acquired the prerequisite knowledge (Kunwar, 2020).

3.2 The mathematical code of communication

In mathematics the code through which ideas and situations are expressed is a source of difficulty (Hughes, 1990). The words and symbols used for mathematical communication have a very special way. Mathematical terms and symbols refer to all existing entities, actions and situations, and at the same time to none at all. This situation leads to necessity in teaching specific use of the language. Additionally, the representation of mathematical concepts requires special attention and accuracy (Kunwar, 2020).

Children develop mathematical skills embedded in a comprehensible system of needs and activities. The same goes on to say that, nevertheless, children entering the organized education system are forced to link their pre-existing ideas and skills to the official code of communication of mathematics, trying to restore a cognitive balance in this transition (Hoffmann, 2021).

3.3 The ways of representation of mathematical knowledge

According to Noddings (1990), Cognitive Psychology, among other things, leads to the conclusion that a person learns when he has the ability to construct knowledge on his own as long as the active construction of knowledge is achieved through the representation of reality. Bruner (1990) separated the representation into 1) pratical, 2) figurative, and 3) symbolic. The transactional representation is mainly kinesthetic and tactile. The figurative representation is based on the use of concise images and graphs. Finally, the symbolic representation is characterized by abstract symbolic systems and simultaneous thinking on possible real events. It is true that the three kinds of representations have a direct connection between them and the absence of conquest of one directly has an impact on the rest. Especially in the teaching of mathematics, used the mathematical symbolic system to learning with understanding can lead to the representation of reality and the child is able to understand the concepts representations through concrete materials, symbols and images (Hoffmann, 2021).

A technology-based approach of these important peculiarities described above, 1) the hierarchical nature of mathematics, 2) the mathematical code of communication, 3) the ways of representation of mathematical knowledge, would obviously offer great advantages.

The first being it can be used quickly with large numbers of students, second, it could be anonymous so students might be more open about their understanding (or lack thereof), and third being that it would be possible to collect feedback in real-time during lectures and so inform the direction and pace of what happens next, making the lecture format more responsive to learners' needs. Overall, such a way of technological-based lesson would give a lecturer or teacher feedback on their students' ability to analyze and identify features in a problem that suggest a particular procedure or approach is warranted, while at the same time might encourage students to check and reflect on their answer rather than consider the work is finished when a solution is obtained.

To measure metacognitive skills, ICT's are suggested because making a drawing of the given problem was found to be an important factor for successfully solving mathematical problems. In general, the teaching development is supported by ICT's from the early childhood education (Aranda et al., 2019) since the teachers' professional development in the teaching of mathematics (Revelo Rosero et al., 2018). Finally, ICT's are suggested to explore whether students monitor their work as they do it. While working one-on-one is the ideal situation for monitoring student thinking through a think-aloud approach, or in other situations could at least find out if students have this metacognitive skill, with more flexible options again being open to lecturers and teachers who use technology for instant feedback in a class (Jacobse & Harskamp, 2012).

ADHD and use of ICT'S in high school students

Attention Deficit Disorder and Hyperactivity Disorder (ADHD) is a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. It is estimated that about 3% -7% of school-age children have ADHD (American Psychiatric Association, 2014). ADHD is regarded as a neurodevelopmental disorder that affects a child's function level (family, school, and social). Usually, the persons with attention-deficit disorder do not complete their duties and/or often avoid them. They have difficulty following instructions, focusing on the person that is talking to them and they quite often seem to lose personal belongings or other objects, thus showing disorganization. Unceasing speech, anxiety and nervousness are prevalent. Their attention and concentration are easily disrupted by external environmental stimuli resulting to impulsive behaviour and unbiased mistakes (Alloway et al., 2008). Even the person's impulsivity manifests itself with the tendency to having difficulty in managing time and being impatient, interrupting others and/or answering questions without any consideration beforehand (Alexopoulou et al., 2019).

In general, the use of cooperation in metacognitive learning is important for students when thinking about new concepts and developing mathematical reasoning (Kramarski et al., 2002). More specifically, students with ADHD have always comprised a challenge for education systems, since their typical behaviour obstructs and restricts teaching in the traditional way. Inclusion in general classrooms, especially of students with ADHD, is the common practice in most Western countries, therefore the need for differentiated teaching is mandatory. The ability to directly control attention influences the efficiency in information processing and improves learning. On the other hand, academic underachievement is prominent in ADHD, with approximately 33%–63% of children with ADHD exhibiting difficulties in one or more school subjects, such as math (Mayes &

Calhoun, 2006). ADHD academic difficulties start early and often persist through middle and high school (Scholtens et al., 2013). Moreover, ADHD-related academic difficulties are associated with myriad negative outcomes including increased incidence of failing grades, lower grade point averages and standardized test scores, higher rates of high school dropout, and lower college attendance when compared to their typically developing peers (Arnold et al., 2020).

Educational interventions, especially in such a specific category of students, have been found to positively affect academic skills (Pezzica et al., 2018). The metacognitive approach focuses on one's ability to recognize one's own cognitive functions and to monitor and self-regulate an on-going learning process. This approach has been seen to positively impact academic performance (Krebs & Roebers, 2010) and motivation (Efklides, 2011) in primary school as well as in secondary school (Dignath & Büttner, 2008). Studies have demonstrated that good students use metacognitive strategies while underachieving students do not (Cheng, 1993). Metacognitive training has been found to improve academic performance such as mathematics reasoning (Kramarski & Mevarech, 2003) or comprehension in reading (Carretti et al., 2014) and it has been successfully used with children with learning disabilities (Pezzica et al., 2018).

Every metacognitive intervention, in order to be meaningful and produce an improvement, should be grounded on the system of knowledge and beliefs of the participant. In some recent research, pictorial representation was used in order to assess typically developing children's representation of attention in the classroom (Pezzica et al., 2015). Children were asked to produce two specific thematic drawings on attention vs. inattention. The study confirmed the pictorial representation as a useful tool which does not require language mediation and enables to collect data directly from the personal experience of the children in the classroom (Pezzica et al., 2015).

By taking into consideration the above, it would be significant to mention that children with ADHD do find pleasure in being attentive, rather they consider it as an expensive process that will probably not result rewarding consequences. Through the pictorial instrument, children with ADHD seem to communicate their emotional difficulties associated with the school environment. From a metacognitive point of view, they are aware of what is required in the school context but they probably are not able to pursue it.

According to Drigas and Ioannidou (2013), education systems should create the appropriate conditions to improve learning and to ensure the transfer of skills and knowledge to pupils with special educational needs, such as students with ADHD. To achieve this, however, as recent researches and studies show, the contribution of new technology is needed. The integration of ICT into school helps the child with educational, social, and cultural difficulties, by giving them the experience they need through the virtual reality it creates. However, it should be extended to use at home, but also in society. ADHD is described as a multidimensional phenomenon which has to be taken into consideration along with other cognitive skills and executive functions (Drigas & Tourimpampa, 2014). All ICT procedures, have proved to be important to every function concerning attention, self-regulation, motivation, working memory and speech acquisition. At this point, all experts agree that

ICT's gives the opportunity to all people with disabilities and special educational needs to have equal chances at learning, improving their daily routine, increasing self-protection and independence (Alexopoulou et al., 2019).

Children and adults with ADHD have the tendency to be more focused and concentrated when they are engaged with digital activities, especially gaming. They overcome lack of motivation and appear to have a positive tendency towards these activities. After having realised the gap in the availability of game like training programs focusing on skills referring to daily life situations (Bul et al., 2015).

A central element of the concept of ADHD is the deficit in executive functions (Weisberg et al., 2014). The executive functions include inhibition (self-control, self-regulation), design, working memory, reasoning, cognitive flexibility, problem solving. They are responsible for deliberate, continuous, and directed behavior towards a goal. The ADHD difficulties in organizing, managing time, and planning are due to executive functions deficits.

Conclusions

Fortunately, with the help of ICT, when dealing with students with ADHD, situation can be changed as far as executive functions are concerned. Software relevant to each case and function, provides tempting and motivating stimuli given through audio-visual methods, while at the same time it improves the person's functionality in daily situations. By providing positive and/or negative feedback to the student, focus on the school duties is maintained, while the teacher will be the one who finally involves said software with his classroom methodology, or with his didactic action (Marín-Díaz, 2018). Over the last years, a lot of attention has been placed on the working memory, the cognitive system responsible for behaviour amongst other functions, the level of which, if lower than average, can often be associated with ADHD (Alexopoulou et al., 2019) and enhanced through various techniques that improve attention, to self-regulation, adaptation and flexibility in various areas (cognitive, emotional, behavioral), to recognition, to discrimination and to mindfulness (Doulou & Drigas, 2022).

A major issue with reforming undergraduate mathematics teaching is the problem of enactment. What does new practice look like? Where do we start? ICT instruments are, between others, designed to take into account constructivist learning theories and elements of metacognition (Radmehr & Drake, 2018), so is a good way for starting the process of reform. This paper contributes to the literature in mathematics education by providing examples of how ICT's and metacognition framework can be used in order to explore student learning. The paper attempts to aid in understanding different cognitive process and type of ICT knowledge, by providing details in the context of mathematics which were mapped to metacognition framework for a study of integral calculus learning across senior secondary and undergraduate levels (Radmehr, 2016). It would be possible that such studies challenge the appropriateness of certain questions types, or allow us to determine the most effective types of question for targeting specific types of knowledge, process, or facet of metacognition. These kind of studies could add to our understanding of how to use specific tools effectively to reform the teaching and learning of mathematics at the senior secondary and undergraduate levels. Questions focused on metacognition "What do you think we should try with this problem?" Why do you think that? "How do we know we are correct?" all go to the heart of developing, exploring, and exposing the thinking processes behind mathematical thought and could help scaffold the development of such thinking amongst students, with the study of the subject becoming more dynamic and engaging as a result – with errors and false trails (Radmehr & Drake, 2018). This paper could encourage mathematics lecturers and teachers to consider how ICT's and metacognition could be used in teaching and assessment to improve both the learning experience and the quality of student learning.

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