TECHNIUM

SOCIAL SCIENCES JOURNAL

9R O31 2

$ QHZ GHFD
IRU VRFLDO F

,661

ZZZ WHFKQLXPVFLHQFH FRP

Technium Social Sciences Journal
Vol. 31, 131-152, May, 2022
ISSN: 2668-7798
www.techniumscience.com

ICTs for the Assessment of the Cognitive and Metacognitive abilities of the students with Specific Learning Disorder in Mathematics

Panagiota Chatzivasileiou, Athanasios Drigas

Net Media Lab Mind - Brain R&D IIT - N.C.S.R. "Demokritos" , Athens, Greece

xatzivasileiou.g@gmail.com, dr@iit.demokritos.gr

Abstract. This article is a literature review that analyses the cognitive and metacognitive abilities of the students with Specific Learning Disorder in Mathematics (SLDM). It aims to present the cognitive and metacognitive deficits of these students along with the ways and methods that can improve the corresponding cognitive and metacognitive abilities and analyze the role of metacognition in mathematics education. It also aims to present ICT tools that are used worldwide in order to assess these abilities. These tools are designed for the assessment of either the cognitive or the metacognitive abilities of the students with SLDM and include computer based and mobile applications, serious games, smart-pens and educational software. The results of the study indicate that the existed ICT tools for the assessment of the cognitive abilities of the students with SLDM are more in number compared to the ICT tools for the assessment of the metacognitive abilities of these students which are more limited.

Keywords. Cognitive and metacognitive abilities, Specific Learning Disorder in Mathematics, ICT assessment tools for Dyscalculia, ICT assessment tools for mathematical metacognition

1. Introduction

The Specific Learning Disorder in Mathematics (SLDM) is a Learning Disorder that affects 5-8% of students worldwide (Geary, 2004) and affects boys more often than girls (Shalev & Von Aster, 2008). The SLDM is a type of Learning Disorder that affects the domain of mathematical knowledge (Shalev et al., 2001, Szűcs, & Goswami, 2013, Drigas & Pappas, 2015). The SLDM is not related to or results from inadequate teaching or a poor environment but seems to initiate from impairment in the central nervous system (Kavale et al., 2009).

According to DSM-V, the Specific Learning Disorder often coexists with neurodevelopmental disorders such as ADHD and the Autistic Spectrum Disorders, as well as with mental disorders such as anxiety disorders, depression and bipolar disorder (American Psychiatric Association, 2013).

Students with this learning disorder are characterized by deficits both in the cognitive and metacognitive domain (Miller & Mercer, 1997, Pennequin et al., 2010). The cognitive deficits can be either general or specific (Agaliotis, 2018, Mahmud et al., 2020). The general cognitive deficits include deficits in the executive functions, the social and emotional domain (Drigas & Pappas, 2015, Agaliotis, 2018, Mahmud et al., 2020). The executive functions are the higher cognitive processes such as the working memory, the maintained attention, the attentional control and the inhibitory control (Diamond, 2013, Roebers, 2017, Drigas&Karyotaki, 2017).

The specific cognitive deficits are located in the domain of mathematical knowledge (Shalev, 2004, Rader, 2009, Geary, 2010).

The metacognitive deficits include the ineffective use of cognitive and metacognitive strategies and the difficulty to control the cognitive functions, emotions and behavior (Agaliotis, 2018, Miller&Mercer, 1997, Pennequin et al., 2021, Montague, 2008, Rubinsten&Tannock, 2010). According to the researchers, metacognition constitutes the ability of thinking about our own and others thinking (Fisher, 1998, Papleontiou-Louca, 2003), reflecting and adapting our thoughts, emotions and behaviors in order to attain more positive patterns of thinking and acting (Drigas&Mitsea, 2021). Piaget (1975) referred to metacognition in mathematics as a 'reflecting abstraction' that reflects action to the higher cognitive level of mental representation and at the same time reorganizes and reconstructs the mental activity.

The SLDM is a disorder with a variety of symptoms and types. Geary (1993) proposed three types of SLDM. The first type is characterized by an operational cognitive deficit. The main difficulty is observed in using operations, strategies and algorithms. The second type is characterized by a cognitive deficit in semantic memory. Difficulty is found in recalling basic mathematical facts. The third type is characterized by a cognitive deficit in visuospatial skills. The difficulty is present in the spatial representation of arithmetical information and relations, as well as in understanding concepts related with space. These types of SLDM stem from a dysfunction in different regions of the brain. The operational type often improves in time, although, the semantic memory type tends to be permanent and related with phonological deficits. There are many other categorizations also (Kosc, 1974, Rourke, 1993, Von Aster, 2000).

As interventional methods for this learning disorder have been proposed the use of educational material based on the theory of Maria Montessori (Bennet&Rule, 2005, Aprinastuti et al., 2020) and the application of the principles of the Constructivism learning theory (Hunt & Tzur, 2017). The basic principle of constructivism, the leading theory in mathematics education is that humans construct their own knowledge and is not given to them ready from others (Hunt & Tzur, 2017). The constuctivism learning theory, the theory of self-regulated learning and the theory of metacognition share the same basic element which is the concept of reflection or self-monitoring, namely the operation of thinking and evaluating the cognitive processes (Ziemmerman, 1998, Flavel, 1979, Hacker et al., 1998).

The appropriate dietary patterns have also been examined. Research suggests that high intake of sweetened desserts, fried food, and salt is associated with more learning, attention, and behavioral problems, whereas a balanced diet, regular meals, and a high intake of dairy products and vegetables is associated with less learning, attention, and behavioral problems (Park et al., 2012). Furthermore, a nutrition rich in vitamins, fatty acids, mineral and trace elements can contribute to better physical and mental health (Zavitsanou & Drigas, 2021)

In addition, the development of the cognitive and metacognitive abilities of the students with SLDM can improve their mathematical performance and enhance their self-motivation and self-esteem (Diamond, 2012, Karyotaki, Drigas &Skianis, 2017, Lucangeli & Cabrele, 2006).

The use of ICT tools for the assessment and intervention of SLDM can be very effective as they can detect the existing cognitive and metacognitive deficits and contribute to their improvement (Kucian et al., 2011, Guarnera et D'Amico, 2014, Papanastasiou et al., 2017, Drigas, Dede & Dedes, 2020, Cheng et al., 2020, Aggarwal & Bal, 2020, Wilson et al., 2006, Seo & Bryant, 2012, Jerin et al., 2020, González et al., 2019, Muñoz et al., 2020). ICT tools for the SLDM are also designed in order to asses and develop both cognitive (Schiffer & Ferrein, 2018, Conchinha et al., 2015, Erfurt et al., 2019, Josef et al., 2015) and metacognitive abilities (Cadamuro et al., 2019, Chytrý et al., 2019, Lytra & Drigas, 2021, Prabavathy & Sivaranjani, 2020, Latif & Ahmad, 2021). These assessment and interventional tools can be mobile or computer based applications or applications based on artificial intelligence and robotics. The ICT allows students to approach learning while moving to their own pace. This way they support the self-regulation of learning (Lytra & Drigas, 2021, Trna et al., 2011, Muñoz et al., 2020). ICTs motivate and excite students (Prabavathy & Siranjani, 2020) and at the same time help them concentrate on cognitive tasks (Papanastasiou et al., 2017).

2. Method

The aim of the current study was to analyze the cognitive and metacognitive abilities of the students with SLDM and investigate the role of ICTs in the assessment of these abilities. This study is a literature review article that includes articles and books from 1945 up to date. The keywords for the article search were: the cognitive and metacognitive abilities in Dyscalculia, Specific Learning Disorder in Mathematics and ICT Assessment tools for Dyscalculia, ICT assessment tools for mathematical metacognition. The search engines that were used were Google Scholar and Research Gate. A limitation of the study was the very limited existed literature on the ICTs for the assessment of metacognition in general and mathematical metacognition specifically. Another limitation was the multi-faceted character of the review that tried to combine three crucial factors for mathematical learning (cognition, metacognition and ICTs) and analyze their role for the assessment of SLDM.

3. Literature review

3.1 The cognitive deficits of the students with SLDM

The students with SLDM have both general and specific cognitive deficits. The specific cognitive deficits concern the recalling of basic mathematical knowledge (Shalev, 2004, Haberstroh & Schulte Körne, 2019), the succession of numbers (Muhammad, 2020), the mental calculations (Yoong & Ahmad, 2021), the money (Reisman & Severino, 2020), the algorithms (Shalev, 2004), the concept of space (Rader, 2009), the mathematical problems (Muhammad, 2020), symbols and operations (Reisman & Severino, 2020).

The general cognitive deficits of the students with SLDM include deficits in the executive functions, the social and emotional domain (Agaliotis, 2018, Mahmut et al., 2020, Lindsay et al., 1999).

The visuospatial sketchpad of the working memory (Passolunghi & Cornoldi, 2008) and the working memory in general are characterized by malfunction (Attut& Majerous,2015, Rotzer et al., 2009, Galitskaya & Drigas, 2021, Bull et al., 1999). The ability of attention also malfunctions in many cases (Lindsay et al., 1999, Guarnera & D'Amico, 2014). The students with SLDM are also characterized by deficits in the processing speed (Yazdani et al., 2021), the mental representation (Bull et al., 1999), the inhibitory control (Zhang & Wu, 2011), and in learning and applying cognitive and metacognitive strategies (Montague, 2008, Agaliotis, 2018).

In the social and emotional domain they are characterized by high level of mathematics anxiety (Rubinsten & Tannock, 2010, Drigas &Pappas, 2015, Lai et al. , 2015), reduced self esteem and motivation (Karbasdehi et al., 2019, Montague, 2008) and sometimes impulsiveness (Mohaddes et al. , 2016).

Lindsay et al. (1999) examined the relation between the attention deficits and SLDM and concluded that there are common shared factors that affect both the arithmetic competence and the maintenance of attention. The students with ADHD have deficits in the executive functions, but the deficits in executive functions are also a crucial factor for the SLDM.

Geary et al. (2004) investigated the contribution of the working memory and the counting strategies in the mathematical competence of students with SLDM and their classmates of typical development. The sample consisted of 91 students of first, second and fifth grade of primary school. In all grades, the students with SLDM displayed cognitive deficit in working memory and in the first grade the students with SLDM used strategies of a lower level like counting the fingers and they made more mistakes in the addition problems. For example, they did not begin the addition from the bigger number, a strategy that is crucial for the faster calculations and the automation of addition (Chen et al., 2019).

Rotzer et al. (2009) examined the relationship between the dysfunction of the neuronal networks of spatial working memory and the SLDM. They examined with the MRI method the brain function of regions related to the visuospatial memory in 21 students, 8 to 10 years old, ten of which were diagnosed with SLDM. The results indicated a strong connection among the function of the right intraparietal sulcus and the ability of recalling arithmetic digits and the visuospatial ability also. The students with SLDM had a dysfunction in these brain regions. The researchers suggest that the malfunction of the spatial working memory could hinder the creation of spatial arithmetic representations, like the mental number line, and also lead to difficulties in the storing and recalling of arithmetic data.

Galitskaya and Drigas (2021) displayed the deficits of the students with SLDM in working memory. According to these researchers, the students with SLDM display deficits in all the sub-systems of working memory. The malfunction of the semantic working memory seems to be related with the slow naming speed. The phonological, visuospatial and short-term memory is also deficient and problems have been detected in the central executive as well.

Yazdani et al. (2021) investigated the effect of 8 factors of spatial ability in the executive functions of the students with SLDM. The sample comprised of 128 students of age 9-12 years old half of which had been diagnosed with SLDM. The factors that were studied were the flexibility of closure, the closure speed, the perceptual speed, the visualization, the spatial relation, the spatial orientation, spatial temporal and the way finding. The results suggest that the students with SLDM had lower competence than their classmates of typical development in all the 8 factors of spatial ability.

For the development of the cognitive abilities of the student with SLDM the research suggests both the development and enhancement of the cognitive functions (Kucian et al., 2011, Guarnera & D'Amico, 2014, Layes et al., 2018, Drigas, Dedes&Dedes, 2020, Cheng et al., 2020) and the instruction of cognitive and metacognitive strategies (Montague, 2008, Montague et al., 2014, Rader, 2009, Babakhani, 2011, Mohaddes et al., 2016, Karbasdehi et al., 2019, Lucangeli et al., 2019, Farardiba et al., 2019). Concerning the development of cognitive and metacongitive strategies by children with SLDM, Škof (2015) proposed the combination of the Polya's model for mathematical problem solving with Zimmerman's model for the self-regulated learning.

3.2 The concept of metacognition in mathematics education

The theory of metacognition has its roots in the developmental and cognitive psychology and then was applied in the field of education, as far as self-monitoring and self-regulation constitute crucial facets of learning (Hacker et al., 1998). Metacognitive functions rely on self-monitoring and contribute to the improvement of cognitive competence, as they facilitate the selection and application of cognitive strategies and improve other crucial cognitive functions such as the attention (Drigas & Mitsea, 2021, Corno, 1986). The two components of metacognition are the «knowledge of cognition» and the «regulation of cognition» (Schraw&Moshman, 1995). The researchers define metacognition as «thinking about thinking». Metacognition constitutes the knowledge of people about their own and others cognition (Fisher, 1998, Papleontiou-Louca, 2003).

According to Driga and Mitsea (2021), metacognition constitutes a sum of higher abilities of self-regulation, such as the ability of reflection, self-regulation and adjustment of the thoughts, the emotions and the behavior, as long as, the ability of recognizing among the functional and dysfunctional patterns of thinking and acting. Self-control is the outcome of applying metacognition and stems from the conscious use of the last in everyday life. John Flavell introduced the term meta-memory as the fourth and higher type of memory (Flavell & Wellman, 1975). Later, in his work «Metacognition and Cognitive monitoring» (Flavell, 1979), he proposed a model of cognitive monitoring comprised of three elements: the «metacognitive knowledge», the «metacognitive experiences, goals and problems» and the «metacognitive actions and strategies». According to Flavell, the metacognitive knowledge is the stored knowledge someone has for himself and others as cognitive entities. The metacognitive experiences are conscious experiences that take place during a cognitive action and are related to the awareness of its progress. The experiences affect and are affected by the cognitive and metacognitive strategies someone uses in order to achieve a cognitive goal and evaluate his progress.

Garofalo and Lester (1985) investigated the role of metacognitive skills in the mathematical competence and suggested a cognitive-metacognitive context of mathematical competence in problem solving that could be used as a tool for the analysis of the metacognitive aspects of mathematical competence. This context consists of 4 stages: orientation, organization, execution and verification. The orientation constitutes the strategic behavior for evaluating and understanding the problem. The organization includes the planning of the behavior and the selection of actions. The execution contains the regulation of behavior, in order to adjust to the planning. The verification, at last, constitutes the evaluation of the decisions that had been made, the results of the executed plans and the evaluation of orientation and organization.

Polya (1945) presented 4 stages for the successful solving of mathematical problems that rely on the process of «reflection». These stages are the comprehension of the problem, the invention of a plan, the execution of the plan and the evaluation of the result and the way of thinking.

Mevarech and Fridkin (2006) investigated the effect of the application of a metacognitive instructional program, called «IMPROVE», in the mathematical competence of students that aimed to get in the university in Israel. The sample of the research consisted of 81 students with low grades in mathematics and the experimental group included 38 of them. The students were instructed how to pose metacognitive questions, to interrelate the knowledge, to plan, observe and evaluate their work and use strategies. The program helped the students to develop both metacognitive knowledge and the ability of self-regulation of knowledge.

Özsoy (2011) studied the relation between the metacognitive ability and the mathematical competence in students of fifth grade of primary school. The sample of the research comprised of 242 students of primary school in Turkey. It is worth mentioning that, according to the results, 42% of variability of mathematical competence could be accounted for the metacognition and the metacognitive skills. In particular, the variables that were evaluated were the mathematical competence, the declarative and procedural knowledge and the ability of planning, estimation, self-monitoring and evaluation. The knowledge, the ability of estimation and the ability of evaluation were the metacognitive variables with the highest association with the mathematical competence.

Doesete et al. (2004) designed a conceptual model for problem solving that includes three components of metacognition: the metacognitive knowledge, the metacognitive skills and the metacogntive beliefs. The model is divided in two parts, cognition and metacognition. The first part, that concerns the development of cognitive skills, includes the comprehension and handling of numbers, symbols and the arithmetic system, procedural skills, linguistic comprehension, context comprehension, mental representation, the selection of important information and the development of the concept of number. The second part, that concerns the metacognitive skills and beliefs, includes the prediction, the planning, the self-monitoring and evaluation, the self-perception, the self-efficacy, motivation, competence and, at last, the perception of intelligence and learning.

Karaali (2015) examined the implementation of a metacognitive program in students of mathematics in the University of California. At the end of every week the students should evaluate their progress according to their goals. The aim of the program was for the students to develop self-motivation through self-monitoring, self-regulation and self-evaluation. The program had three phases that cycled. The initial goals led to a conscious cognitive process and consequently in self-evaluation. The evaluation led to motivation and enhanced the conscious effort and the self-regulation of the students. The results suggest that the development of metacognitive skills had a positive impact on their effort and their motivation. The mathimatics anxiety was reduced and the students attended the classes dutifully.

Amin and Mariani (2017) created a model for problem solving, PME, that combines the theory of metacognition with the constructivism learning theory. The basic activities of the model are the planning, the self-monitoring and the evaluation. The process follows the principles of constructivism about the instruction in little teams and the educators act as leaders that encourage the students. The basic goal is the improvement of competence in problem solving through the enhancement of the metacognitive ability.

Suendarti and Liberna (2018) investigated the effect of a metacognitive learning model in mathematics, the I–CARE, in the mathematical competence of students in Africa. In the research took part 60 students. Half of them were in the experimental group and half in the control group. It is worth mentioning that the students in the control group were instructed mathematics by the constructivism learning model, which is one of the most effective methods of teaching mathematics. The «I-CARE» program had 5 stages, the introduction, the connection, the application, the reflection and the generalization. The results indicate that the students that were instructed mathematics with the metacognitive model had a better competence than the students that were instructed mathematics with the constructivism model.

Pappas, Drigas and Polychroni (2018) created a model for the acquisition of different levels of mathematical cognition. The model consists of an eight-layer pyramid. At the lowest level is placed the Sensory Arithmetic. The cognitive processes that take place in this level are sensory coding and spatial cognition. The metacognitive ability that occurs in this level is awareness. At the second level there is the Basic Arithmetic. The cognitive processes in this level are synthesis and structure of data, spatial cognition development and sustained attention. The metacogntive ability is again awareness. At the third level there is the Elementary Mathematical Thinking. The cognitive ability is recall of mathematical concepts from the long term memory. The metacognitive ability is conditional knowledge. At the fourth level there is the Intermediate Mathematical Thinking with information processing as the cognitive process and monitoring of skills and knowledge as the metacognitive ability. At the fifth level there is Coherent Mathematical Thinking with inter-connection of mathematical knowledge and development of new strategies as cognitive abilities and self-organization, procedural knowledge and self-regulation as the metacognitive abilities. At the sixth level there is Advanced Mathematical Thinking with abstracting and visualization of math concepts as cognitive abilities and shifting and updating as the metacognitive abilities. At the seventh level is placed Mathematical Wisdom with cognitive flexibility as cognitive process and perfecting, abstracting and detaching as metacognitive processes. At the last level there is Mathematical Transcendence with extension of boundaries and creativity as the cognitive ability and intuition and planning as the metacognitive processes.

3.3 The metacognitve deficits of the students with SLDM

The students with SLDM are also characterized by deficits in the domain of metacognition. They often fail to choose and apply appropriate cognitive and metacognitive strategies, they face difficulty in predicting and evaluating a solution and their overall competence (Agaliotis, 2018, Miller&Mercer, 1997, Pennequin et al., 2010) and deal with high levels of mathematics anxiety (Lai et al., 2015, Rubinsten&Tannock, 2010). They also face difficulty in regulating their emotions (Montague, 2008).

In order to improve and diminish these metacognitive deficits the researchers have designed a variety of interventional programs that aim either to develop the ability to handle different cognitive and metacognitive strategies (Hacker et al, 2019, Wonu&Worika, 2019) or to regulate and adjust their emotions and behavior. The last ones are called self-regulation programs (Karbasdehi et al., 2019, Lucangeli et al, 2019). Self-regulated learning includes goal setting, strategic planning, organizing, reflection, monitoring and control of cognitive functions, time management and evaluation (Ziemmerman,1998).

Garrett et al. (2006) investigated the metacognitive skills that proceed or follow an activity. They examined the metacognitive skills of prediction and evaluation in 17 students with learning difficulties in mathematics and 179 students without learning difficulties in mathematics. The students attended the second, third and fourth classes of primary school and were asked to predict at first which of some given problems they would be able to solve successfully. Then, after they solve the problems, the students were asked to evaluate their answers. The results revealed that the ability to evaluate the problem solving process increased with age in contrast to the ability to predict the ability or inability to solve a problem which was constant. The students with learning difficulties in mathematics lacked compared to those without learning difficulties both in the metacognitive skill of prediction and evaluation. Nonetheless, the students with learning difficulties in mathematics were aware and able to predict to the same extent their inability to solve specific problems.

Desoete et al. (2006) examined the metacognitive skills of 191 students with learning difficulties in mathematics and 268 students without learning difficulties in mathematic. The students attended the third class of primary school in Belgium. The researchers examined the relationship between mathematics, metacognition and intelligence. The results revealed a significant relationship among the ability of prediction, the ability of evaluation, intelligence and the ability of recalling procedural and conceptual mathematical knowledge in the students without learning difficulties in mathematics. Concerning the students with learning difficulties in mathematics the researchers observed a relationship between the metacognitive and the procedural skills. Furthermore, 4/5 of the students with combined learning difficulties in mathematics, half of the students with procedural difficulties in mathematics and 5% of the students with deficit in recalling ability were characterized by decreased metacognitive ability. The corresponding fraction for the students without learning difficulties in mathematics was 1/5. The students with learning difficulties in mathematics that lacked metacognitive ability seemed to have problems with the skills of prediction and evaluation. The majority of the students with deficient metacognitive skills faced problems only with the prediction of the difficulty level of the problems. Concerning the ability of evaluation of the process of the problem solving, the students with learning difficulties and decreased metacognitive skills faced greater difficulty compared to those with decreased metacognitive skills but no learning difficulties in mathematics. As a result, for these students was more possible to make a wrong or inaccurate evaluation of their progress.

3.4 ICT tools for the assessment of the cognitive abilities of the students with SLDM

In order to assess the cognitive abilities of the students with SLDM the researchers have designed ICT tools that evaluate different cognitive abilities.

Pappas et al. (2015) in their research reviewed 14 ICT tools for the assessment of the cognitive abilities of the students with SLDM. These tools evaluate attention, alertness, working memory, short-term memory, mathnematical learning profiles, neural correlates of non symbolic number magnitude processing, gray and white matter volum, magnitude deficits, flexibility, maintained attention, reaction time and brain activation and non symbolic number comparison.

Drigas and Pappas (2015) displayed ICT tools for the assessment of the SLDM. According to the researchers the digital assessment tools are limited in number. The tools that are presented are Discalculium, Dyscalculia Screener, Basic Numerical Battery and Fuzzy Expert System. These tools were developed in the last decade and are used worldwide. They fall into three categories: internet applications, computer applications and applications of artificial intelligence (Drigas, Pappas and Lytras, 2016).

Cangoz et al. (2013) presented five computerized cognitive tasks for the screening of dyscalculia in children of ages 6-9 years old. The tasks were delivered to students with the use of android tablets. According to the researchers, the 5 tasks respond to the neuro-structural and neurofunctional imaging findings in Developmental Dyscalculia (another term for SLDM) and examine both the exact and approximate number systems.

Peltenburg et al. (2009) examined the learning potential of 37 students 8–12 years old from two special education schools in the Netherlands through an ICT-based assessment using a dynamic visual tool. The tool consisted of seven subtraction problems up to 100, which required ‘borrowing’. The ICT version of the test offered the pupils a set of virtual manipulatives, consisting of a 100 board with a 10 by 10 grid and divided in four parts with a 5–5 structure. The researchers hypothesized that through an onscreen visual representation of the problem, the pupils would be less inclined to reverse the processing of the ones-digits. The results showed that the use of ICT could provide unique advantages by offering pupils flexible manipulatives in a dynamic format which helped them overcome obstacles in solving subtraction problems with borrowing. Additionally, the ICT format made it easier for the researchers to assess pupils’ thinking processes and strategies.

Beacham and Trott (2005) presented the Dyscalculium, a computer based screener for dyscalculia designed for the assessment of the high school students. This screening test assesses

Technium Social Sciences Journal
Vol. 31, 131-152, May, 2022
ISSN: 2668-7798
www.techniumscience.com

the understanding of basic mathematical and numerical concepts and relationships. The test items aim to pinpoint basic difficulties through the activities of recognizing, reading and writing discrete positive whole numbers and their relationships and operations. The test also investigates the students' understanding of fractions, decimals and negative numbers, and systems that rely on these such as money and time. According to the researchers, the benefit of the computer-based version is the ability to automatically mark the mathematical type questions in the screening test and keep a record of each individual score for the students. The sensitivity of the screening test was 83.3% and the specificity 92.3%.

Zygouris et al. (2017) presented a web application screener for dyscalculia that assesses children aged from 8 to11 years old. The sample of the research consisted of 60 students of whom the 30 had a statement of dyscalculia. The three tasks that were used for evaluating children's arithmetic ability were a calculation task, a task that evaluated their skills in understanding mathematical terminology and an arithmetic problem solving task. Statistical analysis revealed that children with dyscalculia had statistically significant lower mean scores of correct answers and larger time latencies in all tasks compared to their average peers that participated in the comparison group.

Del Angel et al. (2018) applied a design and automation workshop implemented with the CATIA software. The CATIA software enables students to design everything they can imagine. The workshop was conducted with ten students between six and twelve years' old who had little contact with technology and the participation of the Technological University of Puebla. The CATIA software was able to detect mathematical difficulties.

Bambang Pudjoatmodjo et al. (2021) presented the 3D dyscalculia assessment game, a serious game that was designed for assessing, identifying and monitoring dyscalculia students. The main character of the game is a little detective that has to solve everyday mathematical problems of addition and subtraction. The player must solve the problem to gain a reward. If the player cannot find the solution, receives a notification in order to keep motivated to play the game. Due to pandemic the game was only tested in the laboratory. The results suggest that the game fulfills the expectations of the user but the interface organization may need improvements.

3.5 ICT tools for the assessment of the metacognitive abilities of the students with SLDM

The use of ICT for the assessment of the metacognitive abilities of the students in mathematics has also been studied. In this chapter we also examine the existed ICTs for the assessment of the students' Problem Solving skills, as these skills often include metacognitive processes.

According to Mayer (2002), the computer-based assessment of problem solving is motivated by the need for educational assessments that are valid and efficient. The researcher suggests six major categories of cognitice processes based on Bloom's taxonomy: remember, understand, apply, analyze, evaluate and create and four major categories of knowledge: factual, conceptual, procedural, and metacognitive.

Karyotaki and Drigas (2016) displayed some online and other ICT-based assessment tools for problem-solving skills. The assessment tools were classified into 4 categories: assessment of Pisa, stand on applications, web and games. According to the researchers, these collaborative problem-solving assessment tools measure group members' cognitive and metacognitive skills, evolving from the social regulation of processes.

Ibabe and Jauregizar (2010) displayed an educational innovation in a university context. Their aim was to determine the relationship between students' frequency of use of online self-assessment with feedback and their final performance on the course. The participants of the research were 116 Psychology students at the University of the Basque Country in Spain. The self-assessment material was created with the Hot Potatoes educational program. The researchers then assessed the degree to which students took advantage of the tool, their satisfaction with it and their perceived knowledge. The results indicate better academic performance in those students that used interactive self-assessment. Finally, the researchers suggest the inclusion of self-assessment in the curriculum in order to improve students' metacognitive skills.

Johnson and Naresh (2011) examined the impact of using a computer pen in order to assess students' use of metacognition during mathematical problem-solving. The sample of the research consisted of 42 pre-service teachers. The Smartpen stores the written strokes and any oral communication that occurs simultaneously during the recording session. Students first shared their thinking through self-talk or group-talk and then worked with others to share their strategies and reflect upon the process. According to the researchers, the problem solvers who lacked confidence in their problem-solving ability were more reserved in their self-talk and often solved problems unrecorded in advance to appear more successful later during the recorded problem-solving session. The results indicate that direct, real-time monitoring by the teacher is needed to capture significant information about students' metacognitive reasoning. Furthermore, the use of the Smartpens to support students' metacognitive thought while engaging in mathematical problem-solving may increase their awareness of metacognitive processes.

Chimuma and Johnson (2016) also investigated the effectiveness of using Smartpens in order to assess students' use of metacognition during Mathematical Problem Solving. The study explored the pre and post use of metacognitive problem solving skills of 15 undergraduate students who were enrolled in a mathematics class in a Midwestern university. Participants' progress in their metacognitive self-talk and group-talk was monitored. The students used Smartpens to capture their writing and spoken words that occurred during problem solving. Results indicate statistically significant differences in participants' mean pre- and post-performance on the complete Metacognitive Awareness Inventory and on regulation of cognition items.

Veenman (2007) presented six articles of the existed literature that concern the instruction and assessment of self-regulation in computer based environments. The researcher concluded that a lot of work needs to be done with regard to the definition, the assessment, and the validity of assessment of self-regulated learning.

4. Discussion & Conclusions

In this study we presented the cognitive and metacognitive deficits of the students with SLDM and examined the significance of the development of their cognitive and metacognitive skills. We also investigated the existed ICT tools for the assessment of these skills.

The review of the literature revealed that the existed literature for the ICTs for the assessment of the metacognitive abilities of the students with SLDM is more limited than the literature for the ICTs that assess the cognititve abilities and includes mainly articles on the use of the smartpens, in order to capture the metacognitive self-talk of the students, and the computerized assessment of the problem solving ability.

The Specific Learning Disorder is a multifactorial learning disorder that can be approached in many different ways and that is affected by many different factors. The development of the cognitive and metacognitive abilities of the students with SLDM combined with the integration of the ICTs in the instruction can be crucial factors for the improvement of the learning disorder's symptoms. ICT tools can also be integrated in the assessment process of SLDM and the assessment of the mathematical metacognition.

The combination of the ICTs with the development of the cognitive and metacognitive skills of students with SLDM seems to be a very promising and effective interventional method. ICTs motivate and excite the students and at the same time help them concentrate and attain their attention on the cognitive tasks.

There is a variety of computer based and mobile assessment tools for the cognitive skills of the students with SLDM, such as the serious games and the educational software. These tools assess either the mathematical ability of the students or their cognitive functions, such as attention and memory.

More research must be done on the assessment of the mathematical metacognition with the use of ICT tools. Although there are some assessment tools for problem solving that use ICTs in higher education, the existed literature for primary education is very limited. Thus ICT tools for the assessment of metacognition in general and mathematical metacongition specifically should be developed in order to improve the process of the assessment in this domain.

Concluding this article we should underline in information age era, the role of ICTs in general and special education and in other related domains [114-129, 155-169]. The mobiles play an important role [104-113] in making more accessible the educational procedures. The serious games make the educational applications more attractive to students and pupils [151-154]. The artificial intelligence is a powerful tool in procedures for diagnosis and adaptable interventions and moreover in design of educational applications [145-150]. Finally there are several applications that support educational procedures based on metacognition, mindfulness, meditation and emotional intelligence cultivation strategies [130-144, 170-185].

All the above mentioned applications of information age era, facilitate and accelerate the assessment and diagnosis procedures within education. People with Learning Disorder in Mathematics take a big advantage of all these applications and procedures as already has been presented in this article and this is a very promising situation for the diagnosis of their special needs on mathematics.

References

[1] AGALIOTIS, I., (2018). Instruction of Mathematics in Special Education: Nature and Educational management of mathematical difficulties. Athens: Gregori (in Greek).

[2] AGGARWAL, M., & BAL, S. (2020). Tools of ICT for learning and teaching mathematics. *Journal of mechanics of continua and mathematical sciences*, *15*, 1-12.

[3] AMERICAN PSYCHIATRIC ASSOCIATION. (2013). Diagnostic and statistical manual of mental disorders (DSM-5®). American Psychiatric Pub.

[4] AMIN, I., & MARIANI, S. (2017). PME learning model: The conceptual theoretical study of metacognition learning in mathematics problem solving based on constructivism. *International Electronic Journal of Mathematics Education*, *12*(3), 333-352.

[5] APRINASTUTI, C., ANGGADEWI, B. E. T., SUHARNO, R., & WIYANTARI, W. (2020, October). Development of mathematics manipulative for slow learner and dyscalculia student in elementary school by using Montessori's characteristic. *Journal of Physics: Conference Series (Vol. 1663, No. 1, p. 012065).* IOP Publishing.

[6] ATTOUT, L., & MAJERUS, S. (2015). Working memory deficits in developmental dyscalculia: The importance of serial order. *Child Neuropsychology*, *21*(4), 432-450.

[7] BABAKHANI, N. (2011). The effect of teaching the cognitive and meta-cognitive strategies (self-instruction procedure) on verbal math problem-solving performance of primary school students with verbal problem-solving difficulties. *Procedia-Social and Behavioral Sciences*, *15*, 563-570.
[8] BAMBANG PUDJOATMODJO, S. S., CHE PEE, N., AHERLIWAN RUDAVAN, R., PRIHATMANTO, S., & ALOMOUSH, A. (2021). The 3D Dyscalculia Assessment Game Framework for Dyscalculia Identification. *International Journal Of Computing and Digital System*.
[9] BEACHAM, N., & TROTT, C. (2005). Screening for dyscalculia within HE. *MSOR Connections*, *5*(1), 1-4.
[10] BENNETT, P. & RULE A. (2005). Hands-on long division with skittles for students with learning disabilities. Teaching Exceptional Children Plus, 1(5), 2-23.
[11] BULL, R., JOHNSTON, R. S., & ROY, J. A. (1999). Exploring the roles of the visual-spatial sketch pad and central executive in children's arithmetical skills: Views from cognition and developmental neuropsychology. *Developmental neuropsychology*, *15*(3), 421-442.
[12] CADAMURO, A., BISAGNO, E., PECINI, C., & VEZZALI, L. (2019). Reflecting A…"Bit". What Relationship Between Metacognition And ICT?. *Journal of E-Learning and Knowledge Society*, *15*(3), 183-195.
[13] CANGOZ, B., ALTUN, A., OLKUN, S., & KACAR, F. (2013). Computer Based Screening Dyscalculia: Cognitive and Neuropsychological Correlates. *Turkish Online Journal of Educational Technology-TOJET*, *12*(3), 33-38.
[14] CHENG, D., XIAO, Q., CUI, J., CHEN, C., ZENG, J., CHEN, Q., & ZHOU, X. (2020). Short-term numerosity training promotes symbolic arithmetic in children with developmental dyscalculia: The mediating role of visual form perception. *Developmental science*, *23*(4), e12910.
[15] CHEN, Y., LOEHR, J. D., & CAMPBELL, J. I. (2019). Does the min-counting strategy for simple addition become automatized in educated adults? A behavioural and ERP study of the size congruency effect. *Neuropsychologia*, *124*, 311-321.
[16] CHIMUMA, L. L., & JOHNSON, I. (2016). Assessing Students' Use of Metacognition during Mathematical Problem Solving Using Smartpens. *Educational Research: Theory and Practice*, *28*(1), 22-36.
[17] CHYTRÝ, V., ŘÍČAN, J., & MEDOVÁ, J. (2019). How Teacher's Progressiveness in Using Digital Technologies Influences Levels of Pupils' Metacognitive Knowledge in Mathematics. *Mathematics*, *7*(12), 1245.
[18] CONCHINHA, C., OSÓRIO, P., & DE FREITAS, J. C. (2015, November). Playful learning: Educational robotics applied to students with learning disabilities. In *2015 International symposium on computers in education (SIIE)* (pp. 167-171). IEEE.
[19] CORNO, L. (1986). The metacognitive control components of self-regulated learning. *Contemporary educational psychology*, *11*(4), 333-346.
[20] DEL ANGEL, M. A. B., ABURTO, A. D. M., ABURTO, F. N. M., & PÉREZ, M. G. (2018). Analysis of the dyscalculia with the implementation of a design workshop in CATIA in a primary school in Puebla. *International Journal of Advanced Engineering, Management and Science*, *4*(10), 266190.
[21] DESOETE, A., ROEYERS, H., & HUYLEBROECK, A. (2006). Metacognitive skills in Belgian third grade children (age 8 to 9) with and without mathematical learning disabilities. *Metacognition and Learning*, *1*(2), 119-135.

[22] DIAMOND, A. (2013). Executive functions. Annual review of psychology, 64, 135-168.
[23] DRIGAS, A. & PAPPAS, M. (2015) ICT Based Screening Tools and Etiology of Dyscalculia. *International Journal of Engineering Pedagogy, 5*(*3)*, 61-66.
[24] DRIGAS, A. S., PAPPAS, M. A., & LYTRAS, M. (2016). Emerging technologies for ICT based education for dyscalculia: implications for computer engineering education. *International Journal of Engineering Education*, *32(4)*, 1604-1610.
[25] DRIGAS, A., & KARYOTAKI, M. (2017). Attentional control and other executive functions. *International Journal of Emerging Technologies in Learning (iJET)*, *12*(03), 219-233.
[26] DRIGAS, A., DEDE, D. E., & DEDES, S. (2020). Mobile and other applications for mental imagery to improve learning disabilities and mental health. *International Journal of Computer Science Issues (IJCSI)*, *17*(4), 18-23.
[27] DRIGAS, A., & MITSEA, E. (2021). 8 Pillars X 8 Layers Model of Metacognition: Educational Strategies, Exercises &Trainings. *International Journal of Online & Biomedical Engineering*, *17*(8).
[28] ERFURT, G., HORNECKER, E., EHLERS, J., & PLASCHKIES, S. (2019). Hands-On Math: A Training System for Children with Dyscalculia. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-6).
[29] FLAVELL, J. H., & WELLMAN, H. M. (1975). Metamemory.
[30] FLAVELL, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American psychologist, 34(10)*, 906.
[31] FISHER, R. (1998). Thinking about thinking: Developing metacognition in children. *Early Child Development and Care*, *141*(1), 1-15.
[32] GALITSKAYA, V., & DRIGAS, A. (2021). The importance of working memory in children with Dyscalculia and Ageometria.
[33] GAROFALO, J., & LESTER JR, F. K. (1985). Metacognition, cognitive monitoring, and mathematical performance. *Journal for research in mathematics education*, 163-176.
[34] GARRETT, A. J., MAZZOCCO, M. M., & BAKER, L. (2006). Development of the metacognitive skills of prediction and evaluation in children with or without math disability. *Learning Disabilities Research & Practice*, *21*(2), 77-88.
[35] GEARY, D. C. (1993). Mathematical disabilities: Cognitive, neuropsychological, and genetic components. *Psychological bulletin*, *114*(2), 345.
[36] GEARY, D. C. (2004). Mathematics and learning disabilities. *Journal of learning disabilities*, *37*(1), 4-15.
[37] GEARY, D. C., HOARD, M. K., BYRD-CRAVEN, J., & DESOTO, M. C. (2004). Strategy choices in simple and complex addition: Contributions of working memory and counting knowledge for children with mathematical disability. *Journal of experimental child psychology*, *88*(2), 121-151.
[38] GEARY, D. C. (2010). Mathematical disabilities: Reflections on cognitive, neuropsychological, and genetic components. *Learning and individual differences*, *20*(2), 130-133.
[39] GONZÁLEZ, J., MORALES, I., NIELSEN, M., MUÑOZ, L., & VILLARREAL, V. (2019). Improving the Teaching of Mathematics through Robotics. In *Multidisciplinary Digital Publishing Institute Proceedings* (Vol. 31, No. 1, p. 5).
[40] GUARNERA, M., & D'AMICO, A. (2014). Training of attention in children with low arithmetical achievement. Europe's Journal of Psychology, 10(2), 277-290

[41] HABERSTROH, S., & SCHULTE-KÖRNE, G. (2019). The diagnosis and treatment of dyscalculia. *Deutsches Ärzteblatt International*, *116*(7), 107.

[42] HACKER, D. J., KIUHARA, S. A., & LEVIN, J. R. (2019). A metacognitive intervention for teaching fractions to students with or at-risk for learning disabilities in mathematics. *ZDM*, *51*(4), 601-612.

[43] HACKER, D. J., DUNLOSKY, J., & GRAESSER, A. C. (EDS.). (1998). *Metacognition in educational theory and practice*. Routledge.

[44] HUNT, J., & TZUR, R. (2017). Where is difference? Processes of mathematical remediation through a constructivist lens. *The Journal of Mathematical Behavior*, *48*, 62-76.

[45] IBABE, I., & JAUREGIZAR, J. (2010). Online self-assessment with feedback and metacognitive knowledge. *Higher Education*, *59*(2), 243-258.

[46] JERIN, J. Q., ZAKI, T., MAHMOOD, M., ROCHEE, S. K., & ISLAM, M. N. (2020). Exploring Design Issues in Developing Usable Mobile Application for Dyscalculia People. In *2020 Emerging Technology in Computing, Communication and Electronics (ETCCE)* (pp. 1-6). IEEE.

[47] JOHNSON, I. D., & NARESH, N. (2011). Using A Computer Pen to Investigate Students"Use of Metacognition during Mathematical Problem-Solving. [48] KARAALI, G. (2015). Metacognition in the classroom: Motivation and self-awareness of mathematics learners. *PRIMUS*, *25*(5), 439-452.

[49] KARBASDEHI, E. R., ABOLGHASEMI, A., & KHANZADEH, A. A. H. (2019). The effect of self-regulation empowerment program training on neurocognitive and social skills in students with dyscalculia. *Archives of Psychiatry and Psychotherapy*, *2*, 71-80.

[50] KARYOTAKI, M., & DRIGAS, A. (2016). Online and other ICT-based Assessment Tools for Problem-solving Skills. *International Journal of Emerging Technologies in Learning*, *11*(4).

[51] KARYOTAKI, M., DRIGAS, A., & SKIANIS, C. (2017). Attentional control and other executive functions. *International journal of emerging technologies in learning*, *12*(3).

[52] KAVALE, K. A., SPAULDING, L. S., BEAM, A. P. (2009). A time to define: Making the specific learning disability definition prescribe specific learning disability. Learning Disability Quarterly, 32, 39–48.

[53] KUCIAN, K., GROND, U., ROTZER, S., HENZI, B., SCHÖNMANN, C., PLANGGER, F., GÄLLI , M. , MARTIN, E. & VON ASTER, M. (2011). Mental number line training in children with developmental dyscalculia. *NeuroImage*, *57*(3), 782-795.

[54] LAI, Y., ZHU, X., CHEN, Y., & LI, Y. (2015). Effects of mathematics anxiety and mathematical metacognition on word problem solving in children with and without mathematical learning difficulties. *PloS one*, *10*(6).

[55] LATIF, A., & AHMAD, H. (2021, November). Effectiveness of using The GeoEnzo Application on Metacognitive Abilities in Mathematics Learning. In *Journal of Physics: Conference Series* (Vol. 2123, No. 1, p. 012007). IOP Publishing.

[56] LAYES, S., LALONDE, R., BOUAKKAZ, Y., & REBAI, M. (2018). Effectiveness of working memory training among children with dyscalculia: evidence for transfer effects on mathematical achievement—a pilot study. *Cognitive processing*, *19*(3), 375-385.

[57] LINDSAY, R. L., TOMAZIC, T., LEVINE, M. D., & ACCARDO, P. J. (1999). Impact of attentional dysfunction in dyscalculia. *Developmental medicine and child neurology*, *41*(9), 639-642.

[58] LUCANGELI, D., & CABRELE, S. (2006). Mathematical difficulties and ADHD. Exceptionality, 14(1), 53-62.

[59] LUCANGELI, D., FASTAME, M. C., PEDRON, M., PORRU, A., DUCA, V., HITCHCOTT, P. K., & PENNA, M. P. (2019). Metacognition and errors: the impact of self-regulatory trainings in children with specific learning disabilities. *ZDM*, *51*(4), 577-585.
[60] LYTRA, N., & DRIGAS, A. (2021). STEAM education-metacognition–Specific Learning Disabilities. *Scientific Electronic Archives*, *14*(10).
[61] MAHMUD, M. S., ZAINAL, M. S., ROSLI, R., & MAAT, S. M. (2020). Dyscalculia: What We Must Know about Students' Learning Disability in Mathematics?. *Universal Journal of Educational Research*, *8*(12B), 8214-8222.
[62] MAYER, R. E. (2002). A taxonomy for computer-based assessment of problem solving. *Computers in Human Behavior*, *18*(6), 623-632.
[63] MEVARECH, Z., & FRIDKIN, S. (2006). The effects of IMPROVE on mathematical knowledge, mathematical reasoning and meta-cognition. *Metacognition and learning*, *1*(1), 85-97.
[64] MILLER, S. P., & MERCER, C. D. (1997). Educational aspects of mathematics disabilities. *Journal of learning disabilities*, *30*(1), 47-56.
[65] MOHADDES, G. P., POUR, E. S., JAHANGIRI, Z., & TALEBI, G. (2016). The Effectiveness of Metacognitive Strategies of SQP4R on Decreasing Impulsiveness of Students with Mathematic learning Disability. *International Journal of Humanities and Cultural Studies (IJHCS) ISSN 2356-5926*, *1*(1), 1832-1850.
[66] MONTAGUE, M. (2008). Self-regulation strategies to improve mathematical problem solving for students with learning disabilities. *Learning Disability Quarterly*, 31(1), 37-44.
[67] MONTAGUE, M., KRAWEC, J., ENDERS, C., & DIETZ, S. (2014). The effects of cognitive strategy instruction on math problem solving of middle-school students of varying ability. *Journal of Educational Psychology*, *106*(2), 469.
[68] MUÑOZ, L., VILLARREAL, V., MORALES, I., GONZALEZ, J., & NIELSEN, M. (2020). Developing an interactive environment through the teaching of mathematics with small robots. *Sensors*, *20*(7), 1935.
[69] ÖZSOY, G. (2011). An investigation of the relationship between metacognition and mathematics achievement. *Asia pacific education review*, *12*(2), 227-235.
[70] PAPANASTASIOU, G., DRIGAS, A., SKIANIS, C., & LYTRAS, M. D. (2017). Serious games in K-12 education: Benefits and impacts on students with attention, memory and developmental disabilities. *Program*.
[71] PAPPAS, M. A., DRIGAS, A. S., & POLYCHRONI, F. (2018). An Eight-Layer Model for Mathematical Cognition. *International Journal of Emerging Technologies in Learning (iJET)*, *13*(10), 69-82.
[72] PAPLEONTIOU-LOUCA, E. (2003). The concept and instruction of metacognition. *Teacher Development*, *7*(1), 9-30.
[73] PARK, S., CHO, S. C., HONG, Y. C., OH, S. Y., KIM, J. W., SHIN, M. S., ... & BHANG, S. Y. (2012). Association between dietary behaviors and attention-deficit/hyperactivity disorder and learning disabilities in school-aged children. *Psychiatry research*, *198*(3), 468-476.
[74] PASSOLUNGHI, M. C., & CORNOLDI, C. (2008). Working memory failures in children with arithmetical difficulties. *Child Neuropsychology*, *14*(5), 387-400.
[75] PELTENBURG, M., VAN DEN HEUVEL-PANHUIZEN, M., & DOIG, B. (2009). Mathematical power of special-needs pupils: An ICT-based dynamic assessment format to reveal weak pupils' learning potential 1. *British Journal of Educational Technology*, *40*(2), 273-284.

[76] PENNEQUIN, V., SOREL, O., NANTY, I., & FONTAINE, R. (2010). Metacognition and low achievement in mathematics: The effect of training in the use of metacognitive skills to solve mathematical word problems. *Thinking & Reasoning*, *16*(3), 198-220.
[77] PIAGET, J. (1975).Comments on mathematical education. *Contemporary education*, *47*(1), 5.
[78] POLYA, G. (1945).How to solve it. Princeton University Press. *Princeton, NJ*.
[79] PRABAVATHY, M., & SIVARANJANI, R. (2020). Effects of Virtual Manipulative in enhancing Basic Arithmetic for Students with Developmental Dyscalculia. *Journal of Emerging Technologies and Innovative Research*, 19-26.
[80] RADER, L. (2009). Understanding the Cognitive Processes and Metacognitive Strategies That Work with Mathematical Learning Disabilities. *Journal on Educational Psychology*, *3*(1), 1-6.
[81] REISMAN, F., & SEVERINO, L. (2020). *Using creativity to address dyslexia, dysgraphia, and dyscalculia: Assessments and techniques*. Routledge.
[82] ROEBERS, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental review*, *45*, 31-51.
[83] ROTZER, S., LOENNEKER, T., KUCIAN, K., MARTIN, E., KLAVER, P., & VON ASTER, M. (2009). Dysfunctional neural network of spatial working memory contributes to developmental dyscalculia. *Neuropsychologia*, 47(13), 2859-2865.
[84] RUBINSTEN, O., & TANNOCK, R. (2010). Mathematics anxiety in children with developmental dyscalculia. *Behavioral and Brain functions*, *6*(1), 1-13.
[85] SCHIFFER, S., & FERREIN, A. (2018). ERIKA—Early Robotics Introduction at Kindergarten Age. *Multimodal Technologies and Interaction*, *2*(4), 64.
[86] SCHRAW, G., & MOSHMAN, D. (1995). Metacognitive theories. *Educational psychology review*, *7*(4), 351-371.
[87] SEO, Y. J., & BRYANT, D. (2012). Multimedia CAI program for students with mathematics difficulties. *Remedial and Special Education*, *33*(4), 217-225.
[88] SHALEV, R. S., MANOR, O., KEREM, B., AYALI, M., BADICHI, N., FRIEDLANDER, Y., & GROSS-TSUR, V. (2001). Developmental dyscalculia is a familial learning disability. *Journal of learning disabilities*, *34*(1), 59-65.
[89] SHALEV, R. S. (2004). Developmental dyscalculia. *Journal of child neurology*, *19*(10), 765-771.
[90] SHALEV, R. S., & VON ASTER, M. G. (2008). Identifcation, classification, and prevalence of development dyscalculia.
[91] ŠKOF, S. (2015). Cognitive and Metacognitive Approaches to Mathematical Learning Disorder–A Case Study. *In MEi: CogSci Conference* (p. 70).
[92] SUENDARTI, M., & LIBERNA, H. (2018). The Effect of I-CARE Learning Model on the Students' Metacognition. *Journal of Mathematics Education*, *3*(2), 40-46.
[93] SZŰCS, D., & GOSWAMI, U. (2013). Developmental dyscalculia: Fresh perspectives.
[94] TRNA, J., MAKYDOVÁ, L., & PAVLÍČKOVÁ, L. (2011). ICT support of science learning task solving by students with dyscalculia and gifted students.
[95] WILSON, A. J., REVKIN, S. K., COHEN, D., COHEN, L., & DEHAENE, S. (2006). An open trial assessment of" The Number Race", an adaptive computer game for remediation of dyscalculia. *Behavioral and brain functions*, *2*(1), 1-16.

[96] WONU, N., & PAUL-WORIKA, O. (2019). Enhancing metacognitive knowledge of cognition among junior secondary students with mathematics disability in everyday arithmetic. *American Journal of Educational Research*, *7*(2), 153-160.
[97] VEENMAN, M. V. (2007). The assessment and instruction of self-regulation in computer-based environments: a discussion. *Metacognition and Learning*, *2*(2), 177-183.
[98] VON ASTER, M. (2000). Developmental cognitive neuropsychology of number processing and calculation: varieties of developmental dyscalculia. *European Child & Adolescent Psychiatry*, *9*(2), S41-S57.
[99] YAZDANI, S., SOLUKI, S., ARJMANDNIA, A. A., FATHABADI, J., HASSANZADEH, S., & NEJATI, V. (2021). Spatial Ability in Children with Mathematics Learning Disorder (MLD) and Its Impact on Executive Functions. *Developmental Neuropsychology*, *46*(3), 232-248.
[100] YOONG, S. M., & AHMAD, N. A. (2021). Characteristics of Dyscalculia in Mathematics Learning. *Jurnal Pendidikan Bitara UPSI*, *14*(1), 15-22.
[101] ZAVITSANOU, A., & DRIGAS, A. (2021). Nutrition in mental and physical health. *Technium Soc. Sci. J.*, *23*, 67.
[102] ZIMMERMAN, B. J. (1998). Academic studing and the development of personal skill: A self-regulatory perspective. *Educational psychologist*, *33*(2-3), 73-86.
[103] ZYGOURIS, N. C., STAMOULIS, G. I., VLACHOS, F., VAVOUGIOS, D., DADALIARIS, A. N., NERANTZAKI, E., ... & STRIFTOU, A. (2017, April). Screening for Disorders of Mathematics via a web application. In 2017 IEEE Global Engineering Education Conference (EDUCON) (pp. 502-507). IEEE.
[104] E. G. GKEKA, E. K. AGORASTOU, AND A. S. DRIGAS, “Mobile multimedia education for language disorders,” Int. J. Emerg. Technol. Learn., vol. 15, no. 6, pp. 50–59, 2020, https://doi.org/10.3991/ijet.v15i06.11175
[105] POLITI-GEORGOUSI S., & DRIGAS A. Mobile Applications, an Emerging Powerful Tool for Dyslexia Screening and Intervention: A Systematic Literature Review. International Journal of Interactive Mobile Technologies, 2020, 14(18): 4–17. https://doi.org/10.3991/ijim.v14i18.15315.
[106] DRIGAS, A., DEDE, D.E., & DEDES, S. (2020). Mobile and other applications for mental imagery to improve learning disabilities and mental health. International Journal of Computer Science Issues (IJCSI), 17 (4), pp.18-23. http://doi.org/10.5281/zenodo.3987533
[107] C. PAPOUTSI, A. DRIGAS, AND C. SKIANIS, “Virtual and augmented reality for developing emotional intelligence skills,” Int. J. Recent Contrib. Eng. Sci. IT (IJES), vol. 9, no. 3, pp. 35–53, 2021. https://doi.org/10.3991/ijes.v9i3.23939
[108] J. VLACHOU AND A. DRIGAS, “Mobile technology for students and adults with Autistic Spectrum Disorders (ASD),” International Journal of Interactive Mobile Technologies, vol. 11(1), pp. 4-17, 2017
[109] KARABATZAKI, Z., STATHOPOULOU, A., KOKKALIA, G., DIMITRIOU, E., LOUKERI, P. I., ECONOMOU, A., & DRIGAS, A. (2018). Mobile Application Tools for Students in Secondary Education. An Evaluation Study. International Journal of Interactive Mobile Technologies (iJIM), 12(2), 142-161
[110] A. DRIGAS, G. KOKKALIA, AND A. ECONOMOU, “Mobile Learning For Preschool Education,” Int. J. Interact. Mob. Technol., vol. 10, no. 4, p. 57, Oct. 2016. https://doi.org/10.3991/ ijim.v10i4.6021
[111] A. DRIGAS AND P. ANGELIDAKIS, 'Mobile Applications within Education: An Overview of Application Paradigms in Specific Categories', International Journal of Interactive

Mobile Technologies (iJIM), vol. 11, no. 4, p. 17, May 2017. https://doi.org/10.3991/ijim.v11i4.6589
[112] A. STATHOPOULOU, D. LOUKERIS, Z. KARABATZAKI, E. POLITI, Y. SALAPATA, AND A. DRIGAS, “Evaluation of Mobile Apps Effectiveness in Children with Autism Social Training via Digital Social Stories,” Int. J. Interact. Mob. Technol. (iJIM); Vol 14, No 03, 2020
[113] C. PAPOUTSI, A. S. DRIGAS, AND C. SKIANIS, “Mobile Applications to Improve Emotional Intelligence in Autism – A Review,” Int. J. Interact. Mob. Technol. (iJIM); Vol 12, No 6, 2018
[114] DRIGAS, A. S., & IOANNIDOU, R. E. (2011, September). ICTs in special education: A review. In World Summit on Knowledge Society (pp. 357-364). Springer, Berlin, Heidelberg.
[115] DRIGAS, A., KOUKIANAKIS, L. G., & PAPAGERASIMOU, Y. V. (2005). A system for e-inclusion for individuals with sight disabilities, Mathematical methods and computational techniques in electrical engineering, 146-150
[116] DRIGAS, A. AND LEFTERIS KOUKIANAKIS, ‚Convergence of Culture and ICTs: E-Culture,‘ Springer-Verlag Berlin Heidelberg (2010): 488-496.
[117] THEODOROU, P. AND DRIGAS, A. (2017). ICTs and Music in Generic Learning Disabilities. International Journal of Emerging Technologies in Learning (Vol. 12, No. 4), 101-110. https://doi.org/10.3991/ijet.v12i04.6588
[118] DRIGAS, A. AND J. A. VLACHOU, “Information and communication technologies (ICTs) and autistic spectrum disorders (ASD),” Int. J. Recent Contrib. Eng. Sci. IT (iJES), vol. 4, no. 1, p. 4, 2016. https://doi.org/10.3991/ijes.v4i1.5352
[119] DRIGAS, A. AND KOSTAS S. IOANNIS, “Online and other ICTs Applications for Teaching Math in Special Education”, International Journal of Recent Contributions from Engineering, Science & IT, Vol 2, No. 4,2014.
[120] VRETTAROS J, TAGOULIS A, GIANNOPOULOU N, DRIGAS A (2012) Case study in using Web 2.0 tools by Greek educators. Int J Soc Humanist Comput 1(4):363–374
[121] CHAIDI, I., & DRIGAS, A. (2020). Parents' Involvement in the Education of their Children with Autism: Related Research and its Results. International Journal Of Emerging Technologies In Learning (Ijet), 15(14), 194. https://doi.org/10.3991/ijet.v15i14.12509.
[122] DRIGAS,A., & DOUROU,A.: A review on ICT based applications for intervention and assistance of people with memory deficits. I-JET 8, pp. 1-3(2013). http://dx.doi.org/10.3991/ijet.v8i5.3009
[123] DRIGAS, A. S., KOKKALIA, G. K., ECONOMOU, A., & ROUSSOS, P. (2017). Intervention and diagnostic tools in preschool education. International Journal of Emerging Technologies in Learning, 12(11).
[124] DRIGAS, A., & GKEKA, E., G. (2017). ICTs and Montessori for learning disabilities. International Journal of Recent Contributons from Engineering, Science, & IT, 5(3), 77-84
[125] A. KAMAKARI AND A. DRIGAS, Advanced E-Learning Services for Teachers, International Journal of Knowledge Society Research, 3(4), 2012, pp. 85–96.
[126] BRAVOU, V., & DRIGAS, A. (2019). A contemporary view on online and web tools for students with sensory & learning disabilities. International Journal of Online and Biomedical Engineering, 15(12), 97–105. https://doi.org/10.3991/ijoe.v15i12.10833
[127] DRIGAS, A. S. AND POLITI-GEORGOUSI, S. (2019). Icts as a distinct detection approach for dyslexia screening: A contemporary view. International Journal of Online and Biomedical Engineering (iJOE), 15(13):46–60.

[128] A.S.DRIGAS, J.VRETTAROS, L.STAVROU, D.KOUREMENOS, E-learning Environment for Deaf people in the E-Commerce and New Technologies Sector, WSEAS Transactions on Information Science and Applications, Issue 5, Volume 1, November 2004.
[129] DRIGAS, A.S., VRETTAROS, J. AND KOUREMENOS, D. (2004a) 'Teleeducation and e-learning services for teaching English as a second language to deaf people, whose first language is the sign language', WSEAS Transactions on Information Science and Applications, Vol. 1, No. 3, pp.834–842.
[130] DRIGAS, A. AND M. KARYOTAKI, "A Layered Model of Human Consciousness," International Journal of Recent Contributions from Engineering, Science & IT (IJES), vol. 7, no. 3, pp. 41-50, September 2019. Available: https://doi.org/10.3991/ijes.v7i3.11117. [Accessed: January 28, 2020]
[131] DRIGAS, A. KARYOTAKI, M., & SKIANIS, C. (2018). An Integrated Approach to Neuro-development, Neuroplasticity and Cognitive Improvement. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 6(3), 4-18
[132] PAPPAS M, DRIGAS A. 2019 Computerized Training for Neuroplasticity and Cognitive Improvement. International Journal of Engineering Pedagogy. (4):50-62
[133] DRIGAS, A., & PAPOUTSI, C. (2019). Emotional intelligence as an important asset for HR in organizations: Leaders and employees. International Journal of Advanced Corporate Learning, 12(1). https://doi.org/10.3991/ijac.v12i1.9637
[134] DRIGAS A, KARYOTAKI M 2014. Learning Tools and Application for Cognitive Improvement. International Journal of Engineering Pedagogy, 4(3): 71-77. From (Retrieved on 13 May 2016)
[135] A. DRIGAS AND M. PAPPAS, "The Consciousness-Intelligence-Knowledge Pyramid: An 8x8 Layer Model," International Journal of Recent Contributions from Engineering, Science & IT (iJES), vol. 5, no.3, pp 14-25, 2017. https://doi.org/10.3991/ijes.v5i3.7680
[136] MITSEA, E., & DRIGAS, A. (2019). A journey into the metacognitive learning strategies. International Journal of Online & Biomedical Engineering, 15(14). https://doi.org/ 10.3991/ijoe.v15i14.11379
[137] DRIGAS, A., & MITSEA, E. (2020). The 8 Pillars of Metacognition. International Journal of Emerging Technologies in Learning (iJET), 15(21), 162-178. https://doi.org/10.3991/ijet. v15i21.14907
[138] PAPPAS, M. A., POLYCHRONI, F., & DRIGAS, A. S. (2019). Assessment of mathematics difficulties for second and third graders: Cognitive and psychological parameters. Behavioral Sciences, 9(7), 76. https://doi. org/10.3390/bs9070076.
[139] KARYOTAKI M AND DRIGAS A 2016 Latest trends in problem solving assessment International Journal of Recent Contributions from Engineering, Science & IT (iJES) 4 (2) p 1
[140] DRIGAS, A., & KARYOTAKI, M. (2019). Attention and its Role: Theories and Models. International Journal of Emerging Technologies in Learning (iJET), 14(12), 169-182. https://doi.org/10.3991/ijet.v14i12.10185
[141] TOURIMPAMPA, A., DRIGAS, A., ECONOMOU, A., & ROUSSOS, P. (2018). Perception and Text Comprehension. It's a Matter of Perception! International Journal of Emerging Technologies in Learning (iJET), 13(07), 228–242. https://doi.org/10.3991/ijet.v13i07.7909
[142] A. DRIGAS, M. KARYOTAKI AND C. SKIANIS, "Success: A 9 Layered-based Model of Giftedness," International Journal of Recent Contributions from Engineering, Science & IT (iJES), vol. 5, no.4, pp. 4-18, 2017. https://doi.org/10.3991/ijes.v5i4.7725

[143] ANGELOPOULOU, E., & DRIGAS, A. (2021). Working memory, attention and their relationship: A theoretical overview. Research, Society and Development, 10(5), e46410515288. https://doi.org/10.33448/rsd-v10i5.15288
[144] DRIGAS, A.; GKEKA, E. (2016). Montessori method and ICTs. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 4(1). http://journals.sfu.ca/onlinejour/index.php/i-jes/article/view/5481
[145] KEFALIS C AND DRIGAS A. (2019) Web Based and Online Applications in STEM Education. International Journal of Engineering Pedagogy (iJEP) 9, 4 (2019), 76–85.https://doi.org/10.3991/ijep.v9i4.10691
[146] DRIGAS, A. S., ARGYRI, K., & VRETTAROS, J. (2009). Decade review (1999–2009): Artificial intelligence techniques in student modeling. Paper presented at the World Summit on Knowledge Society
[147] ATHANASIOS S. DRIGAS, RODI-ELENI IOANNIDOU, A Review on Artificial Intelligence in Special Education, Information Systems, Elearning, and Knowledge Management Research Communications in Computer and Information Science Volume 278, pp 385-391, 2013 http://dx.doi.org/10.1007/978-3-642-35879-1_46
[148] DRIGAS, A., VRETTAROS, J.: An Intelligent Tool for Building e-Learning Contend-Material Using Natural Language in Digital Libraries. WSEAS Transactions on Information Science and Applications 5(1) (2004) 1197–1205
[149] DRIGAS, A.S., VRETTAROS, J., KOUKIANAKIS, L.G. AND GLENTZES, J.G. (2005). A Virtual Lab and e-learning system for renewable energy sources. Int. Conf. on Educational Tech.
[150] PAPPAS, M., & DRIGAS, A. (2016). Incorporation of artificial intelligence tutoring techniques in mathematics. International Journal of Engineering Pedagogy, 6(4), 12–16. https://doi.org/10.3991/ijep.v6i4.6063
[151] DRIGAS, ATHANASIOS S., AND MARIOS A. PAPPAS. "On line and other Game-Based Learning for Mathematics." International Journal of Online Engineering (iJOE) 11.4, 62-67, 2015 https://doi.org/10.3991/ijoe.v11i4.4742
[152] DRIGAS, A. S., & KOKKALIA, G. K. (2014). ICTs in Kindergarten. International Journal of Emerging Technologies in Learning, 9(2). https://doi.org/10.3991/ijet.v9i2.3278
[153] PAPOUTSI, C., & DRIGAS, A. S. (2016). Games for Empathy for Sensitive Social Groups. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 4(3), 39–43. https://doi.org/10.3991/ijes.v4i3.5923
[154] KOKKALIA, G., DRIGAS, A., Economou, A., Roussos, P., & Choli, S. (2017). The use of serious games in preschool education. International Journal of Emerging Technologies in Learning, 12(11), 15-27. https://doi.org/10.3991/ijet.v12i11.6991
[155] DRIGAS, A., Electronic-Digital Culture (e-CULTURE): Information Society And Culture, Athens 2005
[156] DRIGAS, A., & KARYOTAKI, M. (2013). E Learning ICTs Application in Nutrition Science. International Journal of recent Contributions from Engineerinf, Science and IT, 1. DOI: 10.3991/ijes.v1i2.3279
[157] DRIGAS, A., L.G.KOUKIANAKIS, S.DOMOXOUDIS, E-Government Structure for e-Protocol, eApplication Submission and Internal Organizational and Operational Support, WSEAS TELEINFO 2005 International Conference, Prague, Czech Republic, March 13-15, 2005
[158] VRETTAROS, J., TAGOULIS, A., GIANNOPOULOU, N., & DRIGAS, A. (2009). An empirical study on the use of Web 2.0 by Greek adult instructors in educational procedures.

World Summit on Knowledge System (WSKS), 49, 164-170. http://dx.doi.org/10.1007/978-3-642-04757-2_18
[159] ALEXOPOULOU, A., BATSOU, A., & DRIGAS, A. (2020). Mobiles and Cognition: The Associations Between Mobile Technology and Cognitive Flexibility. International Journal of Interactive Mobile Technologies (iJIM), 14(03), pp. 146–156. https://doi.org/10.3991/ijim.v14i03.11233
[160] DOULOU, A., & DRIGAS, A. (2022b). Electronic, VR & Augmented Reality Games for Intervention in ADHD. Technium Social Sciences Journal, 28(1), 159–169. https://doi.org/10.47577/tssj.v28i1.5728
[161] KOKKALIA, G. K., & DRIGAS, A. S. (2015). Tools and E-tools for Memory and Attention Problems in Pre-school Education. International Journal of Recent Contributions from Engineering, Science & IT, 3(3), 13-19. http://dx.doi.org/10.3991/ijes.v3i3.4729
[162] GKEKA, E.; AGORASTOU, E.; DRIGAS, A. Artificial Techniques for Language Disorders. Int. J. Recent Contrib. Eng. Sci. IT 2019, 7, 68–76.
[163] GALITSKAYA, V., & DRIGAS, A. (2019). ICTs and Geometry. International Journal of Engineering Pedagogy (iJEP), 9(5), pp. 103–111. https://doi.org/10.3991/ijep.v9i5.11241
[164] BAKOLA, N. L. N., RIZOS, N. D., & Drigas, A. S. (2018). ICTs Supportive and Therapeutic Contribution in Psychoemotional Disorders in Childhood and Adolescence. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 6(2), 69-78.
[165] DRIGAS, A., PAPPAS M. A., AND M. LYTRAS, “Emerging technologies for ict based education for dyscalculia: Implications for computer engineering education,” International Journal of Engineering Education, vol. 32, no. 4, pp. 1604–1610, 2016.
[166] DRIGAS, A. & KOKKALIA, G. 2017. ICTs and Special Education in Kindergarten. International Journal of Emerging Technologies in Learning 9 (4), 35–42.
[167] DRIGAS, A., AND L. KOUKIANAKIS, A Modular Environment for E-learning and E-psychology Applications, WSEAS Transactions on Information Science and Application, Vol. 3, 2004, pp. 2062-2067.
[168] DRIGAS, A., & MITSEA, E. (2021). The Role of Clinical Hypnosis and VR in Special Education. International Journal of Recent Contributions from Engineering Science & IT (iJES) 9(4):4-17
[169] DRIGAS, A., & MITSEA, E. (2021). Neuro-Linguistic Programming & VR via the 8 Pillars of Metacognition X 8 Layers of Consciousness X 8 Intelligences. Technium Social Sciences Journal, 26, 159-176.
[170] DRIGAS, A., & PAPOUTSI, C. (2021). Nine layer pyramid model questionnaire for emotional intelligence. International Journal of Online & Biomedical Engineering, 17(7). https://doi. org/10.3991/ijoe.v17i07.22765
[171] DRIGAS, A., PAPOUTSI, C., & SKIANIS, C. (2021). Metacognitive and Metaemotional Training Strategies through the Nine-layer Pyramid Model of Emotional Intelligence. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 9(4), pp. 58–76
[172] DRIGAS, A., & L. BAKOLA: The 8x8 Layer Model Consciousness-Intelligence-Knowledge Pyramid, and the Platonic Perspectives. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 9 (2), pp. 57–72, (2021), https://doi.org/10.3991/ijes.v9i2.22497.

[173] DRIGAS, A., & MITSEA, E. (2021). 8 Pillars X 8 Layers Model of Metacognition: Educational Strategies, Exercises &Trainings. International Journal of Online & Biomedical Engineering, 17(8). https://doi.org/10.3991/ijoe.v17i08.23563
[174] KONTOSTAVLOU, E. Z., AND DRIGAS, A. (2021). How metacognition supports giftedness in leadership: a review of contemporary literature. Int. J. Adv. Corp. Learn. 14, 4–16. doi: 10.3991/ijac.v14i2.23237
[175] DRIGAS, A., KOKKALIA, G. & ECONOMOU, A. (2021). An 8-Layer Model for Metacognitive Skills in Kindergarten. NEUROLOGY AND NEUROBIOLOGY, 4(1), 2-10. http://dx.doi.org/10.31487/j.NNB.2021.01.01
[176] DRIGAS, A., & SIDERAKI, A. (2021). Emotional Intelligence in Autism . Technium Social Sciences Journal, 26(1), 80–92. https://doi.org/10.47577/tssj.v26i1.5178
[177] DRIGAS, A., & PAPOUTSI, C. (2015). Empathy, special education and ICTs. International Journal of Recent Contributions from Engineering, Science & IT (iJES), 3(4), 37-42. doi: 10.3991/ijes.v3i4.5192
[178] KONTOSTAVLOU, E.Z.; DRIGAS, A. Executive functions training and giftedness. Retos 2022, 43, 1005–1014.
[179] DRIGAS, A., MITSEA, E., & SKIANIS, C. (2022). Clinical Hypnosis & VR, Subconscious Restructuring- Brain Rewiring & the Entanglement with the 8 Pillars of Metacognition X 8 Layers of Consciousness X 8 Intelligences. International Journal of Online and Biomedical Engineering (iJOE), 18(01), pp. 78–95. https://doi.org/10.3991/ijoe.v18i01.26859
[180] PAPOUTSI, C., CHAIDI, I., DRIGAS, A., SKIANIS, C., & KARAGIANNIDIS, C. (2022). Emotional Intelligence & ICTs for Women and Equality. Technium Social Sciences Journal, 27, 253-268.
[181] DRIGAS, A., & MITSEA, E. (2022). Conscious Breathing: a Powerful Tool for Physical & Neuropsychological Regulation. The role of Mobile Apps. Technium Social Sciences Journal, 28, 135-158.
[182] MITSEA, E., DRIGAS, A., & SKIANIS, C. (2022). ICTs and Speed Learning in Special Education: High-Consciousness Training Strategies for High-Capacity Learners through Metacognition Lens. Technium Social Sciences Journal, 27, 230-252.
[183] DRIGAS, A., MITSEA, E., & SKIANIS, C. (2022). Neuro-Linguistic Programming, Positive Psychology & VR in Special Education. Scientific Electronic Archives, 15(1).
[184] ZAVITSANOU, A., & DRIGAS, A. (2021). Attention and working memory. International Journal of Recent Contributions from Engineering Science & IT (iJES), 9(1), 81-91. https://doi.org/10.3991/ijes.v9i1.19933
[185] ANGELOPOULOU, E., KARABATZAKI, Z., & DRIGAS, A. (2021). The role of working memory and attention in older workers' learning. International Journal of Advanced Corporate Learning (iJAC), 14(1), 4-14. https://10.3991/ijac.v14i1.20355