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

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**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 develop and enhance these abilities. These tools are designed for the development of either the cognitive or the metacognitive abilities of the students with SLDM and include computer based and mobile applications, serious games, educational software and robotics. The results of the study indicate that the existed ICT tools for the development of the cognitive and metacognitive abilities of the students with SLDM can have a crucial impact on the improvement of the symptoms of this Specific Learning Disorder. They can enhance the cognitive abilities of the attention, the working memory and the visuospatial ability along with the mathematical ability and also improve the metacognitive abilities such as reflection, self-regulation, the problem solving ability and the mathematical metacognition.

**Keywords.** Cognitive and metacognitive abilities, Specific Learning Disorder in Mathematics, ICT tools for Dyscalculia, ICT tools for mathematical metacognition, ICTs for problem solving

## 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, Roebbers, 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, Papeleontiou-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 constructivism 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, Drigas, Dede&Dedes, 2020). The problem solving ability includes many

cognitive and metacognitive aspects of learning such as organizing, predicting and evaluating (Garafalo&Lester, 1985, Polya, 1945, Babakhani, 2011, Wonu&Paul-Worika, 2019) and could be listed in the metacognitive abilities of the students with SLDM (Verschaffel et al, 2019).

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 assess 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 ICTs 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, Aggarwal&Bal, 2020). The 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 for the development 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, ICT tools for Dyscalculia, ICT tools for mathematical metacognition and ICTs for problem solving. The search engines that were used were Google Scholar and Research Gate. A 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 improvement of the symptoms of the 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 metacongnitive 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, Papeleontiou-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 metacognitive 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 mathematics 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 metacognitive 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 metacognitive 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 (Karbadehi 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 mathematics. 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 development of the cognitive abilities of the students with SLDM**

The development of the cognitive abilities of the students with SLDM using ICT tools has interested the researchers worldwide.

Kucian et al. (2011) investigated the effect of an interventional program for students with SLDM with the use of computer based mathematical tasks. The aim of the program was the development of a mental number line. The sample of the research consisted of 16 students with SLDM and 16 students of typical development, with age 8-12 years old. The program lasted 5 weeks and contained digital tasks that enhanced the spatial working memory. The results indicate that the program improved the ability of spatial number as well as the ability of problem solving in both groups. Furthermore, the function of the correspondent cerebral regions was observed with fMRI. In both groups was observed a decrease of the brain function in the cerebral regions that are related with number processing. According to the researchers the decrease of brain activity especially in the frontal lobe is related with the automation of the cognitive processes that are involved in mathematical thinking.

Guarnera and D'Amico (2014) examined the impact of a program that aimed to enhance the attention of students with SLDM with the use of computer based activities. In the research took part 14 students of the fourth and fifth grade of the primary school in Italy. The tasks had to do with the reaction time, the visuospatial and auditory recognition, the maximum number of digits someone is able to recall, the divided attention, selectivity and the capacity to inhibit interference of non-pertinent signals and attention sifting. The results suggest that intervention for the enhancement of attention of the students with SLDM improved their ability of number processing. Furthermore, the reaction time was decreased in the attention tasks which may reflect an increase in the data processing speed.

Papanastasiou et al. (2017) examined the benefits and impacts of the serious games on students with attention, memory and developmental disabilities. According to the

researchers educational videogames can foster creativity, motivation and engagement. They also enhance spatial ability, control and communication. Serious games have a positive impact on visuospatial working memory, selective and divided attention and executive control.

Drigas, Dede & Dedes (2020) presented a review of the existed applications for mobile phones that aim at developing the ability of mental imagery for children with SLDM and more severe disorders such as depression and anxiety. According to the researchers, mental imagery is a crucial skill as it is responsible for the depiction of the visual stimuli in the working memory and the creation of mental images in the brain. The mental imagery is an essential ability for perception, pattern recognition, strategic planning and problem solving. The applications that are displayed in the article are applications for mobile phones, virtual reality applications and applications with avatars. The researchers conclude that the development of the ability of mental imagery through the ICTs can improve the symptoms of learning disorders, the spatial ability, the perception, the memory, the critical thinking and the self-confidence.

Cheng et al. (2020) examined the effect of an interventional program for the enhancement of the symbolic arithmetic through the training of visual perception. The program lasted for 8 days and the sample consisted of 80 students with SLDM from four primary schools in China. The activities of the program were digital and exhibited some apple trees. The students should decide, as quickly as possible, in which of several different branches there were more apples. The results indicate that the experimental group had a significant improvement in the arithmetical competence, the estimation of the number of the presented objects and the visual perception. Aggarwal & Bal (2020) presented a big variety of ICT tools that assist the learning and teaching of mathematics and make, at the same time, mathematics interesting for the learners. The researchers classified the ICT tools in to five categories: smart classrooms, social media, mathematical software, mobile apps and websites. The mathematical software was further discerned to expensive and free of cost mathematical software. According to the researchers, ICTs can change the role of students and teachers in the process of learning mathematics. Furthermore, the students can learn anywhere, anytime, while the audio visual way of learning contributes to understand and learn the concepts easier as compared to other ways of learning.

Wilson et al. (2006) presented "The Number Race" software, an adaptive computer game for the remediation of dyscalculia. The sample of the research consisted of nine 7–9 year old children with mathematical difficulties. Children completed adaptive training on numerical comparison for a total of 10 hours over a five week period and made progress in several core areas of numerical cognition such as counting, transcoding, enumeration, subtraction, and symbolic and non-symbolic numerical comparison. Speed of subitizing and numerical comparison increased by several hundred msec. Subtraction accuracy increased by an average of 23%. According to the researchers, however these results need to be followed up with larger, controlled studies.

Seo & Bryant (2012) investigated the effectiveness of the Math Explorer software at enhancing the word problem-solving skills of students with mathematics difficulties. The study was conducted over 18 weeks and the participants were four students with mathematics difficulties in Grades 2 and 3. All students were able to use a four-step cognitive (reading, finding, drawing, computing) and three-step metacognitive strategy (do, ask and check activity) to solve addition and subtraction word problems. According to the researchers, after the intervention phase, three out of the four students successfully maintained their improved word problem-solving performance levels during the follow-up phase. The positive findings of this

study may be related to the presentation of the cognitive and metacognitive strategies in Math Explorer.

Jerin et al. (2020) developed the DyscAid, a mobile application that provide assistance to dyscalculic people. The menu of the app has four different tasks: calculation, count, transpose and monetary. In the first two tasks the user gives the data with speech or text and the outcome is given back in the opposite way. In the transpose task the user is able to capture numbers found in a text and read it out loud. In the monetary task the user gives the values of the money he gives and the money something costs and the app calculates the change. The sample of the research was 12 teenagers (age 12-15) with 4 of them clinically diagnosed with dyscalculia. The participants had proficiency in both English and Bangla language and were familiar with smartphone applications. The outcomes of the user evaluation revealed that the interface design with Bengali text, icon, and voice-based applications shows better usability in terms of efficiency, effectiveness, and satisfaction than the English version of the task.

González et al. (2019) and Muñoz et al. (2020) presented the progress in the development of a project where robotics is implemented for the teaching of mathematics in preschool and first grade students of three public schools in the province of Chiriquí, Republic of Panama. A series of playful educational activities were developed, using low cost robotic tools. The objective of the project was to design, develop and implement educational robotics to improve logical-mathematical skills aimed at preschool and first grade students in public schools, using the programmable educational robots Bee-bot. The results indicate that the students obtained a favorable level of performance in the different challenges proposed.

Schiffer & Ferrein (2018) reported on their attempt to design and implement an early introduction to basic robotics principles for children at kindergarten age. The humanoid robot Pepper from Softbank, which is a great platform for human–robot interaction experiments, was used to present a lecture on robotics by reading out the contents to the children making use of its speech synthesis capability. According to the researchers, the children were very excited and at the same time very concentrated.

Conchinha et al. (2015) presented a strategy for inclusion and knowledge consolidation based on playful learning using educational robotics. Participants were two boys aged 15 and a 14 years old girl. All students attended the third cycle in Brazil, and were diagnosed with special needs, with specific learning disabilities. According to the researchers, the students were captivated by the project and motivated to take part in all stages showing that educational robotics may be significant on allowing students to learn while playing and also by promoting their inclusion on different and engaging activities.

Erfurt et al. (2019) in Germany presented a training system for an exercise that trains connections between verbal and numerical representations of numbers and finger counting. The system enabled the children to train without guidance and feedback by a trainer. The sample of the research consisted of 30 children of the primary school in 1st grade from two local schools. The child was sitting at a table with the hands placed on it. A trainer called numbers from 1 to 10 and the student had to show the number with his fingers. In a second phase, simple addition tasks were given where the results ranged from 0 to 10. Learners received visual and auditory feedback after they displayed the correct number of fingers. According to the researchers, the children were eager to complete all arithmetical tasks, had fun, and smiled when their answers were correct.

TRNA et al. (2011) (2015) presented innovations of learning tasks for students with dyscalculia as therapy including compensatory aids for the physics and mathematics based on the use of ICTs. The researchers suggest supporting methods such as the excel charts that

automatically perform calculations, the compiling graphs, the special instructional and checking web sites, the instructional video recordings of the course of the laboratory learning tasks and measuring units with USB connection and a computer output.

### **3.5 ICT tools for the development of the metacognitive abilities of the students with SLDM**

ICT tools seem to not only enhance the mathematical learning of the students with SLDM, but also to increase their metacognitive ability.

Cadamuro et al. (2019) examined the relationship between metacognition and ICTs. The researchers presented 14 studies on the relationship between the ICTs, the metacognitive skills and the learning outcome. Some articles investigated the effects of ICT environments combined with metacognitive aspects on the learning outcomes and others investigated the reciprocal relationship between ICTs and metacognition. Their analysis revealed that the relationship between metacognition and ICTs is three-folded. Firstly, working in technology-mediated contexts supports the development of metacognitive skills which, in turn, leads to better learning outcomes. Secondly, metacognitive skills are necessary to take advantage of web-based training. At last, ICTs are accessed by learners in a metacognitive way. The learners make decisions, monitor and self-regulate their learning even when metacognitive prompts are not present and do not passively receive knowledge.

Chytrý et al. (2019) found a positive connection between the teachers' progressiveness in using digital technologies and the students' level of metacognitive knowledge in mathematics. According to the researchers, the low efficiency of using appropriate strategies to solve problems in the classroom is not due to the lack of knowledge of how to classify concepts, but rather due to the failure to apply this knowledge strategically. The participants of the study were 47 teachers and 278 students at grade 5. The students of the teachers with higher tendencies of implementing innovation were performing better in tests focused on metacognitive knowledge.

Lytra & Drigas (2021) studied the effect of the appliance of STEAM education in the instruction of the students with Specific Learning Disabilities in relation to the development of metacognitive skills. According to the researchers, the development of the metacognitive skills of the students through the STEAM education is possible with the use of the problem solving methodology. The appliance of monitoring, evaluation and organizing processes can lead to the self-regulation of the students and help them recognize their weaknesses and compensate them through the appliance of cognitive and metacognitive strategies. This way the students become more flexible and able to adapt to the future cognitive challenges.

Hunt & Tzur (2017) in the U.S.A. designed a constructivist interventional program for teaching the concept of fraction to students with SLDM that faced enormous difficulty with fractions. The aim of the research was to discover the different types of interaction between the educator and the students in constructivist learning context. The sample consisted of two students with SLDM of the fifth grade of a primary school. The research methodology was based on the constructivist teaching experiment. The results revealed three types of interaction between the educator and the two students during the intervention. According to the researchers, all of the interactions were related with the thorough comprehension of the mathematical functions and relations, the self-monitoring and the evaluation of the way of thinking of the two students. The basic activity that was used by the researchers was the game "French fry". The students had to distribute a potato fairly to three people using paper stripes that they should adjust at the right size without using a ruler. After they became familiar with the process, they were presented with a simulation of the game on the computer. The students were able to adjust

a digital bar in order to divide the potato in to several numbers of people. Both the two students with SLDM had a positive reaction at the intervention and made significant progress with the concept of fraction.

Prabavathy & Sivaranjani (2020) investigated the effectiveness of specific digital mathematical tasks that were presented to the students in combination with reflective questions in order to improve the basic arithmetical skills of students with SLDM. The research was conducted in India and the sample consisted of 32 students of the fourth class of the primary school with SLDM symptoms. The interventional program lasted two months for two hours a day. The use of the virtual multi-sensory tasks motivated the students and facilitated their learning about the mathematical concepts. According to the results, the mean score of the students was increased from 19.09 to 54.69. The digital instructional tasks enhanced the basic mathematical skills of the students. The students participated in the learning activities with more enthusiasm and their self-confidence, learning awareness, motivation and ability for automated connection between the numbers and theirs symbols was increased.

Latif & Ahmad (2021) examined the effectiveness of using the GeoEnzo Application on metacognitive abilities in mathematics learning. The GeoEnzo constitutes a dynamic geometric system softwar that can easily draw geometric shapes such as cones, triangles, circles, cubes, lines, and others. The subjects of the study were students of class XII SMK Mega Link Majene in Indonesia. The research instrument was used to reveal students' metacognitive abilities in understanding and solving problems on three-dimensional material. The results of the analysis showed that the average value of students' metacognitive abilities in understanding the material and solving questions was increased. The t-test revealed that the use of GeoEnzo application is effective for students' metacognitive abilities in mathematics learning.

Mitsea et al. (2022) presented the functions of ICTs in Special Education in relation to speed learning and the cognitive processes that they develop. According to the researchers, ICTs such as video games, virtual reality, mobile applications and software can be used for the enhancement of the skills that constitute the indicators of speed learning. These indicators are spatial attention, visual span, processing speed, reaction time, cognitive load, executive functions, metacognition, motivation and mnemonics.

Kramarski & Dudai (2009) explored the group-metacognitive support for online inquiry in mathematics with metacognitive self-questioning. The study investigated 100 Israeli 9th graders who used two different group-metacognitive support methods in online mathematical inquiry, the group feedback guidance and self-explanation guidance, compared to a control group. The study evaluated each method's effects on students' mathematical inquiry ability and self-regulated learning measures. The results indicate that students that were exposed to online guidance in providing and receiving group feedback, based on the IMPROVE self-questioning strategy, significantly outperformed students of the other two groups.

Verschaffel et al. (2019) carried out a systematic review of the literature on ICT-based learning environments for metacognitively oriented mathematics education. Based on a systematic screening of the databases Web of Science and ERIC, 22 studies were retrieved, situated at various educational levels. Most studies involved drill-and-practice software, intelligent tutoring systems, serious games, multimedia environments, and computer supported collaborative learning environments, with metacognitive pedagogies either integrated into the ICT software itself or provided externally by the teacher, mainly for arithmetic or algebraic word problem-solving but also related to other mathematical topics. The results of the analysis indicate that ICT-based mathematics learning environments supported by metacognitive

pedagogies enhanced both the mathematical learning and achievement and the metacognitive thinking and learning, more than environments with no ICT or metacognitive support.

Lara Nieto-Márquez et al. (2020) investigated some digital teaching materials and their relationship with the metacognitive skills of students in primary education. The research was conducted at a state school in Spain, with a sample of 130 students in Grade 3 of the primary school (8 years old). The research involved the use of a digital teaching platform called 'Smile and Learn'. The activities of this platform train different cognitive areas such as science, logic, spatial skills, emotions, literacy and arts. The feedback included for the digital activities seems to develop the metacognitive knowledge of the students as they were able to keep track of their successes and mistakes, the time taken to perform the tasks and their progress. The results revealed a higher use of logic and spatial activities by the teachers in primary education. Furthermore, a relationship was observed between the use of digital tasks that had specific feedback and trained the logic and the visuospatial skills and the metacognitive knowledge. According to the researches, addressing logical–mathematical and spatial skills through digital materials might impact the cognitive work that facilitates metacognitive knowledge.

#### **4. Discussion & Conclusions**

Concluding this article we should underline in information age era, the role of ICTs in general and special education and in other related domains [109-129, 144, 145, 150-160]. The mobiles play an important role [100-108] in making more accessible the educational procedures. The serious games make the educational applications more attractive to students and pupils [96-99]. The artificial intelligence is a powerful tool in procedures for diagnosis and adaptable interventions and moreover in design of educational applications [146-149]. Finally there are several applications that support educational procedures based on metacognition, mindfulness, meditation and emotional intelligence cultivation strategies [130-143, 161-176].

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 intervention and rehabilitation of their special needs on mathematics.

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 development of these skills.

The review of the literature revealed a big number of ICT tools that are designed for the improvement of the cognitive and metacognitive abilities of the students with SLDM. These ICT tools include computer based and mobile applications, serious games, educational software and robotics.

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.

The results of the research indicate that the existed ICT tools for the development of the cognitive and metacognitive abilities of the students with SLDM can have a crucial impact on the improvement of the symptoms of SLDM. The existed ICT tools can enhance the cognitive abilities of the students with SLDM such as the attention, the working memory and the visuospatial ability along with the mathematical ability and also improve the metacognitive abilities such as the metacognitive reflection and self-regulation, the mathematical metacognition and the problem solving ability.

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