A new decade for social changes
ICTs for the Assessment 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 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, Szücs, & 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, Rubinstein & 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 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).

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 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.


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 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
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 (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 (Zimmerman,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, mathematical 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
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 to 11 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 cognition 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 cognitive 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 metacognition 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.

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