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Secondary Mathematics Teachers: What they Know and Don't Know about Dyscalculia

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Abstract. Although much research on teachers' knowledge and attitudes towards their students with dyslexia has been accumulated, students with dyscalculia have not gained the same attention. Teachers' knowledge about the nature and characteristics of students with dyscalculia seems to be limited and this has a strong impact on their instructional decisions. In secondary education, where teachers' pre-service educational programs are more focused on the scientific subject instead of appropriate instructional methods, teachers' knowledge about dyscalculia has not yet been taken into account. The aim of this study was to examine the extent to which mathematics teachers know what dyscalculia is, and what its features are. Possible differences that may occur between teachers with and without special education training were also examined, as well as differences that may occur as a result of their working experience. One hundred and fourteen secondary mathematics teachers, with an average service time of twelve years, completed an electronic questionnaire in which they had to respond to 19 questions about the definition, the content and the major characteristics of dyscalculia. Although they seemed to understand the innate profile of dyscalculia, 31% of them attributed dyscalculia to learning gaps resulted by student absence from school while 67% of the teachers felt that mistakes of students with dyscalculia in solving algorithms may be reduced if more time is provided to the students. Furthermore, confusion prevailed regarding skills of students with dyscalculia to solve word problems. The findings in this study contribute to the ongoing discussion on the appropriate education and training of secondary mathematics teachers, which should not neglect the special characteristics and difficulties of students with dyscalculia. The teachers' knowledge about dyscalculia is suggested as the base for the design of appropriate teaching practices to address specific learning disabilities in math.

Keywords: dyscalculia; learning disabilities; views; beliefs; secondary teachers

Introduction

The definition of Dyscalculia has gained significant interest by the scientific world in the last four decades. A variety of terms, such as "mathematics disorder, learning disabilities in mathematics, specific learning disabilities in mathematics, e.tc." have been used to describe the dyscalculia phenomenon. In 1970, Kosc was the first to highlight the developmental nature of the disorder and define dyscalculia as an innate disorder with genetic base, that exists without a simultaneous disorder of general mental functions (Kosc, 1974). Currently, the term dyscalculia refers to the specific learning disabilities in mathematics presented with difficulties in areas such as: number knowledge and processing, learning and memorizing arithmetic facts, executing arithmetic calculations fluently and accurately, as well as mathematic reasoning (American Psychiatric Association, 2013). The prevalence rates of dyscalculia seem to be of the same size with those of dyslexia's. Several publications have appeared documenting dyscalculia percentages of 5,6% (Dirks, Spyer, van Lieshout, & de Sonneville, 2008), 6,1% (Landerl & Moll, 2010), 10,5% (Mogasale & Patil, 2012), 3,4% (Reigosa-Crespo, et al., 2011), 4,5% (Jovanovic, et al., 2013) and 2% (Dhanda & Jagawat, 2013). As in any other disorder prevalence rates vary depending on the age group, the screening measures applied and the discrepancy criteria selected in each study. However, the above rates are in line with Geary (2004), according to whom 5% to 8 % of the students have some kind of dyscalculia.

Although the strong presence of dyscalculia in the student population has led to increased scientific interest about the study of the phenomenon and its characteristics, dyslexia has still a dominant position in research. The fact that dyslexia is a language disorder, manifested when students enter school, makes teachers' role highly important for its screening and future progress. This central role of teachers in the academic and social inclusion of students with dyslexia has been documented in a plethora of studies focusing specifically on either the knowledge of the educators (Kerr, 1998; Moats, 2014; Ness & Southall, 2010; Regan & Woods, 2000; Soriano-Ferrer & Echegaray-Bengoa, 2014; Soriano-Ferrer, Echegaray-Bengoa, & Joshi, 2016; Wadlington & Wadlington, 2005; Washburn, 2009; Washburn, Joshi, & Binks Cantrell, 2011; Williams, 2012) or their attitudes towards dyslexia (Gwernan-Jones & Burden, 2010; Hornstra, Denessen, Bakker, van den Bergh, & Voeten, 2010; Kerr, 2001; Tsovili, 2004; Woolfson, Grant, & Campbell, 2007).

Unfortunately, researchers have not shown the same interest about teachers' knowledge of and attitudes towards dyscalculia. Relevant research interest has been expressed mostly by studying teachers' beliefs of the nature and meaning of mathematics and the instructional methods they use (Cady & Rearden, 2007; Handal, 2003; Stipek, Givvin, Salmon, & MacGyvers, 2001). Educators' perceptions about the difficulty of the mathematics as a subject and about their ability to teach (Cady & Rearden, 2007), their perspectives about the knowledge they have or should have on the subject itself (Mosvold & Fauskanger, 2013), as well as the assessment tools needed in order to fully evaluate students' performace (Adams & Yang Hsu, 1998; Watt, 2005) have been widely investigated.

Research about the knowledge of teachers has focused on their background knowledge on the subject of mathematics (Even & Tirosh, 1995), mathematics instruction (Ernest, 1989) and the different ways of assessing students' reasoning (Ernest, 1989; Even & Tirosh, 1995). Teachers' knowledge about all the above areas has gained the attention in recent years, especially within pressure for instructional effectiveness and teacher accountability (Tickle, 2000 in Zakaria & Musiran, 2010) and high academic performance of students (Hill, Rowan, & Loewenberg Ball, 2005).

Only recently, considerable attention has been paid also to the phenomenon of dyscalculia. The relevant research has focused on clarification of the definition and the nature of the difficulties (i.e. Geary, 2004; Jiménez González & Garcia Espínel, 1999; Mazzocco & Myers, 2003; Martin, et al., 2012; Silver, Pennett, Black, Fair, & Balise, 1999), the characteristics and the specific errors of students in mathematics (i.e. Andersson, 2008; Bryant, Bryant, & Hammill, 2000; Compton, Fuchs, Fuchs, Lambert, & Hamlett, 2012; Fuchs & Fuchs, 2002; Geary, 1990), the prediction, early identification and assessement of these difficulties (i.e. Desoete, 2008; Desoete, Ceulemans, De Weerdt, & Pieters, 2012; Geary, 2011; Geary, Bailey, Littlefield, Wood, Hoard, & Nugent, 2009; Gersten, Jordan, & Flojo, 2005; Gilbertson Schulte, Elliot, & Kratochwill, 2001; Kling & Bay-Williams, 2014; Morgan, Farkas, & Wu, 2009; Stock, Desoete, & Roeyers, 2009) and the effective teaching practices that should be used (Gallagher Landi, 2001; Gonsalves & Krawec, 2014; Ives, 2007; Leh & Jitendra, 2012; Montague, Warger, & Morgan, 2000; Powell & Fuchs, 2015).

However, despite the large amount of academic knowledge available, very few publications are available in the literature, to the authors' best knowledge, that address the issue of teacher knowledge of dyscalculia. The relationship between secondary mathematics teachers' beliefs and learning disabilities in mathematics was examined by DeSimone & Parmar (2006) in a study with 226 middle school mathematics inclusion teachers. Most of them had a Master's Degree and had taken part in limited inclusion-or Learning Disabilities-related workshops. Teachers were asked to answer a questionnaire about their beliefs regarding the academic profile of students with learning disabilities in mathematics, as well as their readiness beliefs to teach in inclusion classrooms. Although they stated feeling "quite comfortable" or "very comfortable" in their abilities to adapt instruction for students with learning disabilities, their comfort relied especially to their general beliefs about their strategy knowledge they use to succesfully adapt instruction. Based on the results reported, it was evident that they had an unclear picture of students with learning disabilities in mathematics and the majority of the teachers believed that there was no distinction between a student with learning disabilities and a low-performing student. The indistinct picture of students' with dyscalculia characteristics is consistent with results from another study by the same authors (DeSimone & Parmar, 2006), in which in-depth interviews, surveys and classroom observations were conducted with seven general education mathematics teachers. According to those teachers, students with learning disabilities in mathematics are very slow in understanding and

processing teachers' instructions, they find it difficult to focus and concentrate and they also need constant reinforcement for their efforts. Teachers believed that students' difficulties in reading lead to additional problems in understanding and solving word problems. The explanation and presentation of a concept with various ways was regarded as an effective practice, but unrealistic, given the limited available time for teaching during the school day. In 2010, Saravanabhavan & Saravanabhavan conducted a survey in India investigating the knowledge of regular high school, special school and pre-service teachers about specific learning disabilities. Regular education teachers' knowledge was higher than the two other groups, but still quite below the desired level, a fact which was explained by the researchers by the inadequate training and the small number of workshops available regarding the specific learning disabilities. As Kamala & Ramganesh (2013) revealed three years later in a study focusing on the knowledge of 94 teacher educators about dyslexia, dyscalculia, dysgraphia and behavioral problems of students with specific learning disabilities, even teacher educators had low level of relevant knowledge.

In conclusion, it appears that very little is known about teachers' knowledge and their skills to efficiently teach students with dyscalculia, although currently the presence of students with dyscalculia in school classrooms is increasing. On one hand, instruction of these students is certainly challenging, especially for the secondary mathematics teachers, since their academic training is focused mostly on the subject of mathematics itself. On the other hand, while many efforts for implementing interventions for students with dyscalculia in secondary education are made (Graham, Bellert, & Pegg, 2007; Ives, 2007; Krawec & Montague, 2014), the background knowledge of the teachers about the special characteristics and difficulties of these students is not taken into account.

Our goal in the present study was to investigate the knowledge of secondary mathematics teachers about dyscalculia. In particular, we focused on examining their knowledge about: a) the nature and definition of dyscalculia and b) the content of dyscalculia and the characteristics of students with dyscalculia. Furthermore, possible relationships between teachers' knowledge and their teaching experience, as well as their relevant training were examined.

Methodology

Participants

One hundred and fourteen secondary mathematics teachers participated in the survey, 47 of them male and 67 female. The majority of the teachers (n=48) worked as private math tutors, 41 of them taught in public middle and high schools and the rest of the participants taught in private afternoon tutoring centres (phrontistiria). As far as their teaching experience, 42% worked six to 15 years, 31% worked up to five years, whereas the smallest part of them (27%) had 16 to 35 years of teaching experience. The percentage of the participants who did not have any training in special education was 58%.

Instrumentation

A questionnaire designed by the authors was distributed to the participants through the Internet, and data selection lasted three weeks. The questionnaire consisted of 19 questions about teachers' knowledge and teachers had to respond by choosing between "True" or "False". In particular, the first five questions (A1 - A5) concerned the nature and definition of dyscalculia (e.g. *Dyscalculia isn't due to insufficient teaching*) and the other 14 questions (A6 - A19) referred to specific characteristics of students with dyscalculia (e.g. *They respond to word problems impulsively*.)

Results

The analysis of the results indicated that less than half of the teachers (40.4%) answered correctly to all of the questions about the definition and nature of dyscalculia (A1 – A5). Only two teachers gave the correct answers to questions A6 to A19 and it was just one, who didn't give a single wrong answer to all 19 questions.

As presented in Figure 1, the descriptive analysis of the answers revealed that the majority of the participants (86%) knew about the innate nature of the disorder and were correct about the prevalence rates of dyscalculia, which are more than 1%. Participants who felt that inappropriate teaching is not responsible for the appearance of dyscalculia reached the percentage of 83%. Nevertheless, fewer (74%) knew that dyscalculia is not a result of low I.Q. and 69% of the teachers were aware of the fact that long student's school absence is not the cause for dyscalculia.

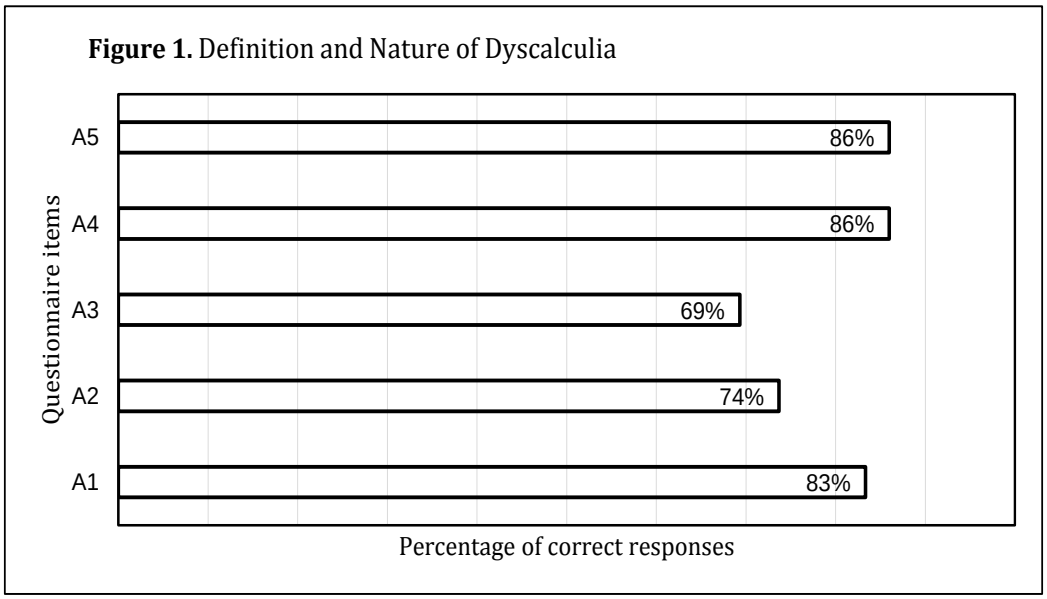

Figure 1: Percentage of correct responses regarding the definition and nature of Dyscalculia. Description of questions: A1. Dyscalculia isn't due to insufficient teaching, A2. Dyscalculia isn't due to low I.Q., A3. Dyscalculia doesn't stem from learning gaps due to long student's school absence, A4. Dyscalculia is an innate learning disorder, A5. Dyscalculia is present in more than 1% of student population.

Regarding the content of dyscalculia (Figure 2), data analysis indicated that almost all of the participants (99%) knew that linking arithmetic terms to their symbols is an area of difficulty for these students. A large number of the participants (95%) were aware of the fact that students have difficulties in choosing the correct arithmetic operation in order to solve a problem, whereas 93% of the participants knew that students with dyscalculia find it difficult to explain their answers. The comprehension of arithmetic terms (e.g. sum, bigger than, e.tc.) and the retrieval of basic arithmetic facts was considered by 91% of the teachers as a major difficulty of students with dyscalculia. A percentage of 84% of the teachers knew that students with dyscalculia respond to word problems impulsively and 82% of them knew that students have difficulty in manipulating measures of weight and length. Teachers, who knew about students' difficulties in memorizing multiplication tables, reached the percentage of 73%, while 63% of the teachers knew that students face difficulties in designing and interpreting a diagram and 60% of them were aware of students' money exchange difficulties. Only 58% of participants knew about students' difficulties in "telling the time" and 55% were correct about students' difficulty in translating the word information of the problem into visual representation. Further, only 37% of the teachers recognized that the reason for students' mistakes in word problem solving is not only their difficulty in reading. Regarding the ability to execute arithmetic algorithms, only one third of the teachers (33%) knew that students' mistakes weren't due to the limited time provided to them.

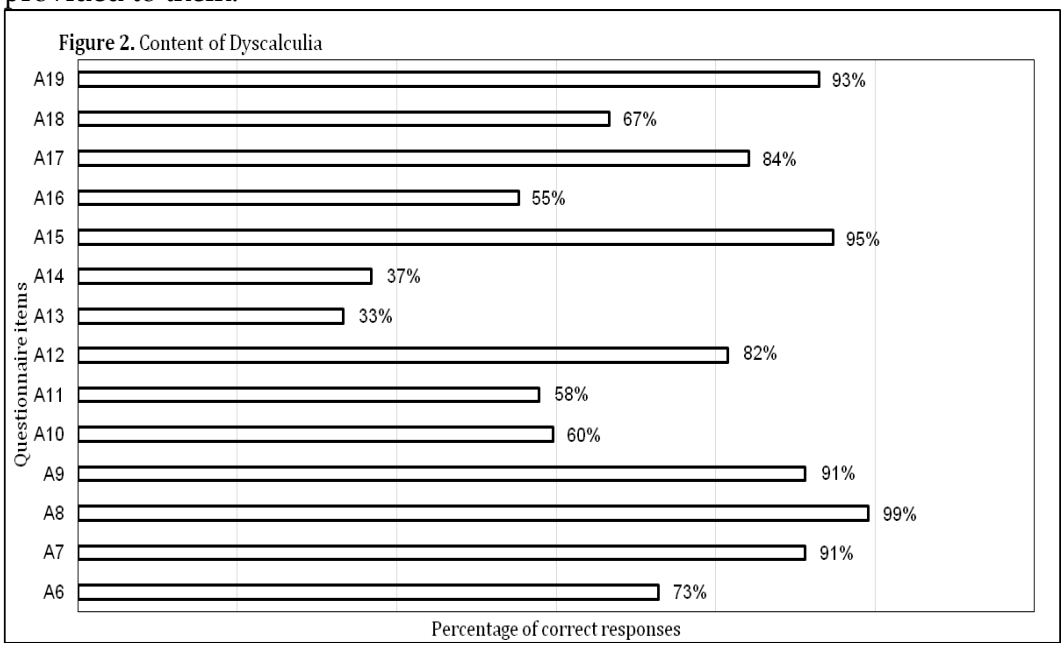

Figure 2: Percentage of correct responses regarding the content of Dyscalculia. Description of questions: A6. They have difficulty in learning the multiplication tables by memorizing them, A7. They make a lot of mistakes in recalling basic arithmetic facts (results by adding and subtracting into the first tens, e.g. 6+4), A8. They have difficulty in understanding the content of arithmetic terms (e.g. sum, bigger than, e.tc.), A9. They have difficulty in making connections between arithmetic terms and their symbolic representations (e.g. +, >, e.tc.), A10. They have difficulty in making money exchanges, A11. They have difficulty in "telling the time", A12. They manipulate ineffectively the measures of weight and length, A13. They may execute

incorrectly an arithmetic algorithm even if they have plenty of time, A14. Their difficulty in solving word problems isn't due to their difficulty in reading them, A15. When they solve a word problem, they usually have difficulty in choosing the appropriate arithmetic operation, A16. They can't translate the word information of a problem into a visual representation (schema, picture, table, and diagram) in order to solve it, A17. They respond to word problems impulsively, A18. They have difficulty in designing and interpreting of diagrams, A19. They have difficulty in explaining the answers they give.

No statistical significance was found between the total responses of the group of teachers with no training courses taken and the one with some kind of training. However, there was statistical significant difference between these two groups in only 2 particular items of the questionnaire. Specifically, there was a statistical significance (t=2.988, df 112, p=.003) between the "no training" group (M=1.53, SD=.503) and the "some kind of training" group (M=1.27, SD=.447) regarding their knowledge about students' skills in money exchange. Statistically significant was also the difference (t=2.545, df=112, p=.012) between the first (M=1.53, SD=.503) and the second group (M=1.30, SD=.464), when responding about students' difficulty in "telling the time". Finally, the one way analysis of variance (ANOVA) performed, for the examination of the relationship between the responses and the teaching experience, revealed no statistically significant correlation.

Discussion

Definition and Nature of Dyscalculia

In the present study we intended to investigate the knowledge of secondary mathematics teachers about dyscalculia and its characteristics. As far as knowledge about the definition and nature of dyscalculia are concerned, teachers' answers were contradictory. Teachers seemed to be aware of the fact that dyscalculia phenomenon is real and highly prevalent in student populations, as well as of the innate nature of the disorder. Unfortunately, some of them still seemed to confuse dyscalculia with intellectual disability. Teachers in our study appear to be uncertain about the relationship between general intelligence and dyscalculia, even though teachers are well aware of the fact that dyslexia is not attributed to low I.Q. (Regan & Woods, 2000; Wadlington & Wadlington, 2005). The underlying conception that dyscalculia is related to low intelligence, is a significant finding, which should be taken seriously into account. The connection between learning ability and intelligence and the perception that one's ability is stable has a strong effect on the expectations and efforts a teacher makes (Dweck, 1986). In the case of students with dyscalculia, who appear to show a low performance in mathematics, the perception of teachers that their difficulties are due to lack of adequate intelligence may lead to limited opportunities for learning, low expectations and less efforts on part of the teachers during instruction.

Another interesting finding from the current study refers to the role of schooling. Participants were certain about the low contribution of insufficient instruction to the appearance of dyscalculia, but they did not show the same certainty, when they were asked about the connection between dyscalculia and

students' school absence for a prolonged time. Although both the above notions are not the cause of dyscalculia, we notice teachers' tendency to blame student attendance more easily, than their own teaching for any students' difficulties. On one hand, the misconception that learning gaps due to a prolonged students' school absence are connected with dyscalculia contradict almost all of the traditional learning disabilities definitions, according to which learning disabilities are not a result of insufficient and inappropriate instruction (Bateman, 1965 in Hammill, 1990; Kass & Myklebust, 1969; Kirk & Kirk, 1983; NJCLD, 1991). On the other hand and most importantly, we have to take into consideration that learning disabilities, as defined by Individuals with Disabilities Education Improvement Act of 2004 (IDEA, 2004), are manifested as the lack of student progress and their academic failure despite the presence of early, evidence-based instructional programs and practices. This, immediately, highlights the significant role of the instructional methods teachers use before a student is identified as a student with learning disabilities.

Teachers' knowledge in relationship with teaching experience and training

As presented in the results, teaching experience did not appear to affect teacher knowledge about dyscalculia. Whereas experience seems to help teachers in adapting their instruction for students with learning disabilities (DeSimone & Parmar, 2006), the effectiveness of these adaptations is questionable, if teachers are not familiar with students' learning profile and characteristics. In our study, knowledge about dyscalculia and the special education training courses taken by the participants were not connected. It can be assumed, that their in-service training was either generic or limited and consequently did not lead to an increase of their knowledge of dyscalculia. This assumption relies on earlier findings of a study about teachers' attitudes towards their training in special education in Greece (Padeliadu & Patsiodimou, 2000), where secondary teachers seemed to prefer a generic training program concerning a variety of special education areas instead of a more specified one. In a study of DeSimone & Parmar (2006) the results also showed that the number of training courses did not affect teachers' self-efficacy beliefs.

Content of Dyscalculia and students' difficulties

Secondary mathematics teachers' knowledge about the origins and general picture of dyscalculia phenomenon seems to be more solid than the knowledge about the specific characteristics, which constitute the learning profile of a student with dyscalculia. However, the knowledge about the nature of dyscalculia itself is inadequate both for a deeper and global understanding of a child with dyscalculia and the implementation of an appropriate and efficient instructional intervention.

The majority of the teachers participating in this study knew about students' difficulty to understand the content of arithmetic terms and their connection with their symbols, as well as to retrieve arithmetic facts. The participants of the study also considered the explanation of the answers students give and the memorization of multiplication tables as main difficulties presented by all students with dyscalculia. Furthermore, they seemed to be aware of the fact that

students with dyscalculia give answers to the word problems without second thought.

However, it is important to notice that the question which concentrated the largest number of wrong answers was the one regarding arithmetic algorithms. Teachers falsely tend to believe that the difficulty in executing an arithmetic algorithm (e.g. 459 + 345) is the limited time provided. On the contrary, possible reasons for students' difficulties are limited procedural knowledge or arithmetic deficits, which consume all of the student's attention and may prevent them from following the series of steps involved in the algorithm. Further, other reasons for students' difficulty in computing an algorithm can be their levels of attention, their working memory or phonological processing (Fuchs, et al., 2006), but definitely limited time frames is not the only cause, as teachers assumed.

Nevertheless, teachers in this study seemed quite confused with student's abilities regarding word problem solving, which is a basic area of difficulty for these students. The selection of the right arithmetic operation to solve a word problem was correctly considered as one of the most prevalent difficulties manifested in this area. However, almost half of the teachers believed that students with dyscalculia are able to translate word information of a problem into a visual representation and one third of them thought that it is easy for students to design and interpret a diagram. One possible explanation for this finding may be attributed to the misconception that all of these students have higher abilities in visuo-spatial processing (Mammarella, Lucangeli, & Cornoldi, 2010; Passolunghi & Mammarella, 2011; Schuchardt, Maehler, & Hasselhorn, 2008). The ability to visualize the information of a problem constitutes a significant predictor of problem solving accuracy (Krawec, 2014), meaning that the selection of the right arithmetic operation might be simply the outcome of a deeper difficulty in visualizing the word information. Interestingly, even when students with dyscalculia use visual representations for a problem, they prefer pictorial rather than schematic representations, which is a less advanced and mature way of representing information (van Garderen, 2006). Nevertheless, since the visualization of a problem contributes significantly to its solving, this skill needs to become a discrete part of students' intervention program.

The majority of the participants considered the role of decoding in problem solving as specifically important, attributing the problem solving inaccuracy of students to their diffuculty in reading the word information. In DeSimone & Parmar (2006) teachers also believed that decoding difficulties stand as an obstacle for word problem solving, but in their study the student group, they were referring to, was characterized as generally learning disabled, with no specific reference to dyscalculia. Other studies showed that students with dyscalculia without comorbid reading difficulties perform better in word problems than the students who have comorbid reading difficulties (Andersson, 2008; Fuchs & Fuchs, 2002). Consequently, word problem reading difficulties may stand as an obstacle to its solving, only when student's reading skills are low.

In addition, it is interesting to have a more careful look in participants' knowledge about the students' ability to handle money exchanges, to tell the time and to process the measures of weight and length. Teachers in the study recognized that students with dyscalculia find it difficult to process weight and length measures. Although the number of studies focusing on these skills is limited, school reality proves that students with dyscalculia face severe difficulties in this area and usually fail to transfer the knowledge they get through teaching to their everyday activities (Patton, Cronin, Bassett, & Koppel, 1997). The fact that secondary mathematics teachers knew about this kind of difficulty may be due to the extented appearance of these skills into the curriculum, which makes these difficulties easily identified by teachers.

A small number of teachers were aware of students' dificulties in telling the time and dealing with money exchanges. More than half of them wrongly believed that students with dyscalculia find it easy to "tell the time". However, "time telling" and especially "digital time telling" is as difficult as the decoding of one and two-digit numbers is for these students, since time and minute values are presented as numbers. In a survey conducted by Andersson (2008), results showed that students with dyscalculia could not easily tell both analogical and digital time. It should be pointed out, that the students in the above study were students of 3rd and 4th grade of primary school, which is a much younger population than the age group that secondary teachers have to teach everyday. Time deficits were noticed in another research, too, in which students with dyscalculia, from 10 to 14 years old, showed a low performance in tasks of accurate time estimation and time production (Hurks & van Loosbroek, 2014). The limited research in this area is the reason why the ability of students with dyscalculia telling the time in middle and high school should be further examined. The ability to tell the time, handle money exchanges and process the measures of weight and length are applied math skills, dominant in every dimension of students' everyday life, especially as they move towards adulthood. A further investigation of the appearence of these skills in students with dyscalculia should be taken into consideration.

In summary, the findings of the present study revealed that although secondary mathematics teachers appear to be certain about the high prevalence rates of dyscalculia, they may be confused about the factors that lead to dyscalculia. Moreover, while they seemed to know more about the manifestation of students' difficulties, they appeared to know less about the underlying cognitive deficits of these difficulties. Furthermore, the results showed no connection between teachers' knowledge and their teaching experience, as well as teachers' knowledge and their relevant training, pointing to the need for more specific and focused on dyscalculia teacher training.

Conclusion and Suggestions

To conclude, in this study, we sought to reveal any misconceptions and/or limitations in the knowledge of secondary mathematics teachers about dyscalculia. Furthermore, our goal was to shed some light on the required content of any future training for teachers working with students with

dyscalculia. Our findings lead us to suggest that training of secondary mathematics teachers should focus especially on dyscalculia and should concern specifically two issues: a) the clarification of dyscalculia nature, so teachers can discriminate between general low intellectual functioning and dyscalculia and b) the complete description of the learning problems and manifestations of students with dyscalculia, so teachers can fully understand students' needs. Specific training courses focused on both dyscalculia and effective practices for students with dyscalculia are required in order for secondary mathematics teachers to meet students' needs and provide them with the best instruction in general classroom settings (Kamala & Ramganesh, 2013). Further, a training program based on the Response to Intervention model would increase teachers' sense of responsibility about their students' academic performance and assist them to play an active role in early identifying students who struggle and adapting their instruction accordingly (Vaughn & Bos, 2012).

The design of specific and intense training exclusively on the area of dyscalculia is imperative and it seems that it is a demand of the teachers, too, who feel inadequate to cope with the educational needs of students with disabilities (Avramidis, Bayliss, & Burden, 2000; Easterday & Smith, 1992). Since intact knowledge of students' characteristics has a positive and strong effect on the instructional effectiveness of teachers (Ernest, 1989), future informed teacher practice may eventually contribute significantly to our scientific knowledge and expand our comprehension of dyscalculia itself.

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