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Mathematical Giftedness and the Need of Mathematics Specialists in Elementary Grades[1]

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The change of the developed countries to highly technological societies continuously requires that they nurture and use the full potential of mathematically and scientifically talented people. As this is a process that should start early in order to be efficient, the main responsibility of identifying and addressing the specific needs of these people is assigned to public school systems and, in particular, to elementary teachers. In this regard, three significant areas of concern arise and are discussed in this paper:

(a) The complexity in identifying mathematically promising and mathematically talented elementary students;
(b) The highly responsible and difficult task for elementary teachers to differentiate and serve the mathematically promising students within an inclusive classroom; and
(c) The need of teachers with specialized training and mathematics knowledge in pre-high school grades.

The last one should be considered predominantly as a logical consequence of the first two. The main goal and, hence, the purpose of the paper is to promote understanding of this crucial necessity of mathematics specialists and to advocate for a change in this direction.

Keywords: mathematical giftedness, necessity of mathematics specialists, elementary teacher education
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INTRODUCTION

Mathematics is attractive, interesting and exciting. However, as opposed to sports, arts, shows, or literature, its beauty is not evident until one reaches a certain level of awareness and proficiency. It is unfortunate that many students give up before achieving this level.

In most developed countries, recent tendencies of declining interest toward mathematics, lower and poorer mathematics skills and knowledge have become a concern not only of educators and parents. For instance, Bill Gates brought it to the attention of a wide audience of business and social leaders during his recent visit in Ottawa in February, 2007. On the other hand, it has been admitted that in the existing public education system the student most neglected in terms of realizing full potential, is the gifted student of mathematics (NCTM, 1980).

Sheffield (1999), one of the prominent advocates of the special education for mathematically gifted students, summarizes its benefits:

(1) Helping students become deep mathematical thinkers;
(2) Developing an informed citizenry;
(3) Allowing students to experience the joy and the beauty of mathematics;
(4) Enabling students to be competitive at the university level and beyond; and
(5) Developing world leaders in our increasingly technological world.

Elementary grades are the place to identify and start taking care of exceptional students, in both ends of the spectrum. Although special care is usually assigned to lower ability students so that they may cover the basic standards, almost no attention is paid to mathematically talented students (Kenderov & Makrides, 2006). As a result, "mathematically promising students abound in the public system, waiting to be recognized, approached, nurtured, and most of all, taught" (Hoeflinger, 1998, p. 244). Barbeau & Taylor (2005) argue that highly motivated students need challenges so that they don't turn their active minds away from mathematics and towards endeavors they find more appealing. In addition, Usiskin (1999) emphasizes the importance to start challenging these students at a younger age, "well before students reach the sixth or seventh grade," since, as related to the advantages of starting early; learning mathematics is similar to learning a second language or to music performance.

Therefore, not only special attention is needed to mathematically promising children, but also it is important to start it from their elementary school years, if the goal is to assist their talents and potential to develop fully.

With respect to difficulties and problems related to teaching and caring for mathematics talents in public school system, three significant areas of concern arise and

are discussed in this paper:

- The complexity in identifying mathematically promising and mathematically talented elementary students.
- The highly responsible and difficult task for elementary teachers to differentiate and serve the mathematically promising students within an inclusive classroom.
- The need of teachers with specialized training and mathematics knowledge in pre-high school grades.

The latter one should be considered predominantly as a logical consequence of the first two. The main goal and, hence, the purpose of the paper is to promote understanding of this crucial necessity of mathematics specialists and to advocate for a change in this direction.

IDENTIFYING MATHEMATICALLY PROMISING AND MATHEMATICALLY TALENTED ELEMENTARY STUDENTS

Mathematical giftedness

There is no single and simple definition that applies to gifted students in the public education systems. Though, characteristics usually are similar to the ones defined by the Alberta Ministry of Education (Alberta Learning, 2004, p. 23), which recognizes the following types of giftedness:

i. General intellectual ability.
ii. Specific academic aptitude.
iii. Creative thinking ability.
iv. Social ability.
v. Artistic ability.
vi. Musical ability.
vii. Kinesthetic ability.

The mathematical giftedness is a very complex category that does not fit exactly in any of these and perhaps, can be best classified somewhere within and across the second and the third one.

Diezmann & Watters (2002a) define it as an advanced capacity to reason either analytically or spatially. *Analytically gifted students* are generally fast and accurate workers, who are able to articulate their chain of reasoning. *Spatially gifted students* may underachieve in classrooms due to the typical emphasis on analytical tasks and may experience significant difficulty verbalizing their reasoning. High spatial ability rather

than high analytical ability generally underpins creative breakthroughs in mathematics and science. The spatially gifted individuals process information simultaneously rather than sequentially.

Hong & Aqui (2004) differentiate among students who are *academically gifted in mathematics* and those who are *creatively talented in mathematics.*

As emphasized by Hoeflinger (1998, p. 244), identification of mathematically gifted students is not easy, because their promise in mathematics is not directly evident from their achievements on standardized tests, nor is it related to the interest, effort or excitement shown during mathematics instructions. "Classroom teachers who have little background in recognizing the attributes of gifted children or who are less knowledgeable in the area of mathematics often mistake hard work for promise." Sheffield (2006, p. 4) also states that "no single measure or combination of measures is sufficient to identify the majority of students from diverse backgrounds with mathematical promise." In addition, experience from the Talent Search programs indicates that many mathematically gifted students are not actually identified for their school's gifted programs, possibly because they do not demonstrate the characteristics of "all-around" gifted students (Rotigel & Lupkowski-Shoplik,1999).

Cognitive Characteristics of Mathematically Gifted Students

Rotigel & Fello (2004) describe the *mathematically gifted students (MGS)* as individuals who:

- Can see the relationship among topics, concepts and ideas without the intervention of formal instruction specifically geared to this particular content.
- Have intuitive understanding of mathematical function and processes. They can find an answer skipping steps and being unable to explain how they got it.
- Often want to know more about the "how's" and "why's" of mathematics idea than the computational "how-to" processes.
- Prefer to learn all they can about a particular mathematics idea before leaving it for a new concept. Get frustrated when the regular classroom schedule demands moving to another activity.

Sheffield (1999, p. 52) distinguishes within this group of learners: "Just as special education teachers distinguish among levels of intellectual difficulties by defining students of lower abilities as mildly, moderately, severely, of profoundly retarded, we can also look at different levels of mathematically promising children: [mildly, moderately, severely, of profoundly gifted]"

Social characteristics of mathematically gifted students and related issues

Mathematically gifted students are affected in multiple ways by the attitudes of others (Diezmann & Watters, 2002b). Their interests and capabilities set them apart from other children and identify them as a "marked" group, due to the generally negative attitudes towards mathematics that are held by the general populace. Gifted girls are considered to be "doubly-marked." Reflection of the negative community attitudes is labeling these students as "little Einsteins" or "nerds."

Teachers' attitudes vary from highly supportive to extremely negative; sometimes indifference or unawareness. The most significant factor affecting teachers' attitudes to gifted students is whether or not they have done any specific study in gifted education.

Thus, although MGS have characteristics that predispose them towards high performance and creative achievement, they need considerable support and resilience to overcome negative attitudes and fulfill their potential (Diezmann & Watters, 2002b).

TEACHING MATHEMATICALLY GIFTED ELEMENTARY STUDENTS

The complexity of the concepts and the practice of identifying the mathematically gifted students (MSG), together with the necessity to start addressing their specific needs in their elementary school years, affect the role of the elementary teachers in the entire process of serving them.

MGS need to be exposed to challenging tasks, within an effective learning environment (Diezmann & Watters, 2000).

Challenging tasks include:

(a) Difficult mathematics problems;
(b) Developing mathematics ideas beyond those typically addressed for their age group;
(c) Open-ended investigatory problems; and
(d) Competitive mathematics problems and topics.

Challenging tasks facilitate *development of cognition* (high level thinking and reasoning, patterns and relationships, working abstractly). Challenging tasks encourage the use and *development of metacognitive skills*: dealing with novel tasks; knowing how to exploit useful previous knowledge; knowing when to discontinue with inappropriate or unproductive strategies (Taplin, 1995; as cited by Diezmann & Watters, 2000). Challenge enhances *motivation.* Success on challenging tasks develops self-efficacy and self-esteem; challenging tasks facilitate the development of autonomy, which is necessary

for creativity in mathematics.

As opposed to the common belief that students should not be exposed to very challenging work, Stanley (1991) argues that "there is evidence that gifted students crave such work:

> Figuratively, they were starved for mathematics at the proper pace and level and rejoiced in the opportunity to take it straight rather than being "enriched with mathematics puzzles, social studies discussions, trips to museums, critical thinking training not closely tied to mathematics, and so forth. (Stanley, 1991; as cited by Diezmann & Watters, 2000, p. 2)

As far as the effective and challenging learning environment is concerned:

- It should provide opportunities to incorporate evidence, logic, argumentation, and involves students in sharing ideas, building on each other's ideas, and critiquing ideas.
- MGS prefer to work independently on relatively easy tasks, but prefer to work in a group on sufficiently challenging problems, in order to share knowledge and access a support network.
- Differentiation of instructions for these students is seldom a reality when they are placed in a regular classroom (Rotigel & Lupkowski-Shoplik, 1999, p. 334). Often, the only "enrichment" for high-ability students is assigning more of the same tasks (Saul, 1999).
- A more linear approach to mathematics is often a better match, instead of the spiral curricula (Rotigel & Fello, 2004).
- Many programs for gifted students do not emphasize learning mathematics concepts in depth. Instead, they often treat mathematics as the "puzzle of the week" (Sheffield, 1999).
- The common practice implemented in many schools — to accelerate mathematically gifted students by placing them in a class with older students — can be problematic for many reasons, including their social and emotional development (Rotigel & Lupkowski-Shoplik, 1999).

Consequently, the teachers of young mathematically gifted students have important *responsibilities* (Diezmann & Watters, 2000) that include (but are not limited to):

- Selecting tasks that are appropriately challenging.
- Proactively and consistently supporting students' cognitive activity without reducing the complexity and cognitive demand of the task.
- Facilitation of cognitive apprenticeship - strategies like scaffolding, modeling and coaching are most effective for developing expertise in domains such as mathematics.

- Monitoring and responding to the student's thinking, interpretative listening, and dialogue (probing responses, paraphrasing, and opportunities for vocalizations the understanding). This implies that the teacher needs to be flexible and responsive to the student in implementing tasks. Student-teacher interaction is crucial in responding to the capability of the learners and leading them to extend their achievements.
- Dealing with issues and problems that arise from the specific social characteristics of this group of students.
- Being inspirational and able to pass the admiration toward mathematics to students.

At this point it is necessary to stop for a reality check:

- How many elementary generalist teachers are prepared, qualified and willing to take these responsibilities?
- How much class time do they actually dedicate to the few mathematically promising students in their diverse and inclusive classroom?
- What support do these teachers get from the educational system to be motivated and able to cope with the intense and consistently challenging role that these responsibilities require?

THE SOLUTION: MATHEMATICS SPECIALISTS IN PRE-HIGH SCHOOL CLASSROOMS

No doubt, mathematically gifted students need to be taught by professionals that satisfy the long list of specific requirements from the previous section – in relation to their training, subject matter knowledge, pedagogical content knowledge, experience in challenging mathematics, and, last but not least, their passion and interest in this demanding area of math. In terms of teachers' academic background, they need to be "confident in their own mathematical knowledge and teaching abilities in order to accept the divergent thinking abilities of their gifted students" (Rotigel & Fello, 2004). Evidently, a few elementary teachers who have been qualified and trained to teach all academic subjects can meet the above requirements. Nevertheless, the traditions and practice in most school systems in North America assign by default this hard task to generalist elementary teachers who carry on the entire education process for students from all pre-high school grades.

The concept of teaching elementary grades by teachers who are interested, demonstrate positive attitude and are knowledgeable both of the subject matter and the pedagogy of mathematics should be regarded with care, as it directly affects all students'

experience and learning.

Many educational systems around the world require specialization for elementary teachers in upper elementary grades (ages 9–13, which corresponds approximately to grades 5 to 8 in Canada and US) - both in their preparation and in their teaching assignments. Examples from Sweden, South Korea (Reys & Fennell, 2003), China (Ma, 1999; Goulding, Rowland & Barber, 2002), Singapore (American Institutes for Research, 2005), Bulgaria (Bankov, 2004), provide evidence of the benefits and advantages of such practice with respect to students' achievements and mathematics proficiency.

In the past 50 years, the significance of the problem of good mathematics knowledge and training of elementary teachers has been a focus of many research studies and has been recognized by several important US government documents related to education. The message passed by the National Research Council in 1989 is explicitly clear:

> "We are one of the few countries that still pretend an elementary teacher can effectively teach all subjects. We need to find teachers who are interested and capable in mathematics to teach math" (as seen in Burton, 2006, p. 20).

The problem of the adequate pre-service training and in-service professional development and support becomes a great concern for mathematics educators of gifted students as a significant volume of research from the past two decades provides a lot of evidence of the opposite.

Many research studies conducted in 90s try to identify specific elementary mathematics topics of concern in relation to the ability and preparation of teachers. It has been confirmed that most of the examined elementary teachers demonstrate inadequate conceptual knowledge on the specific content areas (Post, et al., 1991, as cited by Burton, 2006; Menon, 1998). Ma's (1999) comparative study of Chinese and US teachers' knowledge of fundamental mathematics explore the differences of the ways these two groups of teachers approached and articulated four (usually considered) difficult concepts from the elementary curriculum. According to Ma, American teachers have limited and sometimes, incorrect understanding of these concepts, as opposed to the Chinese teachers who are able to perform the calculations, provide examples of the concepts in context, justify the procedures.

Seaman & Szydlik (2007) present an interesting summary and explanation of the whole spectrum of problems and issues related to the elementary teachers' qualification and practice in mathematics teaching, by defining and exploring the concept of the mathematical sophistication. Seaman & Szydlik propose a list of 9 norms that indicate mathematical sophistication (in fact, these are the basic norms respected and valued in the mathematical community). They state that majority of pre-service elementary teachers fail to make sense of mathematics due to their lack of mathematical sophistication. The

study conducted with a group of elementary pre-service teachers taking mathematics content courses suggests that pre-service elementary teachers display a set of values and avenues for learning mathematics that is significantly different from that of the mathematical community. Based on the results of the study, Seaman & Szydlik conclude that the poor procedural knowledge indicate poor conceptual understanding, but also, an inability to use the "avenues of knowing" of the mathematical community to gain either one of them. Seaman & Szydlik (2007) suggest that mathematics courses for teachers should focus on their educating about and integrating into the mathematical community. They must come to value mathematics definitions, to develop habits of classifying objects based on those definitions, and to invent examples and non-examples of mathematics.

All in all, research confirms the need of good specialized teachers' knowledge: first, because it is crucial for all students' advancement and effective teaching, and second, because many teachers do not have it.

CONCLUSION

According to the common practices in public schools in US and Canada students up to grade 8 (including promising mathematics students) are taught by generalist teachers. There are few exceptions, mainly results of local initiatives and pilot projects, which illustrate various models of mathematics specialist teaching and their implementation (Reys & Fennell, 2003; Nickerson & Moriarty, 2005). However, they cannot make a significant difference in the trend of poor teaching of students who are gifted and talented in mathematics. Therefore, the practice of generalist teachers is indirectly accountable for not serving and developing to the full potential these students.

The acknowledgement of the problem and the recommendations from the education professionals in support to the mathematics specialist's model are evident; nevertheless, the problem does not become less complex. Many other barriers and issues restrict the implementation of this model. Given that these cannot be changed and overcome easily, efforts should be put on adequate training and preparation of elementary teachers, with respect to the best practices from national and international experience. Mathematical sophistication of teachers is crucial to their ability to improve and further develop their mathematics knowledge. Its construction often requires "unlearning" things and studying them again, following the "avenues of knowing" in mathematical community. Therefore, mathematics courses for teachers should focus on acquiring mathematics sophistication as one of their first priorities.

Talented people and those of higher ability constitute a critical resource for the development of society. "Unlike other resources, like mineral deposits, which disappear

once discovered and used, the abilities and the talent disappear forever, if not identified and not used"(Kenderov & Markrides, 2006). The American society cannot afford to under-develop and under-use the intellectual potential of its mathematical talents. Thus, there is an urgent need for finding a solution.

Am I optimistic? Well, at least I know I am not the only one who shares the concern.

"Mathematics specialists can make the difference in improving mathematics instruction. We need you – NOW!"
Francis Fennell, President of NCTM, in the President's Message
"We Need Elementary School Mathematics Specialists NOW"

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