Beyond the Competitive Aspect of the IOI: It Is All about Caring for Talent

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Abstract. The IOI is not just an informatics competition, but a means to care for talent in informatics. Caring for talent involves a broad range of issues, including identification of talent and education adjusted to that talent. There is (almost?) no generally accessible literature focusing on informatics talent. To show what such literature could offer, we review several books that address talent in mathematics. These books also contain much that is directly applicable to talent in informatics.

Key words: international olympiad in informatics, international mathematical olympiad, developing talent, training, books.

1. Introduction

The statutes of the International Olympiad in Informatics (IOI website, 2011; Regulations) state in article S1.7:

"The main objectives to be accomplished by the IOI are:

- to discover, encourage, bring together, challenge, and give recognition to young people who are exceptionally talented in the field of informatics;
- [further objectives omitted . . .]"

Similar phrases appear in the regulations of other olympiads. All olympiads have chosen the competition form as a means to achieve these ulterior goals, but they clearly do not have the competition as their first goal. Note that not all talented pupils are motivated by a competition (Verhoeff, 1997).

In this article, we address various aspects related to the goals of discovering, encouraging, challenging, and, in particular, developing talent. We do so by reviewing six books about discovering, developing, training mathematical talent. Our hope is that similar books will, one day, be published in the area of informatics, so that these can be reviewed. But even the math-oriented books offer good advice in general, and they can serve as examples worthy of imitation. Keep in mind that informatics resembles mathematics, because it is also a so-called *science of the artificial*, as opposed to an empirical science, like physics.

2. How to Care for Talent

It is one thing to say that you wish to discover, encourage, and challenge talent. How to do so is quite another thing. The latter is a recurrent concern of teachers, parents, school administrators, and policy makers. There are many prejudices, misunderstandings, and myths on how to care for talented pupils, even among those with (some) experience. And, as it turns out, that included the author.

There is not much literature on developing talent when compared to the amount of 'regular' teaching material. In this section, we will review three books that do address this topic (see Fig. 1).

On the side, we teach enrichment classes at a primary school, touching on topics in mathematics and informatics. While looking for some new material, we accidentally came across Assouline and Lupkowski-Shoplik (2005). This was before the second edition (Assouline and Lupkowski-Shoplik, 2011) came out, so the review here is for the older edition. However, the second edition has the same structure, with some rewrites to put it in a broader perspective and some interspersed updates.

Assouline and Lupkowski-Shoplik (2005) was bought with the hope of finding concrete material for enrichment classes. At first, it was disappointing not to find anything technical that could be used in classes. But after reading the book, its real purpose became clear, and we got hooked.

The book is written by two authors who both were introduced into the world of pupils with a talent for mathematics by Julian Stanley. Stanley acquired fame in this area in the 1970s, by doing research, publishing about it, establishing an institute devoted to math talent, and training a new generation of researchers. The authors now direct their own research institutes for math talent.

Soon, it was understood that we always had been somewhat naïve, because there has been considerably more research on talent than many parents and teachers realize. The first chapter treats a series of myths (in the second edition, renamed to "excuses")
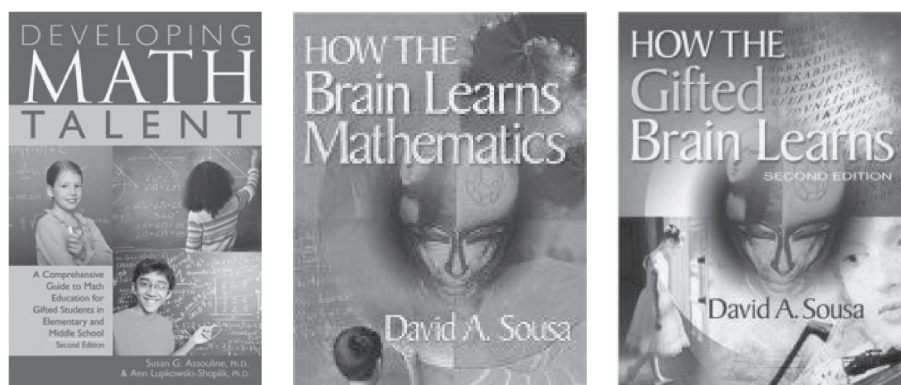

Fig. 1. Three books concerned with (mathematical) talent (Assouline and Lupkowski-Shoplik, 2011, Sousa, 2008, 2009).

and provides brief counterarguments, which are elaborated in subsequent chapters. Some myths are well known to mathematicians, such as "mathematically talented students are computation whizzes", or "if mathematically able students study mathematics at an accelerated pace, they will run out of math curriculum before they reach high school" (the vastness of mathematics is not easy to explain to the layperson). But other myths are more subtle: "results from standardized, grade-level testing are sufficient for identifying mathematically talented students", or "the best option for mathematically talented elementary school students is enrichment", or "mathematically talented students cannot be identified until high school".

There are a number of interesting things that you can learn from this book, for instance, that it is important to distinguish *good*, *talented*, and *exceptionally talented* pupils. This is especially important when fine-tuning their (math) education. Standardized grade-level tests are not appropriate, because all three groups will end up in the top 5% where they cannot really be distinguished. This is the saturation region or *ceiling* of the test. Research involving thousands of pupils, has provided evidence that so-called *above-level tests*, i.e., standardized tests designed for older pupils, can be used to pull these three groups apart.

To develop math talent it does not suffice to offer some more assignments of material already mastered (the book calls that *busywork*), nor extra topics in a general or cultural enrichment class, like philosophy or debating. It can be the case that pupils with talent for mathematics obtain only average scores in other subjects, and therefore they will not be identified as gifted and do not even qualify for a general enrichment class. Talent, be it in sports or music or math, needs to be developed in an educational program tuned to that talent. Furthermore, math talent is not really developed by offering some ad hoc enrichment material from the field of mathematics. It needs a systematic approach that *accelerates* a solid training in math.

Gifted pupils with a talent for math are ahead of the class in mathematics from the very start, and the gap only increases when their development is properly facilitated. Simply skipping a grade (even if only for math) is not a good solution, because also there the tempo is too low, and the dangers of boredom lurk. The authors also provide a more important reason to accelerate: "If a student is not permitted to accelerate, he or she may be … denied the opportunity to study a more advanced subject later. … [W]aiting to study a subject eliminates the chance to take new, more challenging courses." Society needs talent to make progress.

The book by Assouline and Lupkowski-Shoplik (2005) has a systematic organization, larded with tables, lists, and examples. There is a chapter aimed at parents, who are the prime advocates for their children to get schools to offer an adjusted curriculum (also see Bosse and Rotigel (2006)). A full chapter is devoted to talent search, and one to organizing assessment and individual mentoring. For teachers there is a chapter on various options, either inside the regular classroom or outside (including mathematics competitions and clubs). The final chapter treats a couple of concrete cases of exceptional pupils and summarizes all insights. The book has a focus on the situation in the United States of America, with ample references to American literature and sources. However, most of

the advice is generally applicable. People involved in olympiads, in whatever role, often encounter talented students and are asked for advice. This book provides a solid basis.

Cognitive Psychology and Brain Research

Two books by Sousa (2008, 2009) caught our attention. They present recent research in neuroscience and the implications this is having for education. The first book is specifically about cognitive development and how this affects the learning of mathematics, from a very young age on. It turns out that the human brain is much more capable of dealing with abstract mathematical concepts than many parents and teachers believe. Devlin (2000) even provides evolutionary arguments for this.

In music and sports it seems to be accepted practice to offer special support for developing talent, but this is much less the case for academic talent, for no good reason. As in music and sports, it is worthwhile to start young with the development of talent in mathematics and informatics. We have the impression that a lot of talent is already lost and wasted before secondary education starts. The book provides many concrete aids to improve math education, from preschool up to adolescence.

The second book (Sousa, 2009) starts by exploring the phenomenon of gifted persons in a broad sense, comparing various definitions, emphasizing that giftedness is not equivalent to high IQ (intelligence test score), but also involves creativity, problem-solving ability, intense interest, and motivation. It cites experimental evidence that giftedness is not brought about by either nature (inherited genes) or nurture (environment and upbringing) alone, but by a suitable combination of nature *and* nurture. Other chapters address topics like how to challenge, how to deal with underachievement, and the twice-exceptional brain (gifted in one area, deficient in another). There are separate chapters on gifts for language, mathematics (though Assouline and Lupkowski-Shoplik (2011) goes deeper), and arts. One of the main theses of the book is debunking the myth that "[gifted] students can take care of themselves". Or put differently: "Teachers at all grade levels have the responsibility to recognize and plan for the needs of the gifted. ... The loss of such potential is a serious blow to society as well as to the student and teacher."

3. How to Train Talent

The three books discussed in the preceding section did not offer specific advice or material on the technical side. In this section, we will review three books that arose from training initiatives for mathematical olympiads and other math contests. The book by Faires (2006) was conceived in the United States of America, that by Zawaira and Hitchcock (2009) in Zimbabwe, and Holton (2010) in New Zealand. To compare the books on their contents, it is necessary to know more about the mathematical olympiad.

The International Mathematical Olympiad (IMO) was established in 1959 with as primary aim "to discover, encourage and challenge mathematically gifted young people in all countries" (IMO 2011 website, 2011). (Note how the IOI objectives cited in the introduction resemble this wording.) To achieve this aim, the IMO offers a challenging
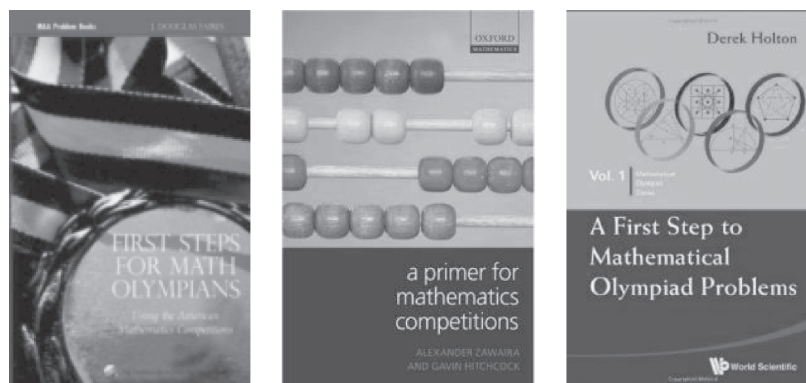
Fig. 2. Three books concerned with the training of mathematical talent (Faires, 2006; Zawaira and Hitchcock, 2009; Holton, 2010).

competition with math problems that require an investigative mentality. To ensure that the problems are accessible to participants from all over the world, they cover a limited range of topics, and the problems and solutions must be 'elementary' but 'non-routine'. Traditionally these topics are geometry, number theory, algebra, and combinatorics, specifically without calculus and probability theory.

Over the years, the level of the competition has risen. Currently, the harder problems at the IMO are even challenging for professionals. In part, this increase happened because more effort is put into discovering talent, resulting in more competitors with raw talent. But also because more and more countries have a systematic training program to develop discovered talent.

Faires (2006) intends to cater for the top 10% to 15% of an average senior high school class, and not just for the elite. The material is divided into eighteen short chapters, which each treat a theme, such as polynomials and their zeroes, or the geometry of the circle. Some of the material covered is not so relevant for the IMO, but can be useful for other math contests; this includes probability theory, solid geometry, and complex numbers. Each chapter closes with examples and multiple-choice exercises. Complete solutions are provided in the back, together with references to original sources.

To give you an impression of the level that Faires (2006) strives for, it can be noted that geometry proceeds up to Ceva's Theorem, the power of a point, and cyclic quadrangles; number theory up to prime factorization and modular arithmetic; combinatorics up to inclusion-exclusion and the pigeonhole principle (although the latter is presented in a chapter on number theory); and algebra has an underdog position. There is extensive attention for (special) functions, whereas function equations and inequalities are not treated. Still, it would be wonderful if the top 10% of a regular class would really perform at this level.

Zawaira and Hitchcock (2009) are more ambitious and have organized their material with the math olympiad in mind. They start with a overview of that olympiad and even pay attention to such questions as "what benefits does . . . training bring" and "what careers are appropriate for people with mathematical aptitude". There are eight hefty

chapters built around grand themes. Each chapter starts with a few problems as appetizers; the solutions appear only at the end of the chapter. Motivation, theorems (mostly with complete proofs) and examples are intertwined. Separate sections with problems and solutions close a chapter.

The chapter themes of Zawaira and Hitchcock (2009) are: geometry (including theorems of Menelaus en Ptolameus), algebraic inequalities and induction (Cauchy–Schwarz, AM–GM), Diophantine equations, number theory (including little Fermat, Wilson, and Chinese remainder), trigonometry, sequences and series, Newton's binomial theorem, and combinatorics (including partitions and derangements). The ninth chapter consists of miscelaneous problems, where you have no clue in what direction to start looking for a solution. As with Faires (2006), also here, many of the problems are multiple choice, which is somewhat counter to IMO tradition, but the intention is that you prove your answers.

Holton is an experienced author on mathematical problem solving. Holton (2010) is Volume 1 in the new *Mathematical Olympiad Series*, which features attractive titles of various authors, mostly on specific subareas. Although nowhere mentioned, Holton composed this book from booklets Number 1 through 8 of his *Problem Solving Series*, without major changes. This older series was published by the *The Mathematical Association* (of New Zealand) in 1988–90. It can be expected that booklets Number 9 through 15 will also be combined and republished in the future. At the time (over twenty years ago), those booklets where aimed at training and selection of the national team for the IMO. Nowadays, the IMO level is much higher and the book is not longer suitable for that purpose. Holton makes it clear that he considers problem solving the essence of all mathematics, and he emphasizes the need for mathematical creativity.

In the first chapter, Holton illustrates several general problem-solving techniques using some accessible problems. The subsequent chapters treat combinatorics, graph theory, number theory (little Fermat, but no Chinese remainder), geometry (two chapters, but no Ceva nor cyclic quadrangles), and proof techniques. The exposition is aimed at beginners and not at advanced students. Except for graph theory, Holton (2010) presents less theory than Faires (2006). The final chapter offers several IMO problems and accompanying background information.

A Comparison

The three training books have considerable overlap in content and purpose, but the approaches are rather different. Faires (2006) is clearly aimed at breadth and a lower level, and it comes across as dry. Also Holton (2010) keeps it simpler, especially on theory, but the presentation style is much more appealing, especially for self-study. All three books contain an index, but only Zawaira and Hitchcock (2009) refer to other books, journals, and websites. The typography of Faires (2006) and Holton (2010) is beyond reproach, whereas that of Zawaira and Hitchcock (2009) looks amateurish.

It is remarkable that only Holton (2010) pays attention to the *meta-cognitive level*, like Pólya in his famous *How to Solve It*. None of these books explicitly refers to Pólya,

not even Holton, who presents his own problem-solving guidelines. We would think that talented students would especially be interested in developing an understanding of the problem-solving process.

Good training establishes a solid foundation of basic knowledge, develops experience with many and diverse problems, and compares different techniques to solve each problem. These books supply useful ingredients for such training. With Faires (2006) and Holton (2010), at most one or two of the six IMO problems come in range, whereas with Zawaira and Hitchcock (2009), maybe a third or even fourth IMO problem might become accessible. Of course, contestants still need to practice, practice, practice.

4. Conclusion

In this article, we have drawn your attention to the broad set of issues surrounding talent and how to care for it. Our aim has not been to treat this topic in any depth, but to point you to informative literature.

Since discovery, encouragement, and challenging of talent are among the main objectives of the IOI, it would be good if more literature on talent in informatics would emerge. For lack of such literature, we have reviewed six books concerning talent in mathematics, a mature and neighboring discipline. Because informatics is so close to mathematics in many respects, the lessons and insights set forth in these books are also of direct use to persons, such as in the IOI community, who encounter and work with pupils talented in informatics.

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