

## **Crystallizing experiences in developing mathematical abilities of Polish laureates of International Mathematical Olympiad (IMO)**

Maja Wenderlich

*Maria Grzegorzewska University*

In this research report, I present the crystallizing experiences related to the shaping of interests in mathematics: that is, experiences that involve people with extraordinary talent or potential abilities with the material of a given field in which this talent can manifested. The study covered Polish international winners of mathematics Olympiads organized in 2000-2019. The history of mathematics shows that the groundbreaking discoveries of mathematics were made by young people (period adolescence and early adulthood). Examples are the achievements of Evarist Galois, Srinivas Aiyangar Ramanujan, and Terence Tao. The main goal of this research report is a presentation of the breakthrough events in the lives of talented adolescents and young adults, which were related to the orientation of their minds towards mathematics.

**Keywords: crystallizing experiences; math skills; IMO; the course of human life.**

### **Introduction**

The International Mathematical Olympiad is the World Championship Mathematics Competition for High School students and is held annually in various countries. The first IMO was held in 1959 in Romania, with 7 countries participating. It has gradually expanded to over 100 countries from 5 continents (IMO, 2020).

It is worth noting that the International Mathematical Olympiad was established thanks to the initiative of Central and Eastern European countries, namely Poland, Romania, Hungary and then Czechoslovakia, in which the national mathematics Olympiads were organized earlier (the Polish Mathematical Olympiad has existed since 1949). In turn, the International Mathematics Olympiad has been held three times in Poland so far: in 1963 in Warsaw and Wroclaw, in 1972 in Torun and in 1986 in Warsaw. Currently, students from over 100 countries around the world take part in the competition (IMO 2020).

The International Mathematics Olympiad itself was an inspiring object of creativity: e.g. books: *The Math Olympian* (novel about a girl whose dream was to participate in the Math Olympiad) by Richard Hoshino (2015) or films: *X + YA Brilliant Young Mind* (a boy who from an early age showed above-average ability and did everything to take part in the Olympics).

The participation of so many countries from different continents proves that mathematics is a universal language, understood by the whole world. Math symbols, letters, and other characters make up the written language of math. Galileo himself claimed that "Mathematics is the language with which God has written the universe" (Federer, 2018). It is hard to argue with that.

During the International Mathematics Olympiad, Poles also managed to win gold, and obtained the maximum number of points (the so-called perfect score), which

is a rare and particularly appreciated achievement. During the 60-year history of IMO, 7 Poles managed such a feat.

When I was conducting research on my doctoral dissertation entitled *Milestones in the life of outstanding mathematicians and mathematically gifted youth* (Wenderlich-Pintal, 2019), I realized that the group of Polish mathematical Olympians is diverse, fascinating and requires further research. The fact of particular importance was that in this age group it is possible to ensure better organization of education or to direct the destiny of these people in such a way that they have a greater chance of achieving success (Bühler, 1999, Spitzer, 2012).

While studying the pedagogical and psychological literature, I noticed that there is still very little research concerning mathematical talents from the point of view of specific events and situations that initiated the career path and contributed to the achievement of extraordinary achievements. Research by Walters and Gardner (1984, p. 6), already classified as psychological classics, is worth pointing out. The authors defined crystallizing experiences as “events, experiences involve remarkable and memorable contact between a person with unusual talent or potential and the materials of the field in which that talent will be manifested.”

According to Walters and Gardner (1984), a crystallizing experience is an extraordinary encounter - usually in adolescence - with an authority in a given field of creativity or with its characteristic material, or even equipment and instruments, which becomes a breakthrough in the later life. The course/fact of this meeting results in the fact that a creative person begins to focus their life on a selected problem, material or experiences. The authors suggest that in the case of the greatest talents, crystallizing experiences are inevitable, and most importantly, they occur more often among musicians and mathematicians.

These views served as an inspiration for the purpose of my research. However, I decided that it is worth considering other factors that could have influenced the development of mathematical skills, whether it was just a stroke of luck (Shermer, 2017), or other aspect. Bühler’s (1999) methodological concept of conducting research on the course of human life helped me to plan the research program. Therefore, in this convention, I considered the course of life of mathematically gifted youth.

### **Description of the data**

Data for this study come from interviews with 15 winners of the International Mathematics Olympiad during 2004-2016. Each interview lasted from half an hour to two hours and was transcribed. Due to the necessity of maintaining anonymity in the research, I do not provide the identifying information of the respondents, although I do have detailed information.

As mentioned earlier, 15 people took part in the study, 14 males and 1 female. The subjects ranged in age from 19 to 31. Seven people received a gold medal. One of the respondents received the gold medal twice. Five people received a silver medal and three bronze. One participant has two medals: silver and bronze (table 1).

Table 1. Types of medals received by the respondents

Gold medals	Silver medals	Bronze medals
7	5	4

The sample selection was deliberate. On the official website of the International Mathematics Olympiad, there is an online search engine for winners. This is how I was able to find the names of the Polish laureates. In order to find out about them, I used social media such as Facebook and LinkedIn. At the end of the interview, I asked the respondent to name a person who in their opinion is an outstanding young mathematician. Then, I contacted that person and conducted an interview. Thus, each person examined by me was also a competent judge.

All respondents went to university and majored in mathematics or IT. Half of them had a doctoral degree at the time of the interview. Two of them did not consider a scientific career - they ran their own companies.

Five of the surveyed Olympians come from families of two or more children. Three of the participants are the firstborn children in their families. The socio-economic status and education of parents were varied. The Olympians had positive school experiences, and most of them were excellent students.

What all the laureates had in common is that they showed mathematical talents quite early. Also, everyone took part in national and international mathematics competitions with above-average results. Most of them participated in maths circles and workshops developing maths skills.

## Methods

A biographical method was used in the study, following the example of Bühler's (1999) *The course of Human Life*. The main purpose of this research was to establish the events that were engraved in the minds of outstanding mathematicians and significantly influenced their mathematical achievements. The researcher conducted interviews independently. The technique chosen was a partially structured interview. It began with the question: "Are there any people, things, events, situations, and all the contexts in your consciousness that influences the orientation of your mind towards mathematics?" Then, if there was such a need, the researcher asked about specific periods of life: childhood, school period, or people, e.g. parents, teachers, etc.

Walters and Garder (1984) wrote that, especially among mathematicians and musicians, we can talk about crystallizing experiences. So it happened also in this case. All respondents were able to indicate certain turning points in their lives.

## Data analysis

To analyze the data, I used a new take on the theory of Bühler introduced in the course of human life (Wenderlich-Pintal, 2019). I have presented each biography graphically on an axis using the Office Timeline program (figure 1). After analyzing each biography, I created categories. Some of the crystallizing experiences are common to the respondents, some occur only once.

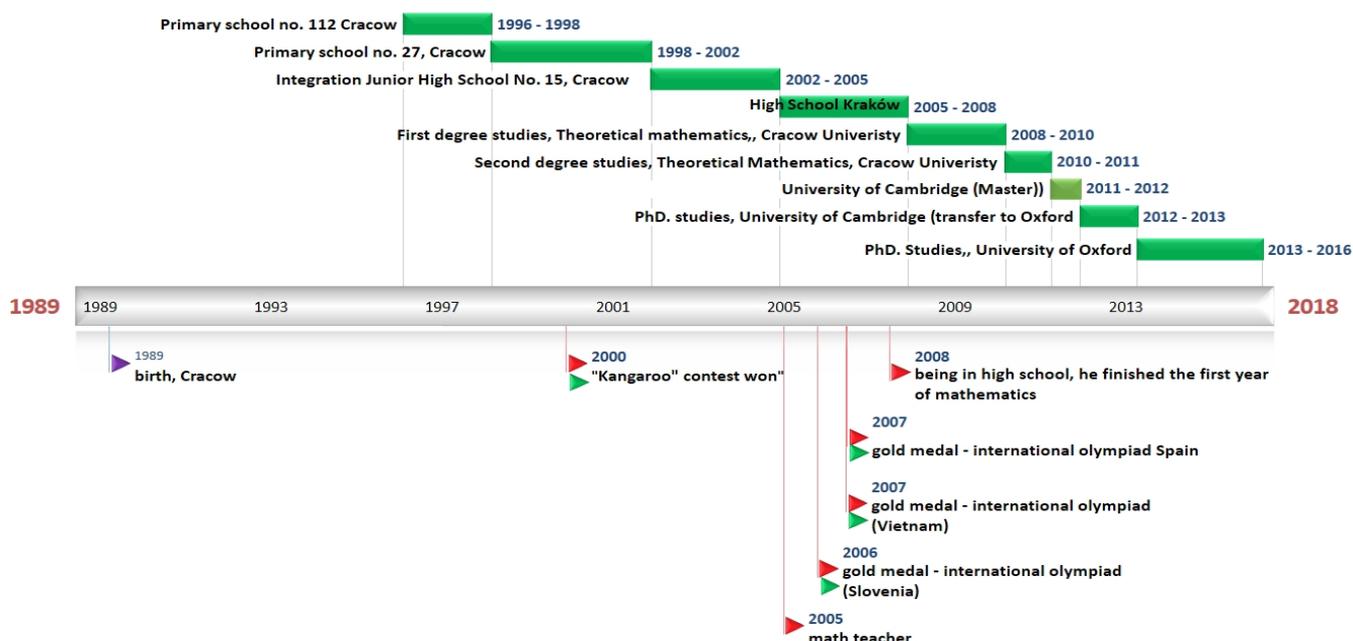


Figure 1. An example of a chart that was created for each test person

### Critical events in the lives of Polish Olympians of Mathematics

Each of the examined Olympians mentioned crystallizing experiences in their life. Based on their stories, I was able to distinguish such categories:

#### *People supporting the development of mathematical talents*

All respondents mentioned other people who helped in the development of interests in mathematics and their talent that people provided the support. All respondents mentioned their parents who helped them develop their talents. Mothers in particular were instrumental in influencing their sons' interest in mathematics. It was they who, from the earliest years of their children's lives, found the makings of talents that needed support. Half of the mothers did not have university degrees or any education related to mathematics. However, their sons showed that they are gifted in this domain. Fathers were mentioned by two laureates. Among the family also appeared an older brother and a grandfather, who themselves, because of their passions, began to interest them in mathematics.

Another group of people who saw the potential in the winners of the Olympics were teachers. Four respondents pointed to teachers from primary school. One of them talked about a teacher who helped in choosing further education. The rest were talking about learning aids - noticing special educational needs related to mathematics. The vast majority of respondents mentioned high school teachers who supported their pupils in learning mathematics by offering additional classes, but also helping them to function at school by talking to teachers of other subjects and asking them to excuse their absence or lack of homework. After some time, they themselves claimed that they were not expected to do the same as was expected of their peers. Some helped in choosing further education - the field of study. They showed alternative forms of gifted development.

The next group were academic teachers, whose appearance in the respondents' lives was related to the selection of a specific area of interest during their studies. Only one respondent mentioned their scientific authority, a mentor who

supported his achievements and general attitude. Two, on the other hand, talked about fascinating, delightful academic lectures.

### ***Success in school and extracurricular mathematical activity***

All mathematics laureates took part in mathematical school competitions with very good results from an early age. Often, initially it was at the initiative of the parents of the respondents that these children took part in competitions. The outstanding successes resulted in the willingness to continue working and developing. If other adults noticed the children's successes, they gave them positive reinforcements, through a kind word or admiration. It was a motivation to continue working even harder. Obtaining prestigious awards or high positions in out-of-school competitions, such as the Olympics, was the basic and main factor of the direction of further education.

### ***Books and textbooks***

Some of the laureates mentioned books or textbooks that influenced their later interests. They were often given to them as a gift. Interest began with reading and solving simple tasks. This feeling of pleasure and satisfaction after solving the task was strong and made them want to continue working. There was a strong desire to obtain more information in this field.

### ***School and academic conditions for developing mathematical abilities***

Almost all of the respondents spoke about the wonderful learning atmosphere among their peers that encouraged them to continue working. This atmosphere was present in high school, during studies, and out-of-school environments that were related to the development of mathematical skills, such as: camps, workshops, research clubs, joint research trips, e.g. trips to national and foreign Olympics. It happened that it was only in this out-of-school environment that a young man met a soul mate, friends who had similar interests and mindset. It was in this environment that he could really be himself, spend time in the way they wanted. Some of these friendships continue today. One respondent mentioned that a current friend, whom he met in an institution specializing in organizing classes for children with outstanding mathematics, is very close to him, like a brother. To this day, he is amazed by such a similar way of thinking and perceiving reality.

### ***Random events and cases***

The winners of the Olympics talked about random situations such as: the possibility of correcting the teacher's error - here the teacher's reaction was crucial - if he did not condemn the student for it - he revived his greater interest in the subject. It happened that a first grade student mistakenly solved the test intended for junior high school students with a fantastic result.

### ***Foreign trips and scholarships***

Scholarships for talented students, trips abroad as a part of international competitions or exchanges and trips abroad to study are all events which resulted in expanding mathematical skills, and helped to develop scientific horizons.

### ***The beauty of math***

The vast majority of respondents indicated the beauty of a mathematical proof as a motivating force for further work. The power of aesthetics was unmatched, the respondent all the time wanted to experience an elegantly solved task to feel the beauty. All the respondents emphasized that the tasks of the Mathematics Olympiad are of a different nature than the problems solved during their studies.

The respondents stated that the issue of regular exercises, i.e. solving a large number of tasks preparing for the Olympics, is of great importance. The tasks solved during the studies are of a completely different nature. Olympic math does not equal scientific math.

### ***Others***

Some laureates mentioned: maths summer schools, trips to maths camps, playing chess, internet forums where you could exchange ideas for solving a task, as well as make interesting friendships.

### **Conclusion**

Research conducted on Polish laureates of the international mathematics Olympiad, showed the existence of crystallizing experiences in the lives of gifted people. In line with the assumptions of Walter's and Gardner's theory (1984) and the results of my research (Wenderlich-Pintal, 2019), these experiences occur throughout the course of their lives. During the research conducted on a group of Polish laureates of the Mathematical Olympiad, eight categories were found in which these crystallizing experiences were manifested.

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