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Challenges of Teaching and Learning about Science. A Case Study of Exploring the High Potential of Young Gifted Children from Primary School

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Abstract

In this paper, we describe an exploratory approach to the high potential of primary school gifted children learning science. Several sets of tools were applied, in three stages, to identify children with high potential in the Science field by evaluating their cognitive abilities across five fields: adaptability, complex communication/social skills, non-routine problem-solving skills, self-management/self-development, and systems thinking. Then, we described how primary school teachers and science educators can create educational contexts that may foster the emergence and development of gifted children's potential for learning science. Conclusions were focused on research-based recommendations for science educators, parents, schools and authorities.

Key words: Abilities; gifted children; learning; Science; teaching

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1. Theoretical premises

In the early 21st century, teachers are facing complex issues in the field of science education. The state of science education today reflects the fact that the need for scientific advances is at its peak, teachers and children face critical scientific challenges, like initial training and continuing professional development of science teachers including assessment standards and competency development for standardized examinations of children in the field of science; availability of appropriate textbooks and classroom resources; increased use of the Internet as a source of information. Improving science education requires coordinating a complex set of cognitive, affective, and motivational strategies and skills with our understanding of how children acquire and process scientific knowledge, how they develop their aptitude potential for the field of science, how to overcome misconceptions by familiarizing children with the language of scientists, as well as the cognitive and applied reasoning strategies of scientists, and validated sources of scientific information.

The teaching process must be adapted to address the unique challenges that gifted children face in science, primarily by understanding their behavior and accepting and developing their abilities. If the teaching methods do not correspond to the particular needs and interests of the students, they will not be able to develop their potential (Renzulli, Siegle, Reis, Gavin, Sytsma, 2009). Hoover and Feldhusen (1990) argued that the formulation of reasonable hypotheses is a fundamental feature of talent in the Sciences. Gifted science students demonstrate higher scientific reasoning skills and interest in the sciences field (Shim, Kim, 2003; Van Tassel-Baska, 2005) and are able to transfer knowledge to new situations they encounter, with intuition playing an important role in the process of learning Science concepts (Gilbert, Newberry, 2007; Ngoi, Vondracek, 2004).

Heller (1993) defined scientific talent as a potential for scientific thinking or a special talent for excellence in the natural sciences. In accordance with this definition, Innamorato (1998) highlights the specific characteristics of the student with potential in the field of science, defining scientific talent as the demonstration of creativity, problem-solving skills and data. According to Taber (2007), during the process of identifying children with potential in science, we must first understand that they are capable of achieving high levels of performance in all or nearly all aspects of the Common Core science curriculum and, if given enough support, they may be able to make great progress beyond school requirements and then determine their ability to learn from challenging science instruction, not just high-test scores. Therefore, as teachers, we should be able to identify curiosity, leadership, high cognitive skills, and metacognitive maturity as potential factors of excellence in the Sciences.

The learning and teaching process of gifted children should be closely examined with suitable approaches. A study conducted by Cross and Coleman (1992) involving gifted high school students found that the major problem with science instruction is the slow teaching process and course content. One of the problems could be the assessment and methods of displaying the information used. Tal and Miedikensky (2005) found that embedded types of assessment contribute to the learning process of these students and bring a positive influence in the process of acquiring knowledge.

The purpose of this investigative approach was to identify young school children with high potential in Science, by means of a set of specific tools. The objectives aimed to identify schoolchildren with high potential in Science and analyze some tools applied to teachers of high-potential schoolchildren in the field of Science.

2. Research methodology

2.1. Participants

The sample of the investigative approach was carried out on 18 students aged 8 (in 2018) and 9 years old (in 2019), of which 9 were girls and 9 were boys. We mention the fact that the participating students were studying the subjects of the National Curriculum, from the Common Core, as well as part of the subjects of the Cambridge Curriculum. Among the latter, we were interested in Science and Mathematics, because to achieve the research objectives, the teachers who teach these two subjects to the participating children also participated. We underline the fact that the subjects Mathematics and Science are differentiated by the language of study, namely Romanian and English respectively, but also by content. Thus, the tools applied to the teachers were completed by the Science teacher, the Mathematics teacher and the teacher of Mathematics and environmental exploration in the 2nd grade, and of Mathematics and Natural Sciences in the 3rd grade for each of the 18 participating students. In the last part of the research, the parents of the children identified with high potential in science were also involved by answering the interview questions.

2.2. Instruments

The "Standard Progressive Matrices" test, set A, B, C, D and E, developed in 1938 by J.C. Raven (1941) in collaboration with L.S. Penrose, revised in 1947 and 1956, is a homogeneous test of general intelligence that includes 60 items or elementary tests. Each item consists of an abstract drawing, often of a grouping of figures ("matrix"), from which a part (an element) is missing. After examining the matrix, the subject must decide which is the single figure (out of the 6 or 8 offered on the same board below the matrix) suitable for the correct "end" of the matrix. M.P. Test(s), despite comprising only one type of tasks, can highlight, by the variety of its topics, the ability to restructure (mobility - mental rigidity) and transfer in connection with general intelligence, as the subject practices his solving technique during the tests.

The 'Mensa Puzzle' general intelligence tests are designed by Ken Russell and Philip Carter, the UK's leading publishers of Mensa puzzles and IQ tests. The tests are arranged in three sections - general section, industrial section and verbal section. The tests introduce a unique concept in the field of intelligence tests and are accessible to everyone, as the general section does not require knowledge of the language, overcoming any cultural and linguistic barriers. Of these, Test 3 from the general section was used. According to the authors' description, it tests native intelligence and consists of 20 schematic representations. Tested children had to choose the correct logical structures/sequences within 40 minutes. It is specified that any delay may invalidate the score.

List of characteristics for the identification of talent in Science - G.A.T.E (apud Jigău, 1994) includes a series of 18 statements-characteristics that children with potential in the mentioned field are asked to fulfil. For each item, the extent to which its presence or absence was observed is evaluated, marking with 1= rarely or never, 2= occasionally, 3= frequently, 4= almost always. This list was completed by the same teachers of Science and Mathematics and environmental exploration. The results were compared and the children with the best scores were selected for the next stages of the research.

Checklist-Behaviour of gifted children in science - primary grades is a checklist of behaviours proposed by Manubu Sumida in his study Identifying Twice-Exceptional Children and Three Gifted Styles in the Japanese Primary Science Classroom (2010). The list includes 60 items, divided into four dimensions, as follows: interest, motivation and attitude towards natural phenomena; scientific thinking; skills and expressiveness in observation and experiment; knowledge and understanding of natural phenomena. In the present study, the list was completed by the teachers of Science and Mathematics and environmental exploration, who recorded the frequency with which the behaviours specific to children with potential in the field of Science occured, for each student of the 18 participants (1, never observed ; 2, rarely observed; 3, sometimes observed; 4, frequently observed).

GEMS - The Nomination Sheet was designed by Andrea Cary Zirkelbach for the study "Identifying Gifted Students in Science" (2011), a study that is part of a complex research project - *Gifted Education in Math and Science*, led by Julia Roberts (2008). The list contains a series of seven dimensions about students' interest and engagement in the task. The items are focused on scientific knowledge, attitude during classes, curiosity, degree of confidence in acquired knowledge, problem-solving strategies, abandoning the task when encountering difficulties. This instrument was addressed to the teachers of Science, Math, Mathematics and environmental exploration; each teacher nominated 5 students who had demonstrated the characteristics mentioned in the questions.

The interview was a tool applied to parents of children identified as having potential in the Science field. It concerned four dimensions: the period in which they observed the children's interest in this field, the behaviours observed at home, the ways in which they encouraged and motivated the child in the development of certain skills, participation in certain activities, competitions.

The "Diet Cola" Test, according to the grid made by M. Fowler (1990), can measure a maximum score of 21 through the design of an experiment, their knowledge, use of terminology, interest in researching scientific phenomena, ability to establish relationships between observed phenomena and scientific concepts, interest in the collection, separation and classification of observations, scientific creativity. Children have to design an experiment to demonstrate whether bees are attracted to Diet Coke and express their ideas both through writing and drawing.

2.3. Procedure

The research was carried out during two school years, 2018-2020, in a private educational context, in which several sets of tools were applied in three stages. The first stage was a collective application to identify the general level of intelligence by applying two tests: "Standard Progressive Matrices" (J.C. Raven and L.S. Penrose) and "Mensa Puzzle" (Ph. Carter and K. Russel). The second stage was focused on nomination, in which the following four instruments were distributed to the teachers of Mathematics and environmental exploration, Science and Mathematics: GEMS - Nomination Sheet; G.A.T.E.- List of Characteristics for Identifying Talent for Science; M. Sumida - Checklist: Behaviour of gifted children in science, primary grades (M. Sumida) and interview with parents. In the third stage, specific tests were applied to students: the "Diet cola" test and the accomplishment of scientific projects in order to involve and participate in the "Nikola Tesla" Interactive Science Festival.

Accomplishment of scientific projects in order to involve and participate in the "Nikola Tesla" Interactive Science Festival

The "Nikola Tesla" Interactive Science Festival is held for a week, during which scientific activities are organized, from various visits to factories, museums, to the accomplishment of experiments, projects, models, presentations of great inventors, etc. The culminating moment of this week is represented by the "Experiment Tour" for which each class, from preparatory to high school, prepares a stand with experiments, models, projects based on physical, chemical, biological and mechanical principles. Each child participates, together with his colleagues, in the accomplishment and presentation of the collective projects. Children can also participate with individual projects. All this is presented to other schoolmates, teachers, guests and the jury. At the end of the day each class is awarded for its dominant. For the present study, only individually realized and proposed projects were considered.

3. Results

In the first stage, aimed at identifying the intelligence quotient of the schoolchildren participating in the study, no major and significant differences were identified in the results of the two applied tests. Analyzing student results obtained by applying the G.A.T.E. Science Talent Characteristic List, we identified similarities in teacher nominations. Thus, the highest scores show that the respective students possessed a series of characteristics that they frequently/always manifest within the three disciplines. Whereas in the case of extreme scores (lowest and highest), there were similarities in the teachers' nominations, inconsistencies appeared in the case of some students with average scores, where certain score differences could be observed for different subjects. For example, two students obtained scores of 45 and 47 respectively in Mathematics, indicating a potential in the Science field, but in the subjects studied in English, they did not obtain a positive score in this sense. Discussions with the teachers who teach English or other subjects of study in this language have enabled us to conclude that the foreign language could represent a demotivating factor for certain students. The fact that they cannot express themselves that well in English would represent a lower retention and involvement in these subjects.

Checklist - The Behavior of gifted children in science - for primary classes, according to M. Sumida (2010), was analyzed on the four dimensions it targets, namely: interest, motivation and attitude towards natural phenomena, scientific thinking, skills and expressiveness in observation and experiment, knowledge and understanding of natural phenomena. Comparing this tool with the previous one, the Science Gifted Behavior Checklist, we find that the highest scores are obtained by the same students. Also, in this case there are no significant differences between the teachers' nominations. Interesting to observe in the case of this instrument is the evolution of the scores, according to the four dimensions discussed. Here we can highlight differences from one discipline to another, on the perception that teachers have about students' interest and motivation, skills in observation and experiment, knowledge and understanding of natural phenomena, etc. For example, in the case of some students we can observe lower scores obtained for interest and motivation, but higher for knowledge and understanding of natural phenomena. Also, when comparing the scores obtained on the last two dimensions, namely skills and expressiveness in observation and experiment, knowledge and understanding of natural phenomena, we could see that, in all the three disciplines, higher scores were obtained on the last dimension compared to the first one mentioned above. Thus, participating students possess information, knowledge, retain the notions learned in science classes, build connections between various subjects, but render this knowledge more difficult in the practical part, when it comes to the experiment. We will verify this connection between theory and practice/experiment with the help of the "Diet cola" test, which we will discuss later.

The results of the application of the GEMS Nomination Sheet (number of nominations per item) show a similarity with the other tests previously applied, so that the same students who obtained the highest scores are nominated.

Based on the results of the five instruments used (intelligence tests and nomination lists), an interview aimed at four dimensions was elaborated and applied to the parents of students identified with high potential in science to correlate their perspective with the results obtained by means of the other instruments. Thus, the interviewed parents emphasized their perspective regarding the child's interest in science, talked about specific manifestations in this sense, the ways in which they encouraged and motivated the child to pursue science learning and about the scientific projects carried out by the child or his participation in various competitions. Analyzing the interviews, we found that not all parents noticed the children's concerns and interest in science, nor do they encourage them by carrying out different activities in this respect. It is gratifying that most parents encourage and motivate children by carrying out different activities, such as purchasing books with experiments and scientific information; carrying out experiments at home; provision of certain necessary materials; engaging in various household activities such as gardening; taking care of a pet; enrolling in certain courses that train and develop scientific skills.

We present the results obtained in stage III in which specific tests were applied to schoolchildren identified with high potential in the Science Field. The "Diet Cola" test was applied to the six children identified and confirmed in the previous stages with high potential in the Science Field, and the scores were calculated, according to the grid made by M. Fowler (1990). As mentioned before, the maximum score that can be obtained after taking the test is 21. The school students tested scored between 13 and 17. They designed an experiment to demonstrate whether bees are attracted to Diet Coke and chose to express their ideas through writing and drawing. Regarding the scoring grid, we analyzed the projects proposed by schoolchildren and could observe, through the design of the experiment, their knowledge, use of terminology, interest in researching scientific phenomena, ability to establish relationships between observed phenomena and scientific concepts, interest in collecting, separating, and classifying observations, scientific creativity.

Regarding the participation in the "Nikola Tesla" Science Festival, we noticed that those parents who had noticed their children's potential for science had encouraged the children to carry out individual projects/experiments. It is well known the important role of parents in supporting the child in a certain field, especially the scientific one. The child needs to be provided with different materials, to be supported and observed while handling the materials during experiments, guided in observing phenomena and making connections. The child's needs in this sense cannot not be met only by the school, during Math and Science classes, and his/her potential may diminish unless parents notice this interest and get involved. Concerning the results of the individual scientific projects, there were identified some limits related to the involvement and support of parents; some of the children did not have the necessary materials to carry out their projects or were demotivated by their parents' not being present at the festival.

Thus, in the second stage, 6 of the 18 students participating in the study were identified as having high potential in the Science field by the teachers who teach the specialized subjects, but also by some of the parents. Whereas the scores obtained by the students in the nomination reveal a similarity of the teachers' perspective on their potential, there were small differences in the perspective of some parents. As mentioned, only four of the six students were encouraged, supported, motivated by their parents to develop their scientific potential. Summarizing, we mention the fact that the student must be motivated, stimulated and his curiosity for one field or another must be maintained and encouraged. His education must not be an elitist one, but must be done through accumulation and acceleration activities through which his natural abilities are promoted and developed, both at school, by his teachers, and at home, by his parents, by increasing their responsibility for their learning process.

4. Conclusions and recommendations

By properly organizing the instructional-educational process, by resorting to strategies, programs and modern work methods through which the teacher can provide more extensive, in-depth information about the topics and problems provided in the curriculum of the discipline taught and by making appropriate use of extracurricular activities as well, the creative potential of children in the field of Sciences may be significantly increased. The problem that can arise in the case of using enrichment programs relates both to ensuring the balance between challenges and opportunities, and to preventing overload and overwork.

A particular attention should be given to how primary school teachers and science teachers can create an educational context that foster the emergence, the development and the promotion of children's potential for learning Sciences. Given the challenges of teaching and learning of children with high potential, some recommendations are needed for primary school teachers and science teachers.

The current state of science education reflects the fact that the need for scientific advances is at an all-time high, teachers and students face significant scientific challenges, including at the level of initial training and continuing professional development of science teachers, as well as at the level of assessment and development standards of students' science skills, availability of appropriate textbooks and classroom resources, and increased use of the Internet as a so-called "flipped classroom".

We recommend that the process of teaching high-ability students for the field of Science involves, in addition to the application of precise early identification tools and methods, differentiated didactic procedures and strategies, as well as teachers specialized in the field. It is absolutely necessary that the human resource involved have a very good specialized training in Science, as well as an initial and continuous training specific to the identification and development of high skills in the field. Understanding the fundamental conditions of cognition, motivation, and performance as they apply to high-ability students should not be neglected at all.

Gifted students should have their learning and teaching processes carefully reviewed using the appropriate methods. Special attention should be focused on the teaching style which should not be slow and on the course materials that should be challenging and not dry because these two are the main problems of science teaching. Also, the evaluation and methods of information display could be one of the issues regarding the process of information acquisition.

We recommend that the teacher should have high work standards, be able to motivate students both for independent study and to work in a team, to show skills in coordinating the educational programs developed for students with high ability for Sciences, respectively to create an atmosphere to stimulate scientific creativity and scientific skills. A complex combination of cognitive, emotive, and motivational tactics and abilities must be coordinated in order to improve scientific education.

According to our understanding of how children acquire and absorb scientific knowledge, learning the language of scientists, as well as the cognitive and practical science behind science, can help students overcome misconceptions and enhance their aptitude potential for sciences.

Last but not least, to provide a quality educational program in which there is maximum capacity for analysis, synthesis, evaluation and creation, everyone should know the psycho-behavioural profile of gifted students. The degree of familiarity of the teacher with the characteristics of the child with high ability profile generates support and assistance in the creation or implementation of comprehensive individual programs. Knowledge of students' characteristics, learning levels, and cognitive, social, and emotional needs will develop the ability to use identification and diagnostic data to design and implement differentiated and appropriate instructional and assessment programs/strategies for pupils with high ability in the field of sciences by carrying out activities that stimulate fluidity, flexibility, originality and the elaboration of ideas/solutions. One of the roles of the teacher in approaching and teaching gifted students in the field of Sciences is to provide additional support for amplification or deepening through documentation and information on scientific topics, using scientific experiment, scientific investigation or case study as basic methods in learning different scientific contents, through conferences of interest to students (on such topics as: mathematics, technology, physics, chemistry, biology, medicine, geography, astronomy, robotics, etc.).

By stimulating and developing the creative potential of young gifted students, there are wide possibilities of stimulating the child in the field of science by solving problems, innovations and technical inventions, artistic creations, economic management etc.

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