**Promoting creative thinking in schoolchildren with applied problems in mathematics**

**Abstract**

Introduction. The study of exact disciplines requires a high concentration of attention and searching for ingenious solutions. The ability to think creatively is key to achieving good performance in algebra and geometry. At the same time, the current education programs in mathematics are at that stage of development where they actively cover real-life tasks and scenarios. In this regard, the present study aims to investigate the effects of applied mathematical problems on the creative thinking ability of schoolchildren.

Materials and Methods. The creative thinking assessment procedure involved testing respondents before and after the applied problems in algebra and geometry using the Williams method. The study period covers the first semester of the 2021 school year. The study sample consists of 7th graders attending the same secondary school in one of the central cities in Israel. Overall, there were 94 students enrolled in three parallel classes.

Results. The analysis of research results provides evidence supporting the expected dependence. In the baseline tests, for instance, the majority of respondents exhibited an average level of potential for creativity (21, 17 and 18 children in grades 7A, 7B and 7C, respectively). Meantime, respondents with high and low levels of creative thinking made up smaller groups. The subsequent exposure to applied mathematical problems for everyday situations took place systematically throughout the course. Using the problem mentioned in the novel by Jules Verne, the study found a tendency to find easier solutions or abandon the problem among children. The second creativity test demonstrated an improvement in the creative thinking ability among respondents.

Discussion and Conclusions. Particularly, the majority of children had better creativity skills and higher levels of creative thinking (54, 50 and 52% in grades 7A, 7B and 7C, respectively). The present findings may help improve the education process in exact sciences (such as mathematics) to enhance the role of creative thinking in schoolchildren’s further life.

**Keywords:** mathematics, creative thinking, applied problems, divergent thinking, ingenious solution.

**Introduction**

The conditions of today's globalizing world require individuals to make important decisions quickly and to approach a problem in an unconventional way. The rapid development of scientific and technological progress constitutes a radical challenge for society and involves creative thinking about every aspect of socio-economic activity, among both individual actors and complex systems [1]. As a result, the format of creative thinking is a rather important determinant of a person's success in their professional and personal lives [2]. Martin [3] explored creative thinking as the main basis for visualizing information. According to his theory, the learning process in any field should include project-based forms of information assimilation, which would express the primary need for each student's creativity. Since the creative thinking model is a fairly new trend in education, the effectiveness of academic research is currently limited. In doing so, the concept of educational reform based on learning, taxonomy, analysis, evaluation and creativity has a particular impact on higher-level thinking skills.

Creative intelligence is an essential cognitive function of life, responsible for the ability to generate new ideas and concepts. This format of looking at world challenges allows for divergent thinking and the formation of new links between existing and hypothetical concepts [4]. It should also be noted that creative thinking is an immediate human companion and is intended to be used for artistic, informational, technical and, indeed, educational purposes. The latter aspect probably has its roots in early childhood and flourishes most actively precisely during the most aggressive phase of acquiring knowledge - schooling [5]. The student's academic activities during school life constitute a complex of continuous learning of increasingly new natural processes and phenomena [5]. It remains important to be able to apply a creative approach to the theoretical foundations of any academic discipline, allowing for the independence and unified opinion of a future specialist to be nurtured from an adolescent age. In addition, Abraham [6] stated that creative thinking is a form of self-expression in a unique way that somehow allows us to push the boundaries of not only the humanities but also exact subjects of study. Consequently, mathematics is the fundamental basis for the construction of logical relationships, as well as the primary source of any technical direction of future information improvements.

The curricula of many of the world's leading countries indicate the vector of creative thinking abilities that are needed to master and create technology in the future. And teaching any generation of schoolchildren is not without the inclusion of basic mathematical skills [7]. Noting this relationship, it should be emphasized that creative thinking as a mix of higher-order intellectual abilities acts as an ability to use available knowledge and experience to think critically and creatively in order to solve everyday problems, which in students are mostly related to disciplinary performance [8, 9]. In learning mathematics, however, creative thinking plays a key role in enhancing learning through problem-solving involving initiatives to develop, implement and lead to new ideas for solving a problem [10]. The world's theoretical experience of academics demonstrates a significant interrelation of these concepts. Representatives from different generations have reported positive reactions to the use of practical tasks as a stimulant for divergent thinking in individuals. For example, De Bono [11] and Sternberg & Lubart [12] observed that individuals who practice mathematical tasks in everyday life move flexibly from one aspect to another, rather than simply following existing paths. Any technical assignment, meanwhile, requires the ability to think associatively, using different perspectives of out-of-the-box thinking to create new ideas to solve the problem at hand. Consequently, creative thinking contributes not only to a high level of academic achievement in mathematics, but is also a factor in the student's intrinsic and extrinsic motivation to learn this discipline. A more creative view of the problem posed by a particular task allows the schoolchildren to expand the range of tools for solving it, using not only the theoretical basis in mathematics, but also the requirements of applying it in practical applications in everyday life. In touching upon this aspect of judgment, attention should be paid to the function of mathematics as its visualization, accompanied by the daily construction of an algorithm for strategic solutions to this or that problem in the course of human life. In this aspect of the issue, mathematical tasks with applications that affect a diverse list of social activities are essential to the learning process in the school curriculum. According to world practice, artists and scientists have tried since antiquity to develop problems that really demonstrate the importance and practicality of the discipline of mathematics.

It should be noted, however, that these tasks usually involved a somewhat more complex solution algorithm, as they required the individual to have an original approach to interpreting them, to understand the construction of natural objects and phenomena, and to apply the acquired knowledge to solve the current problem. As such, a person aiming to master problems of a practical nature must not only successfully master the theoretical concepts of mathematics, but also combine analytics with the generation of alternative hypotheses. All of the above encompasses the key attributes of creative thinking, which has the content of being an integral part of shaping an effective learning process in mathematics subjects. One of the countries actively shaping the national education system because of the importance of the mathematical and creative abilities of future generations is Israel. One of the stages in the mastery of creative thinking in practical mathematics is the ability to solve non-standard, creative and exploratory problems [14]. This point should be reinforced by philosopher D. Santayana: “Just as all the arts gravitate towards music, all the sciences gravitate towards mathematics.” In the course of this study, the aim is to diagnose the impact of the application of practical tasks in a mathematics course on the development of creative thinking among 7th-grade secondary school students in a central Israeli city. The following objectives were highlighted in the study:

1. To analyze the readiness of grade 7 schoolchildren to solve applied problems in algebra and geometry.

2. To identify the level of development of creativity in respondents before and after the active introduction of applied tasks in the course of mathematical disciplines.

3. To investigate the impact of learning applied mathematics problems on the development of creative thinking.

**Materials and methods**

The study involved 94 7th graders at a high school in a central town in Israel. The study took place during the 1st semester of 2021. As the methodology of further testing subordinated the condition of conducting it in groups of no more than 35 people, the research took place within each of the classes. The first grade (7-1) had 32 children, of whom 11 were boys and 21 were girls, respectively (mean age = 13.4 years, SD = 5; range 12.9 - 14.2 years). The second class (7-2) contained 30 children, whose gender structure was 16 boys and 14 girls (mean age = 13.8 years, SD = 9; range 13.1 - 14 years). And also, the third grade (7-3) among the parallels of the 7th grades of the studied school had 33 children, where 16 boys and 17 girls (mean age = 13.4 years, SD = 7; range 13 - 14.2 years). It should be noted, however, that the conduct of this study was discussed at a parents’ meeting in each class. According to the results, no parents put forward a ban on the current study. All respondents were in classes without a mathematics major and were in full-time education. The study was conducted as a step-by-step analysis of the children's level of creative thinking before and after the active introduction of practical mathematics tasks into their curriculum. According to the current timetable of all 7th graders, students attended 3 algebra lessons and 2 geometry lessons every week. In doing so, teachers promoted the use of applied tasks in these subjects in every lesson. Consequently, the applied problem solving analyzed in the current study was applied in 1 lesson of algebra and geometry every week in all 7th grades. During the study, teachers were provided with a substantial list of literature, which contained examples of tasks of varying nature and complexity. Teachers who teach all 7th-grade respondents selected 2 collections (one of algebra and one of geometry), which constituted the source of applied tasks to be used in the classroom [15,16]. The teachers had to use at least one task from the application list in the selected lesson that dealt with the topic of the lesson. From time to time (particularly once every 2 weeks) teachers would assign one of these application tasks, both in algebra and geometry, as homework. Each of the problems was submitted to schoolchildren and teachers for parsing, contained illustrative drawings and was solved to the end. As an aspect of assessment, teachers have rather superficially considered the fragment of applied problem-solving in both classroom and extracurricular activities. However, the schoolchildren's performance may have been improved because they were active in solving research problems. It should also be noted that to make the diagnosis clear, the schoolchildren’s reactions to one of the tasks used were analyzed in more detail during the study. This highlights a more general tendency for actions to be inclined towards this kind of mathematical task.

The study analyzed the results of the level of creative thinking before and after the introduction of applied tasks in algebra and geometry for 7th grades into the curriculum. For this purpose, one of the components of Williams’ battery of tests was used, namely the diagnosis of creative (divergent) thinking [17]. Under the terms of the methodology, respondents are required to graphically complete each of the proposed drawings. An analysis of the resulting interpretations generates an assessment of personal creative thinking using 5 criteria: fluency (F), flexibility (L), originality (O), elaborateness (E) and name (N). Each of these components is designed to assess a child's ability to think creatively by constructing analogies and diversity of the individual with the drawings submitted in the test. For the first 2 subtests, the respondent receives 1 point for each composition added, and the subsequent 3 parts are scored from 0 to 3 points, depending on the degree of brightness of the category. Consequently, a study of creative thinking according to Williams can be carried out either separately for some subtests or comprehensively by summing up all scores. In the test, a respondent can score a maximum of 131 points. It is also worth noting that during the analysis of each of the survey segments, respondents' results can be rated according to both the level of standard deviation of the obtained indicator and according to the scale of intensity of manifestation of the level of divergent thinking. In this study, the authors systematized the raw scores obtained for each of the deviation points and analyzed them according to the level of creative inclination (low, medium and high) [17].

**Results**

At the beginning of the school year, students in grades 7-1, 7-2 and 7-3 were tested to determine their level of creative thinking. It should be noted that all respondents complied with the conditions for implementing a fair methodology, which at this stage retains the originality of the first-past-the-post sample. When analyzing the results of the Williams methodology, a more qualitative approach was adopted for each of the classes, so the description itself was used according to the degree of creative thinking (high, medium and low) (Figure 1).

**Fig. 1** *Number of respondents by level of creative thinking, by group (according to the Williams methodology), (before implementation of applied tasks)*

Consequently, the diagnosis of the results obtained for all classes demonstrates the most capacious category of respondents with an average level of creative thinking. The performance of 7th graders in the Williams Limit method differs several times from the average level of divergent thinking. This trend is uniform across all classes studied. Students from 7-3 – 13 children with a high level of this aspect of thinking are more creative. It should also be noted that respondents in this class have at the same time the lowest scores among low levels of divergent thinking – only 2 out of 33 people. Consequently, 7-2 stands out with the lowest but most capacious number of children with low levels of creative intelligence (5, while 7-1 has 4). The same trend of no significant difference is present in the number of children with high levels of divergent thinking among students in grades 7-1 and 7-2 respectively. (Fig. 1) On the basis of the data obtained, it can be stated that there is a satisfactory but not very high level of development of creative thinking among the children surveyed.

The next stage in the implementation of the study was the active introduction of application tasks into the schoolchildren’s learning process. It should be noted that the large number of tasks of different levels of complexity implies a correspondingly large range of responses to them. As a result, the initial academic perception of one of the tasks was analyzed. The success diagnosis of the task concerned task 30, which had an interactive and literary display,

i.e. should be of interest for examination [15]. The content of the task concerned measuring temperature on two different scales (Celsius and Fahrenheit). In doing so, the manual provides 2 ways of solving the problem correctly, which was the main purpose of the analysis of this problem (Figure 2).

**Fig. 2** *Success in solving an applied algebra problem (from a novel by Jules Verne), among 7th graders (problem 30)* [15]

The first method proposed to solve this problem from Jules Verne's novel Children of Captain Grant involves creating correspondences between the known Celsius and Fahrenheit temperature determinants (boiling and melting ice) [15]. Whereas the other method was carried out by using dependency functions, is considerably difficult for 7th-grade students to solve. Therefore, when solving this problem under independent work conditions without the teacher's prompting, most of the children used method 1 proper. However, only one schoolchild in grades 7-2 was able to do the second method, which was a ratio of only 3%. It should also be noted that a large number of children could not solve the problem at all. Consequently, more than half in all grades fall into this category (most in grades 7-1 - 61%). This demonstrates a general moral and intellectual unwillingness to learn applied tasks on their own. In doing so, some of the children suggested their own way of solving the problem. It should be noted that, of course, the author's solution was mostly of a non-mathematical nature (e.g. using the temperature conversion table online), but this demonstrates an unconventional approach to solving problems and, as a consequence, the development of creative thinking. A separate assessment of the results of this analysis from the perspective of grades 7-3, where positive results appear only in variations of mode 1 and the missing response, is necessary (Fig. 2).

As was already evident in the study, creative thinking plays a prominent role in academic performance and perception of applied mathematical tasks in general. In support of this, it is worth commenting on the results of a similar study using the Williams method of determining the level of creative thinking.

**Fig. 3** *Number of respondents by the level of creative thinking, by group (according to the Williams methodology), (after implementation of applied tasks)*

Accordingly, at the end of the first semester of the 2021 school year, schoolchildren of the same composition were tested and retained the original study sample of 3 classes (94 schoolchildren). Consequently, as can be seen immediately in Fig. 3, the category of children with a high level of creative thinking proved to be the most capacious. Thus, 18 out of 32 children in grades 7-1 have a high level of creative intelligence. Somewhat less, but equally weighty against the overall results for the other categories are the data for grades 7-2 and 7-3. There has been a significant decrease in the average creative thinking scores for all children's classes, which is a fairly positive trend. It should also be noted that the lowest scores, as in the first diagnosis (before the introduction of applied tasks), are those of students with low levels of divergent thinking (2, 5 and 4 students in grades 7-1, 7-2 and 7-3 respectively). Thus, in grades 7-1, the number of students with a low level of creative thinking decreased from 4 to 2. At the same time, the number of children with unsatisfactory creative tendencies remained at 5 respondents in grades 7-2, even after the introduction of applied tasks into the mathematics course. On the other hand, the number of children with a low level of creative thinking in grades 7-3, on the contrary, increased - before the introduction of applied tasks there were 2 respondents, whereas after the introduction there were 4.

The final is a comparison of the results obtained before and after the introduction of applied tasks into grade 7 grade algebra and geometry course of a secondary school in a central Israeli city. The results from the study show an overall upward trend in the children's level of creative thinking. At the same time, the cumulative capacity of the medium and low-level groups steadily decreased, indicating a significant contribution of practical tasks from this exact science to the development of divergent thinking in schoolchildren.

The results show a strong correlation between the use of practical tasks in the learning process and their stimulation of creative thinking. Consequently, learning mathematics should be designed to potentially develop students’ creative thinking skills. Researchers at the University of Paris, for example, investigated the impact not only of the academic component of mathematics learning on divergent thinking, but also the component of successful learning through students’ creativity. [18] For example, the study suggested that teachers should expand the range of creative upgrades in mathematics lessons to increase respondents’ motivation to learn the discipline effectively. The experiment diagnosed an increase in enthusiasm and an unconventional approach to solving mathematical problems due to the democratic environment of the child’s interaction with the teacher. A directly related one in the context of using applications in mathematics is a diagnostic based at the University of Melbourne, Australia. According to this, it is quite effective to apply STEM technology in the learning process [19] In turn, this implies the easiest possible coverage and acquisition of knowledge based on practice and in-depth understanding of processes in one way or another related to mathematical problems with practical applications. As a result of the experiment, implementing this approach creates an atmosphere of enthusiasm that engages students in mathematics; increasing their motivation to learn, create and innovate.

**Conclusions**

The current study demonstrates the effective impact of the active implementation of tasks with applied content in exact sciences (algebra and geometry) and constitutes an effective stimulant for the development of creative thinking in schoolchildren. At the beginning of the study, the general trend of children from all 7th grades to a predominantly average level of creative thinking persisted. In grades 7-2, for example, 17 out of 30 schoolchildren (around 57%) were characterized by mediocre levels of unconventional thinking, which constitutes the lowest capacity in this group of all classes. There was an introduction to the disciplines of algebra and geometry of applied problems. In the course of the study, one of the problems (in particular, the problem from the novel Children of Captain Grant) was examined in detail for its solution. The vast majority of children in all classes either preferred 1 way of solving the problem (which was the easiest) or did not solve it at all. The results of grades 7-3 were the most revealing, with a ratio of 52% to 48% of children belonging to the categories described above. Finally, after the practical modernization of the learning process, a re-diagnostics of the respondents’ creative thinking (using the same Williams methodology) shows a positive shift in most results towards a high level of divergent intelligence. More than half of the schoolchildren who showed an average level at the beginning of the study now operate with a high level of creativity (54%, 50%, 52% for grades 7-1, 7-2, 7-3, respectively). It should also be noted that this research has a place in further improvements of the teaching process in the exact sciences (mathematics in particular) in order to strengthen the role of creative thinking and its application in the future life of schoolchildren.

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