DISCRETE MATHEMATICS IN SECONDARY SCHOOL MATH EDUCATIONAL SYSTEM

DISKRÉTNA MATEMATIKA V SYSTÉME VZDELÁVANIA MATEMATIKY NA STREDNÝCH ŠKOLÁCH

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Abstract

The article deals with an overview of current possibilities of integrating a discrete mathematics (combinatorics and graph theory) into secondary school math educational system in Slovakia and foreign countries. The contribution also presents results of two analyses: an analysis of secondary school math curriculum and an analysis of math textbooks, which are for both eight and four year grammar schools, regarding discrete mathematics.

Článok sa zaoberá prehľadom súčasných možností integrácie diskrétnej matematiky (kombinatoriky a teórie grafov) do systému vzdelávania matematiky na stredných školách na Slovensku a v zahraničí. V príspevku sú tiež uvedené výsledky dvoch analýz, analýzy učebných osnov matematiky na stredných školách a analýzy učebníc matematiky pre osemročné a štvorročné gymnáziá, vzhľadom na diskrétnu matematiku.

Key words

discrete mathematics, combinatorics, graph theory, secondary schools

diskrétna matematika, kombinatorika, teória grafov, stredné školy

Introduction

The contribution`s goal is to present an overview of current possibilities of integrating discrete mathematics (combinatorics and graph theory) into Slovak and foreign secondary school math education. Results of two analyses, analysis of secondary school math curriculum and analysis of grammar school math textbooks regarding the discrete mathematics, are described in this article.

Discrete mathematics in secondary schools

Opinions of foreign authors for discrete mathematics in secondary schools

The conference called “Discrete Mathematics in the Schools: How Do We Make an Impact?“ took place at Rutgers University in 1992. It brought thirty-four educators who had been involved in a variety of ways in introducing discrete mathematics in the schools. The program of conference was designed to inform the participants about various perspectives of discrete mathematics and its function in K-12 (Kindergarten through grade twelve) education. J. G. Rosenstein [7] answers some questions in connection with discrete mathematics:

- What is discrete mathematics?

Discrete mathematics deals with arrangements of discrete objects. It includes variety of topics and techniques that arise in everyday life, for example how to find the best route from one city to another (the objects are cities arranged on a map), how to count the number of different combinations of toppings for pizzas, how best to schedule a list of tasks to be done, and how computers store and retrieve arrangements of information on a screen. Discrete mathematics is used in health service, transportation, and telecommunications. Its various applications help students see the relevance of mathematics in the real life.

- Why introduce discrete mathematics into the curriculum?

Because it`s:
Applicable - Recently discrete mathematics has become a valuable tool and provides powerful models in a number of various fields.
Accessible - In order to understand many of these applications, arithmetic and elementary algebra are sufficient.
Attractive - Many challenging problems can interest and attract students, and lend themselves to research.
Appropriate - Both for students who are accustomed to success and are contemplating scientific careers, and for students who aren`t accustomed to success and need a new start in mathematics.

- Discrete mathematics is a new start for students.

The most frequently prescribed remedy for students who have failed in school mathematics appears to be more of the same. It means repetition of content and method. Thus, many students come to see mathematics only as a set of unintelligible procedures, which is not surprising since they were never given an opportunity to explore concepts meaningfully and apply them in new situations. For the student who has been unsuccessful in mathematics, discrete mathematics offers a new start - the possibility of success. Students who have met with mathematics which they can do successfully are promoted to take other look at the mathematics at which they have failed.
For the talented student who has lost interest in mathematics, discrete mathematics offers the possibility of challenge, for example open-ended problems which quickly lead to the frontiers of knowledge, and provides access to applications in a real-life situations.

- Discrete mathematics is a vehicle for improving mathematics education.

Discrete mathematics offers “time“ for experimentation with computers, group learning, problem solving, discovery learning and cooperative learning. When the problems are new to the teachers the students accept the situation positively and are open to discussing, reasoning together, and to the excitement of discovering new solutions which aren`t “in the book“. With discrete mathematics students can see themselves as “mathematicians“ rather than as followers of routine instructions.

Rosenstein, J. G. - Caldwell, J. H. - Crown, W. D. are the authors of 688-page document called “The New Jersey Mathematics Curriculum Framework“ (NJMCF). It was developed to provide information and assistance to teachers and curriculum developers in implementing the mathematics standards adopted by the New Jersey State Board of Education in 1996 (see [8]). These standards describe what every student needs to understand and be able to do at the completion of the 4th, 8th, and 12th grade.

J. G. Rosenstein [9] describes chapter 14 of the NJMCF - Discrete Mathematics: according to him all students will apply the methods and concepts of discrete mathematics to model and explore many practical situations. There are cumulative progress indicators:

By the end of Grade 8 (building upon knowledge gained in the preceding grades) students:

- Use systematic listing, counting, and reasoning in a variety of contexts.
- Recognize universal discrete mathematical models, explore their properties, and design them for specific situations.
- Experiment with recursive and iterative processes through the use of computers and calculators.
- Explore methods for storing, processing, and communicating information.
- Devise, describe, and test algorithms for solving optimization and search problems.

By the end of Grade 12 (building upon skills gained in the preceding grades) students:

- Understand the basic principles of mathematical induction, iteration, and recursion.
- Use basic principles to solve algorithmic and combinatorial problems.
- Use discrete models to represent and solve problems.
- Analyze iterative processes through the use of computers and calculators.
- Apply discrete methods to storing, processing, and communicating information.
- Apply discrete methods to problems of voting, apportionment, and allocations, and use basic strategies of optimization to solve problems.

Students should learn to recognize examples of discrete mathematics in familiar settings. They should also explore and solve many problems for which discrete techniques have proved useful. Five themes of discrete mathematics should be addressed at K-12 grade levels:

- Systematic listing, counting, and reasoning - determining the number of possible orderings of an arbitrary number of objects and describing procedures for listing and counting these orderings.
- Discrete mathematical modeling using graphs (networks) and trees - using efficient methods to organize the performance of individual tasks in a larger project using directed graphs.
- Iterative (repetitive) patterns and processes - understanding how many processes describing the change of biological, physical, and economic systems modeled by simple equations applied repetitively, and using these models to predict the long-term behavior of these systems.
- Organizing and processing information - understanding the application of discrete methods to problems of information processing and computing (sorting, codes, error correction).
- Following and devising lists of instructions (algorithms) and using them to find the best solution to real-world problems – understanding basic strategies of optimization, using flow charts to describe algorithms, and recognizing both the power and limitations of computers in solving algorithmic problems.

Three teachers Crisler, N. – Fisher, P. – Froelich, G. [10] wrote a book called “Discrete Mathematics Through Applications“ in 1994. This book helps secondary school teachers put the NTCM`s discrete mathematics standards to work in the classroom. These authors helped to create the new curriculum, and conducted discrete mathematic teaching workshops over the country. The book includes the following chapters: Election Theory, Fair Division, Matrix Operations and Applications, Graphs and Applications, Recursion.

Opinions of Slovak authors for discrete mathematics in secondary schools

As soon as in the 80ies of last century S. V. Jablonskij [1] affirmed that discrete mathematics is an important part of mathematic education. Many authors, for example J. Bosák [2], Š. Znám [3], F. P. Preparata - R. T. Yeh [4], presented applications of combinatorics or graph theory in various fields of science and real situations.
P. Tóth [5] engaged in the research on integrating graph theory into elementary school mathematics in 2002. He elaborated proposals for integrating topics of graph theory into mathematic curriculum in the second level of primary schools.
I. Scholtzová [6] wrote her dissertation thesis dealing with integrating discrete mathematics into school mathematics in 2003. She elaborated proposals for integrating task groups of combinatorics and graph theory to each single mathematic topics in primary schools.

Conclusion

From mentioned facts results that discrete mathematics has a substantial position in math educational system in secondary schools. Therefore, it is meaningful to pay attention to the possibilities of integrating discrete mathematics (combinatorics and graph theory) into secondary school mathematics.

Analyses of math curriculum and textbooks

Analysis of secondary school math curriculum

There is a list of secondary schools with math curriculum that was analyzed regarding discrete mathematics (combinatorics and graph theory):

- Eight year grammar schools - Combinatorics in obligatory subject Mathematics; Graph theory in elective subjects Seminar of mathematics and Practice in mathematics
- Four year grammar schools – Combinatorics I, II in obligatory subject Mathematics; Graph theory in elective subjects Seminar of mathematics and Practice in mathematics
- Vocational schools - Combinatorics in obligatory subject Mathematics; Graph theory in elective subject Practice in mathematics
- Secondary apprentice schools

The results of this analysis:
Grammar schools have more math (specifically combinatory) lessons than vocational schools and secondary apprentice schools. Due to this fact, I focused on eight and four year grammar schools.

Analysis of grammar school math textbooks

There is a list of math textbooks for both eight and four year grammar schools that were analyzed regarding discrete mathematics (combinatorics and graph theory):

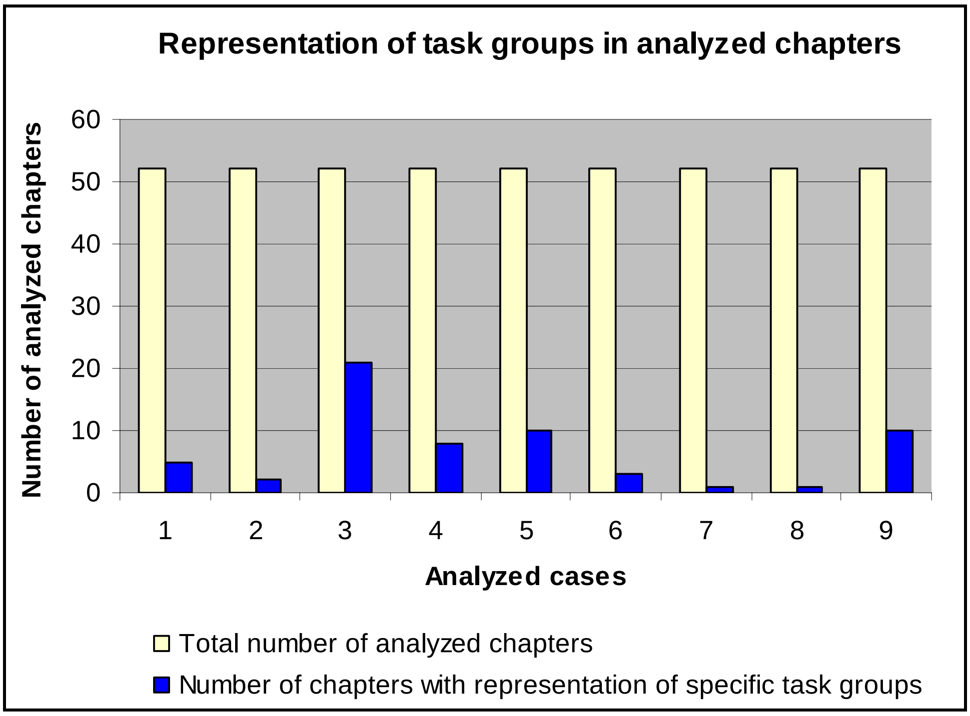
- Mathematics for the 5th – 9th grade of primary schools (the 1st and 2nd part) – textbooks by Šedivý et al,
- Mathematics for the 1st – 4th grade of grammar school and Collection of Math Tasks for the 1st – 4th grade of grammar school – an older textbooks issued by the Slovak pedagogical publisher,
- Mathematics for the 1st – 4th grade of grammar schools and secondary apprentice schools (exercise book 1 – 5) – a later textbooks edited by Orbis Pictus Istropolitana.

In pursuance of discrete math tasks in topics (except for combinatorics and graph theory) I concentrated on the chapters with problems and graphs characteristic for discrete mathematics.

The results of this analysis:
Discrete math tasks are not very different from each other. It is possible to make the following nine groups from the tasks.

1. Creating numbers,
2. Supplementation magic square,
3. Determination of geometrical shapes (abscissae, straight lines, planes, angles) from net or image,
4. Sorting (sorting of angles, plane shapes, powers),
5. Ordering (ordering of angles, broken numbers, numbers, powers),
6. Denotation of path,
7. Make a payment by cash,
8. Colouring walls of polyhedrons,
9. Probability tasks solved by using knowledge of combinatorics.

Next graph represents analyzed cases of representation of task groups in chapters.



As we can see from the graph above, the most of the tasks are related to the determination of geometrical shapes. These tasks consist of 40% of total number of analyzed chapters. The rest of the tasks are below the border of 20%. Therefore, there is a rare frequency of discrete math tasks in grammar school math textbooks except topics of combinatorics and graph theory.

Conclusion

Presented approaches are the base for author`s PhD. thesis called “Discrete mathematics in grammar school math education”. Pedagogical research deals with integrating the tasks of discrete mathematics (combinatorics and graph theory) into grammar school mathematics. It is carried out at the Faculty of Natural Sciences at Constantine the Philosopher University in Nitra. This research follows the dissertation thesis by I. Scholtzová [6].

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