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# Algorithms in mathematics education

Janka Medová<sup>1</sup>

<sup>1</sup>Constantine the Philosopher University in Nitra, Faculty of Natural Sciences and Informatics,  
Department of Mathematics, Nitra, Slovakia; [jmedova@ukf.sk](mailto:jmedova@ukf.sk)

*This paper summarizes my contribution to the plenary panel discussion Big Questions in Mathematics Education and focuses on the role of algorithms in mathematics education. Mathematics and computer science are interrelated from their substance. They share several common concepts including the algorithms, but the way they work with them differ among the two disciplines. Algorithms provide an additional dimension to mathematical knowledge, the deep procedural knowledge. Involvement of coding and work with algorithms in mathematics instruction seems to be a promising activity bridging the two disciplinary approaches. The questions: (i) how the work with algorithms contributes to students' learning and (ii) how to prepare teachers for this kind of activities should be investigated.*

*Keywords: Algorithms; mathematics education.*

Mathematics and computer science are interrelated since the inchoative stages. Various fields of mathematics, including Boolean algebra, algebraic structures, discrete mathematics and probability provided the theoretical base for the emerging field of computer science. Some years later, in 1976, computer science started to pay off its debt by solving the problem of four colors using the thousands of hours of computing time (Appel and Haken, 1978). The nature of mathematics and natural sciences as they are practiced in the professional world is developing towards computational thinking (Weintrop et al., 2016). Nowadays mathematicians perceive computing as an inherent part of doing mathematics (Lockwood et al., 2019). The use of computers allows processing the calculations in mathematical statistics, even the work with big data.

Algorithms lie on the border between mathematics and computer science. Each discipline looks at algorithms from a different point of view. Computer scientists (e.g., Wirth, 1985) define algorithms as finite, general, deterministic, resultative and elementary which has only limited use in mathematical proofs. Mathematicians investigate the existence and correctness of algorithms, whereas computer scientists look at the algorithms in a more utilitarian way, looking for the real-time instantiations, preferring obtaining the result to its preciseness. Therefore, heuristics were developed for solving problems with high complexity.

Algorithms occur in curricula of both mathematics and computer science. Algorithms for basic mathematical operations were the traditional part of mathematics education. In recent years the algorithms have started to disappear from mathematics curricula as conceptual understanding was in main focus of mathematics educators and procedures were often perceived as the 'rote learning'. On the other hand, Star (2007) sees the particular value in the procedural knowledge itself. Star foregrounds the deep procedural knowledge where the procedure is "known deeply, flexibly, and with critical judgment" (p. 133). Deep knowledge of algorithms, its principles and correctness

might be seen as an amalgam between conceptual understanding and procedural fluency, so-called precept (Gray & Tall, 1994). Some studies (Lockwood & De Chenne, 2021) demonstrated the added value involving coding in students' mathematical problem solving. Furthermore, using coding for solving mathematical problems may strengthen the computational thinking of the learners. The questions about how knowledge about algorithms contributes to students' learning of particular mathematical concepts and procedures and how can students profit from generalization of the mathematical procedures in an algorithmic way remain open.

If we want to approach algorithms from both sides, mathematics and computer science, we should decide who should teach about algorithms. There are countries, e.g. Slovakia, where algorithms and programming have had a strong position in curricula since the 1980s, as a part of computer science education. In other countries, e.g., France, algorithms are part of mathematical curricula. Both possibilities have their strengths and weaknesses. Teachers, specialists in mathematics or computer science focus on different characteristics of algorithms, in accordance with the disciplinary practices. Kortenkamp (this proceedings) describe several types of activities usual for work with algorithms in computer science: (i) design of algorithms, (ii) describing the algorithm in a (formal) language; (iii) carrying out algorithms, (iv) proving the correctness of algorithms, and (v) comparing algorithms with respect to complexity, elegance, or simplicity. These activities can be seen also in mathematics lessons and may serve as a bridge between the two disciplinary practices.

The teachers are the agents of any educational change (Kieran et al., 2013) and their work is shaped by their resources, orientations and goals (Schoenfeld, 2010). How the mathematics teachers' predispositions influence their practice regarding the algorithms, what is the knowledge needed to teach algorithms as deep procedural knowledge and whether mathematics teachers see any value in algorithmic approaches to mathematical objects should be examined in further studies.

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