CONDITIONS AND OPPORTUNITIES FOR INTEGRATION OF ELEMENTS OF CONSTRUCTIVIST APPROACH IN THE BULGARIAN MATHEMATICS CURRICULUM

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Abstract: The aim of this article is to provide a brief overview of reforms carried out in mathematics curriculum in two different countries (China and Norway). The direction in which some authors consider these reforms is constructivist-oriented. The subject of the analysis is the conditions and opportunities that constructivist approach provides at the curriculum level for real change in the modern mathematics classroom: opportunities for students to be active participants in the learning process, i.e. students themselves to raise hypotheses, make decisions, explore and discover basic mathematical principles and trends; opportunities to research a comprehensive mathematical concept from the whole to its constituent parts; opportunities for students to use different learning resources (including information technology), to delve into different sources of information (not just current textbooks and notebooks), opportunities to work on projects, opportunities to solve real problems in a team. The thesis we defend is that in search of a balance between development of the mathematical knowledge, skills and competencies from the mathematics curriculum, on the one hand, and continuous improvement of teaching methods altogether with provision of an optimal learning environment, aimed at active participation of the individual student, on the other, solutions that have already been tested at the curriculum level with a focus on placing the student in a constructive role in the learning process, could lead to future practical solutions for the Bulgarian education system.
Keywords: reforms, curriculum, mathematics, constructivist approach

1. INTRODUCTION

With the development of the modern and dynamic world in the era of rapid technological advancement, the development of so-called mathematical literacy is proving to be very valuable. The international PISA study (PISA 2022, 2018) provides a precise definition of this concept, which includes activities such as: knowing and understanding facts and concepts, interpreting data, formulating and reasoning about ideas, and using mathematics to solve real-life situations and problems. The focus is no longer only on calculation speed, endlessly and accurately performing monotonous computations and transformations, or mechanically memorizing rules and theorems. Instead, it is on students' ability to take their place in society and tackle the global challenges of the 21st century by applying what they have learned in real-life contexts. This brings forth the main question of the current inquiry: if today's students are growing up and living with their phones – drawing instant information from them and believing they can easily act in the world with the press of some buttons – what opportunities does the constructivist approach to mathematics education offer within the Bulgarian educational system? Which characteristics of this approach can help bridge the gap between the high level of abstraction in mathematical knowledge and the everyday practice in which this knowledge is embedded in real-life situations, making reflection upon them difficult? A step toward answering this question is the thesis we support – the efforts to revise mathematics curriculum in the spirit of the constructivist concept of education reveal modern opportunities for teaching mathematics by integrating the traditional academic approach with active learning and application of knowledge in real-world contexts. Various studies by different authors and educational systems present theoretical developments, accumulates practice and promising results. Examining these is important not only for gaining confidence in the chosen direction but also for finding practical and workable solutions for implementing it in the everyday life of secondary education in Bulgaria.

2. THEORETICAL FRAMEWORK

What is the constructivist theoretical framework for developing mathematics curriculum? Clements & Battista (Clements & Battista, 1990) describe five "basic tenets" of constructivism: "knowledge is actively created by the child, not passively received from the environment"; "children create new mathematical knowledge by reflecting on their physical and mental actions"; "learning mathematics should be thought of as a process of adapting to and organizing one's quantitative world, not discovering preexisting ideas imposed by others"; "constructivist classroom is seen as a culture in which students are involved not only in discovery and invention but in a social discourse involving explanation, negotiation, sharing, and evaluation"; students should not merely repeat pre-set methods shown by the teacher, because "the sense-making activity of students is seriously curtailed" (Clements & Battista, 1990). First and foremost, this necessitates a rethinking of the goals of mathematics education, which should be flexible and allow for student activity through inquiry and exploration. The processes are also different – they are oriented toward critical thinking and problem-solving rather than mastering and reproducing pre-developed content. Thematic units should be organized around topics connected to students' lives and interests. Problems and tasks should be open-ended to stimulate critical thinking. Numerous integrative connections are made between different subjects, such as science, art, technology, social activities. Teaching is based on posing questions and organizing activities that encourage students to engage in discovery, research, hypothesis-making, and drawing conclusions based on their own experiences and personal insights. Project-based learning activities are also well-accepted and effective, which allow students to work collaboratively on complex tasks, promoting deeper understanding, integration, and retention of knowledge. Teachers shift their roles: instead of delivering knowledge, in the case of mathematics – showing a working method for solving a specific type of problem, they act as guides and facilitators, encouraging students to take the lead in discussions, investigations, and projects.

3. SOME NOTES ON BULGARIAN CASE

A natural question arises: To what extend should constructivism be fully implemented with all its characteristics and to what extend should the principles of the traditional lecture-based approach be preserved? As we know how conservative the Bulgarian educational system is, experience shows that making potential changes to the mathematics curriculum seems a difficult and complex process that deserves special attention. The mathematics curriculum has been revised multiple times with the main tactic for change typically being addition or removal of content for a particular grade level. Until the 1980s, the mathematics curriculum in Bulgaria was flexible and practically oriented, with a well-established practice of offering different textbooks for different types of school in order to better adapt the content to the needs of various students. As a matter of state police, for a number of strategic reasons, the communist regime strongly supported the exact sciences, which, in turn, led to reasonably good results in mathematics. An educational reform was initiated in Bulgaria about ten years after the democratic changes. However, it did not lead to notable results, and in international assessments (in reading, mathematics and science), the country has shown increasingly lower performance. Several conclusions were already drawn at that time: the dominant mode of instruction leads to memorization and reproduction of information rather than development of critical thinking skills and collaborative problem-solving; the Bulgarian educational system do not contribute to the formation and development of skills necessary for handling problems arising from real-life contexts. The mathematics curricula for grades V-VII, introduced in 2021, includes a new overarching goal: "for students to discover the necessary of knowledge and its application in solving specific real-life problems" (Ministerstvo na obrazovanieto i naukata, 2021). This idea is a step forward compared to our long-standing traditional understanding of mathematics – a move toward contemporary trends in mathematics education. The big question, however, is whether, without a concrete didactic and psycho-pedagogical implementation plan and specific model, this objective can truly be realized.
In this context, we present two international examples of mathematics curriculum reforms, supporting the thesis that they embody a constructivist orientation.

4. THE MATHEMATICS CURRICULUM REFORM IN CHINA

Reflecting on the positions on the stage of international assessments, a number of countries have undertaken major reforms in their educational systems in the field of mathematics in order to stay aligned with contemporary demands. China is the country that has consistently ranked at the top in international assessments. After 1996, in a study conducted by the Ministry of Education, it was found that the curriculum was perceived as "complex, difficult, partial, and old" ((Liu, 2009) in (Wang, Liu, Du, & Liu, 2017)). This marked the beginning of a new educational reform in China. The process was long, carefully planned, and involved many stakeholders – "scholars and experts in various fields including mathematics, psychology, mathematics education, and school teachers" (Wang, Liu, Du, & Liu, 2017). It included the prior development of educational resources based on the new curriculum concept and was supported by an abundance of empirical data gathered through experiments involving more than 60,000 students from provinces with varying levels of development. As a result, after two decades, the curriculum reform in China led to changes in: "ambitions, curriculum content, teaching methods, textbooks, and assessment methods. These changes played an important role in promoting the development of mathematics education in China." (Cao, 2024)
In the experimental version of China's Mathematics Curriculum Standards (Mathematics Curriculum Standarts (Experimental Version), 2004), all details are clearly outlined, and collectively, they reflect a constructivist framework for the mathematics curriculum. Compulsory education consists of nine years, divided into three stages: grades 1 to 3 – first stage; grades 4 to 6 – second stage; grades 7 to 9 – third stage. There are four main content domains in each stage: Numbers and Algebra, Space and Figures, Statistics and Probability, Practical and Integrated Applications. The last domain helps students discover the internal connections that can be made between the other

three domains. As a result of the mathematics education, students develop knowledge, skills, and attitudes that include: Number Sense, Symbol Sense, Space Concept, Statistical Concept, Application Awareness, Inferential Ability.

All the core principles and activities that teachers are expected to follow are presented in great detail within the standards, with both vertical and horizontal progression. In the Numbers and Algebra domain students initially practice and reinforce the meaning of numbers, consolidate various computational skills, explore and discover fundamental quantitative relationships. Furthermore, they are encouraged to observe objects and phenomena, play with manipulatives, solve age-appropriate real-life or practical problems, talk about interesting things around them using numbers and their functions in speech and communications, develop what is referred to Number Sense. Mental and oral calculations, estimation skills and diversified use of different algorithms are promoted. Complex calculations and rote memorization of computational rules are avoided. In the upper grades, students are allowed to use calculators and other computational tools. Teachers are advised to focus on solving complex practical problems from everyday life related to the studied numbers and quantitative relationships, and to avoid isolated purposeless complex calculations or separating the processes of computation from the real-life applications of given numbers or expressions.

In Space and Figures domain students acquire basic knowledge and an initial understanding of geometric shapes and solids, rotation, translation and symmetry. Students should participate in determining and describing the relative position of objects, engage in basic measurement activities, build foundational concept of solids. Tasks are selected by teachers with the intention of creating a strong connection between the acquired knowledge and everyday life. It is important for the teachers to encourage students to act intuitively in tasks involving observation and manipulation of objects. Students gradually become familiar with geometric shapes and solids, their corresponding measurements, and their relative positions through observation, exploration, manipulation, recognition of directions, designing and constructing models, and drawing deductive conclusions. The new curriculum reduces the level of difficulty regarding geometric proofs but places greater emphasis on the perception and understanding of shapes, their transformations and positions.

Statistics and Probability, as a separate domain in the mathematics curriculum, allows students to take their first steps in collecting, organizing and presenting data and information. They should be able to answer elementary questions related to collected data. The tasks should be drawn from real life, with main focus on students' understanding of probability and uncertainty. In upper grades, these activities are built upon with attempts at conducting elementary analyses, assessments and forecasts.

The main goal of Practical and Integrated Applications domain is for students to become familiar with the applications of mathematics in real life. Students learn how to exchange, discuss and combine ideas with others. In this way, by solving basic practical problems, students are given the opportunity to independently build mathematical constructs, collaborate with each other and become aware of the role each person plays in society.

The main focus of the changes described above in the structure of the mathematics curriculum of China lies the development from the "Two Basics" toward "Four Basics". To the basic knowledge and basic skills ("Two Basics") are added basic ideas and basic active experience. What does this change actually reflect? "Basic mathematics knowledge includes mathematical concepts, features, rules, formulas, axioms, theorems, and their embedded mathematical ideas and methods. Basic mathematical skills refer to computation, data processing (including the use of calculators), simple reasoning, drawing and making tables and figures." (Ministry of Education, 2001) in ((Xu, 2017)) The concept of basic ideas includes ideas related to mathematical abstractions, mathematical reasoning, or mathematical modelling, while basic active experience refers to students' personal experiences with mathematical activities. The two basic components (basic knowledge and basic skills) have a long-standing tradition. It is primarily linked to an educational system based on reproduction of information and learning for the exam. However, it is reached a point at which these two basic components prove insufficient to meet the demands. Xu (Xu, 2017) summarizes several reasons for this. The first is that during the reform, China focused on a three-dimensional goal – knowledge and skills, processes and methods (mathematical thinking), affective demeanour and values (mathematical activities), while the "Two Basics" are presented only in first of these three goals. Second, many teachers pay greater attention to strictly adhering to and following the curriculum, neglecting the students' actualities, whereas after the reform, teaching should be student-oriented. And third, the "Two Basics" serve only as a foundation, but cannot fully encompass innovative talents; therefore, in addition to improving knowledge and skills, mathematical ideas and mathematical activities should also be developed.

One of the major changes in China's mathematics curriculum is formulated as: "Mathematics for all" (Wang, Liu, Du, & Liu, 2017). In other words, every person has different levels and needs for growth, so they can learn the mathematics important for their development. Students should experience the process of mathematical modelling, which contributes to the interpretation and applicability of the problem-solving process. This, in essence, is one of the key criteria for defining a constructivist-oriented approach to learning. Learners' personal experience, which demonstrates the applicability of mathematics in real life, goes beyond the boundaries of abstraction in mathematics education. According to Zhang & Song, this concept is totally different from the one underlying in the previous teaching syllabus ((Zhang & Song, 2004) in (Wang, Liu, Du, & Liu, 2017)).

Another major change in China is the interdisciplinary connection between mathematics and information technology. Here, technology is not limited to the basic use of a computer or electronic device. The integration of these two subjects aims to improve and visually enhance the presentation of mathematical content and algorithms, which are often difficult to understand without the assistance of technological tools. Furthermore, it is believed that information technology provides access to numerous mathematical educational platforms, enables the use of various scientific calculators, and support activities related to research exploration and discovery.

In 2011, several Chinese researchers (Ni, Li, Li, & Zhang, 2011) conducted a comparative study involving students from 5th and 6th grade. One group was taught the conventional curriculum from grades 1 to 6, while the other group was taught the new, reformed curriculum. Over a period of 18 months, the students were assessed three times in terms of their achievements in computation, routine problem-solving, and complex problem-solving. The affective aspects also included self-reported interest in learning mathematics, classroom participation, views on the nature of mathematics, and views of learning mathematics. The results showed that the group following the reformed curriculum achieved relatively more balanced development across the three areas of mathematical achievement. In contrast, the group that did not participate in the reforms showed faster growth in computational skills and performed better that the reformed group in this area. Moreover, the study pointed out that the influence of teaching materials on both mathematics instruction and student learning tends to be more pronounced in centralized educational systems like this one of China, compared to decentralized systems such as that of the United States.

Chinese students have consistently achieved top results in international assessments such as PISA and TIMSS, although there are certain qualifications and trends within these achievements. One primary issue concerns the representativeness of the student sample – with only two exceptions, participants have always been students from Chinese Taipei and Hong Kong. In the light of the growing social inequality in China, the academic community has raised the question of whether the new curriculum is equally accessible to students with greater social and economic resources as it is to those with fewer such resources.

There are different views regarding the potential success of the mathematics curriculum reform in China. On one hand, some researchers ((You, 2019) in (Guo & Kong, 2023)) argue that although the curriculum has introduced opportunities for active student participation, classroom initiative is still largely led by teachers. The primary teaching orientation remains focused on content mastery and exam preparation. Other researchers ((Cheng & Ding, 2021; Gutherie, 2018; Tan, 2017) in (Guo & Kong, 2023)) offer a different perspective, claiming that strong constructivist methods – such as cooperative learning, inquiry-based learning, dialogue, and discussion – have been introduced into the Chinese curriculum. However, despite these methods, teachers continue to retain leadership and control in the classroom, with an emphasis on practicing and mastering content. In this way, constructivist views are intertwined with the country's traditional educational paradigms. Four possible reasons are noted for these divergent perspectives. Since the reform in China is considered by some researchers ((Tan & Hairon, 2016) in (Guo & Kong, 2023)) to be a "prolonged and constructive process" and is being implemented at different paces across various provinces – depending on economic conditions and the existing educational infrastructure – the first reason identified is the ongoing need for consistent and stable external support for teachers in relation to their teaching ((Beckett & Zhao, 2016; Darling-Hammond & McLaughlin, 2011) in (Guo & Kong, 2023)). Second, in order to understand the true characteristics of China's new educational practice, it is necessary to interpret it systematically from the perspective of teaching behavior, the learning process, and the corresponding instructional goals. Third, according to existing academic literature, the application of a constructivist approach in the classroom typically involves "minimal guidance from the teacher" ((Van Bergen & Parsell, 2019) in (Guo & Kong, 2023)). Some researchers argue that instruction does not take place in the spirit of constructivism if the teacher provides too much guidance or relies heavily on lecturing. In contrast to this view, however, a number of studies have shown that constructivist methods, when applied with minimal teacher guidance, can be ineffective – "especially for students whose cognitive abilities are still developing and whose foundational knowledge is limited" ((Klemencic, 2017; Larison, 2022; McPhail, 2016) in (Guo & Kong, 2023)). Wang ((Wang, 2004; Wang, 2006) in (Ni, Li, Li, & Zhang, 2011)) has expressed doubt as to whether the emphasis on the new curriculum on problem-solving might be weakening the strong foundational mathematical skills for which China is known. Furthermore, if such a weakening is indeed occurring, a logical question arises: would it actually contribute to better development of problem-solving competence?

5. THE MATHEMATICS CURRICULUM REFORMS IN NORWAY

Norway is a country that has undergone several reforms in the subject of mathematics (1974 (M74); 1987 (M87); 1994 (R94); 1997 (L97); 2006 (LK06), and 2020 (LK20)) (Borge, Hole, & Grønmo, 2022). Since the 1990s, emphasis has been placed on the idea that the curriculum, along with teaching and learning methods, should encourage active student participation. The teacher steps back from the traditional role of knowledge-holder and instead becomes a guider, advisor, and even a friend. The 1997 (L97) curriculum was described by Herbjørnsen as "a victory for progressive mathematics teaching methods" ((Herbjørnsen, 1998) in (Borge, Hole, & Grønmo, 2022)). A widely used and supported tool turns out to be project-based learning, where students are encouraged to go through the entire process – from the emergence of an idea to the complete development of a product. Furthermore, students' interests influence the content, and open-ended or experimental tasks and assignments are taking on an increasingly significant and important role. There is a strong emphasis on the individual student's responsibility for their own professional and social development in this educational reform in Norway, which reflects a constructivist perspective (the student builds their own knowledge through constructs). The entire school activity is organized around this idea. Each student is given a weekly work plan for one or more weeks, which includes all activities across all subjects that the student must complete in an order determined by and convenient for them. It turns out that the teachers are the ones who feel uncertain and unadaptable to the change. Collaboration proves to be difficult – sometimes even overwhelming – for them, as they find themselves in a classroom with students engaged in different activities and in need of help and guidance in different subjects. In addition, this school model faced to the heavy criticism while it was in effect. Real results emerged in 2003, known as the so-called "PISA shock" (Borge, Hole, & Grønmo, 2022).

"From about 2003 onwards, the Norwegian discourse on school mathematics switched away from the "soft" and child-oriented L97-approach, focusing instead on competence-based approaches to curricula." (Borge, Hole, & Grønmo, 2022) In 2020, the curriculum was updated, highlighting several distinctive features in each subject ("core elements"). Various experts argue that the reform following the "PISA shock" is not a reform in the true sense of the word (Borge, Hole, & Grønmo, 2022).

The "core elements" of the mathematics subject after the latest changes in 2020 in Norway are: Exploration and problem solving, Modelling and applications, Reasoning and argumentation, Representation and communication, Abstraction and generalization, and Mathematical fields of knowledge (The Norwegian Ministry of Education and Research, 2019). The first element Exploration and problem solving emphasizes strategies and approaches rather than specific solutions. It means that students are expected to search for patterns, discover connections, and discuss their understanding in order to find solutions. To solve a mathematical problem or case, students need to break it down into sub-steps, which they solve step by step in order to reach the final solution. Naturally, in each of these steps, students require computational skills, as well as the ability to assess whether digital tools are needed – and if so, which ones. The second element, Modelling and applications, helps students describe reality (everyday life, people's work, and their social lives) using the language of mathematics. Furthermore, it serves to critically evaluate whether an already constructed model is valid, what the limitations of the model are, how the model can be assessed in relation to the real-life situation, and whether a given model can be successfully applied in other contexts. The third element, Reasoning and argumentation, helps students understand that mathematical rules and results are not random – they follow a specific logic and have precise and clear logical explanations. The fourth element, Representation and communication, helps students express their mathematical concepts, thoughts, connections, and solutions in various situations. Presentations can be contextual, visual, verbal or symbolic. In the fifth element, Abstraction and generalization, abstraction refers to the gradual formalization of mathematical strategies and thinking, while generalization involves identifying connections and structures without having a ready-made solution. The last of the listed elements refers to specific fields of mathematical knowledge (numbers, algebra, functions, geometry, probability, and statistics). Interdisciplinary topics, such as health and life skills, democracy and citizenship, are included in the mathematics curriculum. It is notable that the first five elements are not specific branches of the mathematics subject but are related to working with subject itself. "One of the reasons for focusing on the work with the subject rather than the specific mathematical content in the core elements was to make the students work more on methods and ways of thinking to get a better understanding of mathematics, hereby also making the teachers change their instruction methods." (Borge, Hole, & Grønmo, 2022)

In a study conducted in several Norwegian schools, Berget (Berget, Mathematical modelling in the discourses of the KOM and PISA frameworks and teacher interviews, 2023) found that although mathematical modelling has a 30-year history in Norway, and the main idea behind its inclusion in mathematics education is to help students connect real-life situations with the mathematical content, teachers do not perceive it as relevant for establishing this connection. It is also noted that teachers need more in-depth theoretical knowledge in this area. In another study, Berget (Berget, Mathematical modelling in textbook tasks and national examination in Norwegian upper secondary school, 2022) points out that, regarding specific goals of modelling, there is a discrepancy between the intended curriculum and its implementation in textbooks and exam tasks. This is yet further evidence that, worldwide, educational reforms are a prolonged and complex process in which all stakeholders require continuous support.

6. SOME RECOMMENDATIONS FOR THE BULGARIAN MATHEMATICS CURRICULUM

The curriculum content in the subject of mathematics in Bulgaria does not differ significantly from that in China or Norway. The main difference, however, is the orientation of the curriculum. Similar to the countries discussed, for the period before their reforms, the focus of the Bulgarian mathematics curriculum is on the practice and mastery of the content – primarily the development of good computational skills in the early years, and exam-oriented learning in lower and upper secondary education. In practice, there is a lack of interdisciplinary connections with other subjects, both horizontally and vertically. The predominant approach is a traditional lecture-based model, in which teachers are the active agents and students are passive recipients. Furthermore, the content of textbooks and teacher guides is followed strictly. Even after the adoption of the competency-based approach in Bulgarian education, the orientation of the mathematics curriculum has not changed. This contrasts with China and Norway, where some researchers consider their reforms to be constructivist in nature (such as the development from the "Two Basics" to the "Four Basics" in China, and the introduction of "core elements" in Norway).

7. CONCLUSIONS

Mathematics is a core educational subject that has played a significant role throughout its existence – even in modern times, marked by rapid technological development. The structure and content of the subject are influenced by various internal political and economic factors specific to each country. China and Norway have carried out reforms in their mathematics curricula, driven primarily by negative international assessments and aligned with the strategic policies of their respective nations. These reforms occurred at different times but share similar characteristics and directions of change, to varying degrees corresponding to the constructivist approach. The balance sought in the described reforms lies between existing teaching methods and the potential for active student engagement in the learning and educational process. This, in essence, is the path of each country toward a deeper integration of a constructivist approach to mathematics education. The major question remains: to what extent, and on what psychological and pedagogical foundations, should the theoretical, formal-logical, and "computational" orientation of mathematics curricula and instruction give way to problem-solving (individually or collaboratively), the investigation of socially and publicly relevant issues, modelling, and the use of technological tools?

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