15/1-2. (2017), 95–107
DOI: 10.5485/TMCS.2017.0434
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Teaching Mathematics and Computer Science

Preliminary effects of mathematics curriculum development for primary school student teachers in Sárospatak Comenius Campus

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Abstract. Hungarian students' mathematics performance has been getting weaker in the past few years. A possible solution to stop this tendency is to develop curriculum. Therefore, Hungarian researchers have been refining a particular framework of curriculum development in primary school teacher training programmes. The national curriculum is designed on the assumption that learning can be broken into a sequence of levels and students can evenly succeed in gaining knowledge at successive levels. In this paper, we want to discuss how to reduce students' difficulties with different background to grow competence at successive levels.

Key words and phrases: mathematics education, curriculum development,transition, primary teacher training, didactical methodology.

ZDM Subject Classification: B70, D30.

The problem

Our approach is to ease the difficulties students experience during their first months of study at universities. In particular, advance level mathematics programmes adapt the first courses to students' background from upper secondary school. In Hungary at teacher training colleges, it means for example that subjects like *thinking methods, number theory, geometry, functions, statistics and probability theory* are revisited and extended progressively to an advanced level during the training programme. According to the old curriculum the theoretical knowledge of these subjects were taught in the first two terms and students learnt methodological knowledge in the next few terms of their studies separately. In this way, students could gain theoretical knowledge at an advanced academic level. However, the problem did not disappear. Soon students started their teaching practice at primary schools where they encountered difficulties how to explain mathematics concepts at an elementary level for pupils of age between 6-12 years old. Students were in fact face the challenge or transition: how to use the theoretical aspects in their practices. Therefore, curriculum developers came up with the idea to link methodological knowledge to theoretical knowledge of mathematics with minimum changes in the content in the curriculum.

Theoretical background

Important and historical memory in Hungarian mathematics education would require researching back several hundred years. In the present paper, historical implications are recalled to a certain extent, only if they have a direct impact on present mathematics education. Considering the past 60-70 years takes us closer to recognise and understand characteristic features of mathematics education. The opening of the eight-grade primary school in 1945 and the four-grade secondary school in 1949 founded the structure of education, which exists even to this day according to a study (Vásárhelyi, 2013). In the fifties and sixties reforms improving mathematics education were launched around the world. At that time, many mathematicians and psychologists considered the renewal of mathematics teaching of 6-10 year-old children to be of crucial importance. In some subjects, the content modernisation was successful and mathematics was one of these subjects. Topics like *logic, set theory, combinatory, graph theory* were introduced into the curriculum of primary schools, as the goal was to facilitate the development of thinking. A new mathematics education, 'new mathematics' spread throughout the world. This renewal can be characterised by names such as Jean Piaget, Jerome Bruner, Zoltán Dienes and Tamás Varga.

The Hungarian endeavours were part of the worldwide education reform, but in many respects, they diverged from the dominant foreign trends. In some foreign curricula, new mathematical content was primarily used to convey formal terms of abstract concepts to learners. "In the west (for example in France and in America) extreme ideas like introducing modern mathematics into elementary and secondary education without adapting teaching methods to children's age specificities, failed" (Pálmay, 2007).

The complex mathematics teaching experiment under the direction of Tamás Varga emerged from other educational experiments through its comprehensive and unified methodological concept. The curriculum in 1978 based on Varga's ideas was introduced in all first classes of primary schools. Prior to that, mathematics in primary schools meant the teaching of arithmetic and geometry, the dominant method used was direct teacher guidance, the main educational goal was the routine use of knowledge, the main tool was practicing the application of rules, procedures.

"According to Tamás Varga, young people are able to learn new topics if it is done playfully. In manuals for teachers, continuing teacher-training materials, textbooks, exercise books there are many examples for how to teach children *combinatory, sets, mathematics logic, functions*, etc., raising their interest in learning. Teaching tools were recommended for primary school teachers, for example, how to improve space-vision with the building game Babylon, or the Dienes-set for teaching number systems" (Reményi, 2007).

The 1978 curriculum based on complex mathematics included real mathematics form the first class. The curriculum was classified into five subjects appearing in each class from the first to the eighth years of elementary studies according to age specificities. The five topics are *Sets, logics, Arithmetic, algebra, Functions, sequences, Geometry, measurements, Combinatory, probability, statistics*. The most important novelty in content was the principle of continuous and spiral building of mathematics. Basic mathematical concepts and knowledge were constantly being built, enriched and deepened from the first school year (Vásárhelyi, 2013).

According to the 70's reform plans mathematical goals included the creation and practical testing of mathematical models of real problems.

However, the tight-fisted budget, the inadequate conditions for the implementation of innovations resulted in a decrease in the education. "There are two ways to reduce the dropout: conditions of education will be improved and so does its effectiveness or the otherwise low requirements will be further reduced" (Andor, 1981).

The fast, not always thoughtful series of changes, misplaced reforms over the past 30 years has made life difficult for teachers. The unreasonable, uncontrolled, sometimes contradictory, educational changes generate uncertainty and do not make the teacher career attractive (Donáth, 2012).

Effective solutions may be independence and motivation for work. This is necessary because several generations grew up without seeing adults working hard around them. Following family lifestyles strongly determines children's further way of life. Up to now, it has not been possible to break the vicious cycle that began with the decline in teacher's authority, associated with the lack of financial and social appreciation (Donáth, 2012).

The problem of low mathematical skills is caused by many other reasons such as unsuitable teaching and learning environment, few teaching methods, negative attitude of pupils and parents towards mathematics, shortage of teaching and learning materials, negative interaction between teachers and pupils to mention a few (Michael, 2013).

The curriculum shows that mathematical literacy is of crucial importance in providing the candidate with the necessary skills to live in the society. Such mathematical literacy is necessary to make sense of data encountered in a complex and constantly changing world (Gyöngyösi-Wiersum, 2016). Mathematics can provide the necessary knowledge and skills to empower a person to process a mass of information every day. Students are expected to learn a considerable amount of complex and diverse mathematical knowledge accumulated during thousands of years. Hence, there is a growing gap between academic and primary school level mathematics. However, instead of expanding the curriculum another dimension such as the didactical point of view is to be considered and integrated into it. Students need to be engaged in activities encouraging learning and investigation. Carefully designed teaching methodology and entirely new organisations of tasks provide opportunities for students to develop their epistemic value (also Artigue, 2010, p. 467) and to take part in problem solving activities while learning how to apply their knowledge to real-life situations. In the present project, this means that students' work with the designed elementary problems should be related to, and support, their work with theory and so facilitate the transition from primary to university level and back.

One of the most important principles is gaining experience based on specific activity, using tools, and inserting games and playful activities in classroom lessons. The emphasis should be on understanding, on the process and on creating efficient learners rather than on the product (Carr, 2011).

Through a discussion of the results of the present action research, we can share some interesting first results with practicing mathematics educators.

Framework of the research

In the last few years, students learnt mathematics subjects at advanced level at the first two terms of their training and then in the next four terms of their mathematics studies they learnt how to teach different topics in mathematics at elementary level. The new direction in curriculum development is to link methodology of teaching mathematics to subjects taught in primary schools. In this way, students can gain practical knowledge in their future teaching job and they see what mathematics topics are necessary to teach and how to teach those in primary schools. The hypothesis is that combining theoretical and methodological knowledge may result in successful teaching practices.

When students are admitted to a college or university, they are expected to know a certain knowledge as they had passed their general certificate of secondary education. However, at colleges and universities professors teach mathematics at academic level. At the end of the exam periods, it becomes clear that the results of students are rather poor at mathematics and lots of them fail in the examinations. Hence, one of the main problems in their training is that the basic mathematics knowledge on which professors want to build is missing. It is important to find out which topics cause difficulties for students where their knowledge needs to be improved.

The author teaches mostly mathematics and methodology in a teacher training college (now part of a teacher training university) since 2004 in a small town Sárospatak, in Hungary. In the new curriculum introduced last year in our college the methodological knowledge is better fitted to the theoretical knowledge in each term during 3 years of students' mathematical education. These are not major changes only a rearrangement in the content of the curriculum where theory and methodology are more coherent and not taught separately as earlier. These mixed courses focus on students' practice with concrete calculations with minimum amount of precise definitions while some theoretical part (theorems and proofs) is left in the background or it is entirely omitted. Our aim is to find potentials and possible dangers in these changes. More concretely, we investigate – theoretically and empirically – concrete designs for integrating theoretical mathematics knowledge combined with methodology in parts of students' work, aiming to help students in relating theoretical and methodological aspects. In particular, we are interested in designing new types of tasks starting from elementary level and expanding it to a higher level without considerable changes in the content of the curriculum compensating the lack of teaching experience of beginners and make future teachers successful in their job.

According to international research, the role of practical experience in the process of preparing for the profession is more decisive than that of theoretical training (Lenkovics, 2012).

We can trust in applying innovative teaching methods building on students' activities. Love of mathematics and interest motivate learning more than any other factor. It is important to differentiate in the teaching process, to take into account differences of individuals, to let make mistakes without punishment, to play games at home and in the lessons for pedagogical purposes.

If curriculum developers want to be scientific then their curriculum development work must describe how it is related to the relevant work of others (Romberg, 1992). It includes comparing development work with the existing curricula and connecting the design to theories of teaching, learning, and related research results.

Findings and interpretations

We now give some examples of how elementary mathematics was integrated into the work of students.

The author applied situation games during the lessons and build on students' active participation in problem solving activities. Students acted a certain problem in a situation and then solved it by creating a mathematical model. The principles of teaching management include the methodological diversity, the encouragement of group and individual work instead of the previously dominating frontal form of work.

Figures 1 and 2 present the pre- and post-test results of student teachers in the second and third year. Third-year students completed their studies successfully in *Thinking methods, Number theory, Geometry and Functions* and they started their teaching practice in an elementary school in that semester. Second-year students studied the first two subjects in the preceding list and did not start their teaching practice yet. Students were tested on their mathematics knowledge at primary level at the beginning and then at the end of the term. Test results were discussed with the students and the teacher solved each problem of the test after the *pre-test* then the focus was on expanding elementary theoretical knowledge to upper level. We studied *Functions and basic analysis* with students in the second year and *Probability, statistics* with students in the third year. In those subjects, we combined theoretical and methodological knowledge. More problems at elementary level were included into the new curriculum. At the beginning of mathematic courses during the first few lessons, students revised their elementary mathematics knowledge and they learnt how to teach certain concepts at elementary level. During the rest of the semester, they expanded their elementary knowledge to upper level. Then at the end of the term student wrote the post-test.

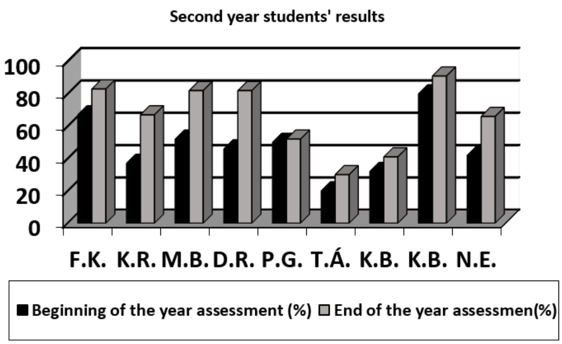

Figure 1

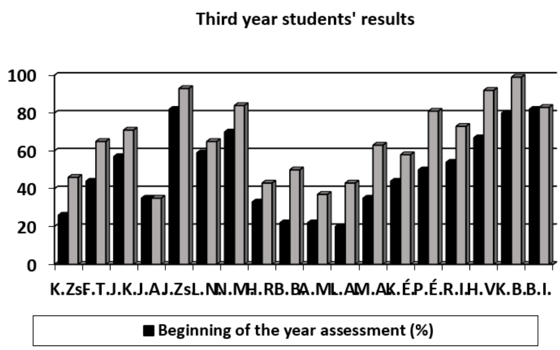

Figure 2

The results indicate that students managed to improve their knowledge during the term and their results were better after the post-test. Except for one student who gained 35 % in both tests, everybody else performed better during the second test. Hence, most students more or less progressed during the teaching experiment.

Some examples on how students succeeded while solving these tests are shown below. Every student in this study had problems with converting units in tasks 17-19 in *the pre-test* below. Most of them did not solve these problems. Only a few of them tried to solve these tasks but none of them correctly.

17. *Complete the following sentence with the appropriate unit of measurement from the following units!*
    $mm, cm, dm, mm^2, dm^2, mm^3, cm^3, dm^3$
    The surface of a page A4 is approximately 6.2...
18. *One hectare is equal to ...* m^2
19. *How many cubic centimetres are the volume of a glass with a capacity of 500 centilitres?*

Only 6 students out of 27 managed to solve tasks 17 and 18 in the ***post-test*** correctly. However, none of them gave a correct answer to question 19. That reveals that students' geometric knowledge needs to be considerably improved.

17. *Complete the following sentence with the appropriate unit of measurement from the following units!*
    $mm, cm, dm, mm^2, dm^2, mm^3, cm^3, dm^3$
    Gergő's desk is 78 ... long.
18. *One hectolitre is equal to ... litres.*
19. *How many cubic centimetres is the volume for a glass of 50 decilitres?*

The following three problems concerned geometric knowledge. Three students solved task 21 correctly. Seven students managed to solve tasks 26 and 27 correctly in the *pre-test*.

21. *How large is the rectangle of the largest area whose perimeter is of 12 cm? (Unit of sides is an integer).*
26. *The longer side of a rectangular garden is 174 m; the shorter side is 93 m. How many metres of wire will you need to enclose it if you leave out 1 meter for the door and 4 metres for the gate? (Make a drawing!)*
27. *One side of a rectangle is 177 mm, the other side is 135 mm. How long is one side of the square whose perimeter is the same as the perimeter of the rectangle? (Make a drawing!)*

The following three problems in the ***post-test*** represented practical knowledge of geometry more related to real life.

Two students could solve task 21 correctly. Four students solved task 26 successfully. Three students could solve task 27 correctly in the ***post-test***.

21. *We want to build a rectangular garden pond for which we have already bought the border whose length is 30 metres. How large should I choose the sides of the pond if I want to provide danio fish with the largest possible area to swim in? (Unit of sides is an integer). (From a methodological point of view, make sure to put down the data correctly.)*
26. *A new carpet was bought for Agi's room. What long bordure you need to buy for the carpet if the room is 2 m 75 cm wide and 4 m 30 cm long? Make a drawing!*
27. *Eszti is sewing a ribbon around the edge of a square-shaped tablecloth whose side is 17 cm. The roll of the ribbon is of length 12 m. How many tablecloths could she sew up with this? How much ribbon would remain?*

We can conclude that geometrical, practical and real life problems are difficult for students to solve. Much more attention should be given to the question how to relate mathematics to real life problems. We can see more examples for this in elementary school books than in college textbooks.

Performance on pre- and post-test tasks

In table 1, we present the overall results of students' work on 27 exercises in different topics of primary mathematics. The tables shows the number of students in groups defined by the following rough but objective criteria (so that, for example, the sum of the first row gives the number of students in group H):

H: overall high achievers, with at least 75% of points in the test.

A: overall average achievers, with at least 50% and at most 75% of points in the test.

L: overall low achievers, with less than 50% of points in the test.

P−: *Pre-test* results.

P+: Post-test results.

Similar exercises were designed in the pre- and post-tests.

	H	A	L
P−	4	9	14
$P+$	10	10	7

We notice that the number of students in groups H and L changed considerably. Probably because after the *pre-test* all the exercises were solved and explained therefore the number of low achievers halved and the number of high achievers more than doubled by the end of the term.

The low performance during the first test shows that students have trouble solving problems at primary level.

Understanding these reasons should help in the development of suitable materials and learning strategies to promote their mathematics knowledge.

Problems that occur later in school and college begin much earlier. Students arrive in higher education with different knowledge and these differences seem to deepen as they advance with their studies.

However, it is promising that after revising primary level mathematics most of the students managed to improve their performance. To find the reason for it students filling up the pre- and post-tests were also asked to answer some questions concerning their opinions on how their mathematics knowledge changed during the term.

Student questionnaire

It is not surprising that students with an overall low performance commit more errors in both the pre- and post-tests. Our aim was not to make easy tasks but to include tasks from each topic in elementary mathematics. The easier alternative, structured interviews based on selected topics, had to be given up because there were not a sufficient number of volunteers (exam period followed the term). However, interesting evidence is found in the test evaluation, done in writing during the exam period and with student replies being anonymous. Every student was informed on his/her pre- and post-test results. Three questions concerned the tests. In the first, students were asked if they improved their results in the post-test. Then in the second and third questions, students were asked to indicate reasons for the changes in their results and to comment how solving elementary exercises contributed to their progress. Students could give open field responses. As many as 25 students have responded; they can not be considered – representative but they represent strong opinion on the matter.

Here are some examples of the comments (translated from Hungarian):

My post-test results were better. We revised elementary mathematics knowledge during the term after correcting the first test with the teacher. When we wrote the first test we just came back from summer holiday, therefore I was under the effect of it and not prepared for the test.

I did not feel any considerable progress. I think it is because the geometry course did not contain practical knowledge to solve problems in the tests. I managed to solve some more exercises we discussed after the first test.

I was on teaching practice at the primary school during the term so I had to revise elementary mathematics knowledge for teaching. That may be the reason for a better second test result.

I felt progress in my knowledge. It would be useful for students if we could see connections between academic and primary mathematics. If we cannot apply our theoretical knowledge in practice then it is not worth much. We should solve more exercises at primary level and learn how to teach pupils to solve them while playing and enjoying the learning process.

Concluding remarks

This paper contributes to our understanding of how difficult it is to master mathematics concepts, problem solving strategies and methodology for students to become successful primary school teachers. Reasons for this difficulty are cited in the first two sections.

In today's education, the knowledge-centred approach is still dominant, often lacking a system approach, real-life applications. Practical knowledge depends on the teacher's ingenuity and theoretical knowledge often does not become a knowledge system. Often, results of exceptionally good teachers do not become a common value; they are usually isolated, and only their immediate colleagues can take over their experience. Teacher training should be more open to innovative pedagogical practice. A professional methodological collection could be created where good teaching practices can be easily disseminated online.

In our action research, we studied how successful it is to combine theoretical and methodological knowledge in the new curriculum. Considering the new curriculum, we hoped that students would develop a deeper understanding of the underlying concepts, perform better at problem solving and at teaching primary level mathematics. We introduced changes in the curriculum last year in our college. Therefore, only preliminary results can be revealed in this research.

However, there are primary school teacher training colleges in Hungary where the new curriculum has been used in the last few years. The author of this paper is interested in finding out if results of the students taught according to the new curriculum are better or if they are more successful. As a possible feedback, we considered results of a national mathematics competition. Last year, in 2016, the National Szendrei János Mathematics Competition was organised in Debrecen and students from Apor Vilmos Catholic College in Vác won. In Vác the old curriculum is applied where theoretical knowledge is taught in the first two terms and then methodological knowledge is taught separately. In the previous years, students from Eötvös Loránd University won. These results show that students from colleges with the new curriculum did not succeed better at this competition.

A possible explanation for this may be that students may not learn the theory as much as before because they cannot directly relate it to primary level mathematics and they do not consider it important and useful. However, their general problem solving skills would be improved if their theoretical knowledge could be expanded to higher level.

Our hypothesis does not hold, as the new curriculum does not mean progress in itself, unless carefully and well applied. More research work needed to find the potentials in it and to reduce the possible dangers. Perhaps introduction of the new curriculum was too fast and not substantiated scientifically.

These results show that it would be worthwhile to improve theoretical knowledge of students and not the curriculum. According to our research work where students' elementary mathematics knowledge was tested, we think that two minorities of students may be identified relatively to the results in figures 1 and 2.

(1) "the indifferent": students whose results did not change much in the post-test (with less than 20% difference), and did not feel much progress.

(2) "the challenged but helped": students whose results were better in the post-test (with more than 20% difference) and felt progress.

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(Received January, 2017)