17/1 (2019), 1–16
DOI: 10.5485/TMCS.2019.0454
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Teaching Mathematics and Computer Science

The transition problem in Hungary: curricular approach

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Abstract. The curricular background of the transition problem from highschool to universty is analysed in Hungary. While students finish their mathematical studies successfully at highschool, pass their final exams, this knowledge seems to disappear at their first year at university. We investigate the mathematical knowledge expected by the Hungarian universities and compare it to expectations of the National Core Curriculum. Based on the levelling tests of four universities we created a seven problem test for highschool students containing very basic problems required both by the universities and the National Core Curriculum. We analyse the results of the test.

Key words and phrases: transition problem, mathematical content knowledge .

ZDM Subject Classification: D34, D35.

1. Introduction, goals

The problems arising in the transition from high school to university mathematics are acknowledged in educational systems worldwide. This transition involves many interactions, among others social, institutional, mathematical content transitions (Alcock & Simpson, 2002). University and university mathematics are new worlds, where new rules are required to live by, which can make a freshmen feel like a foreigner (Gueudet, 2008). These new rules concern administrational, institutional and mathematical changes.

Other changes of several kinds affect students during the secondary-tertiary transition. These changes include the new academic and social environment as well as the shift required to a way of thinking and studying mathematics that differs from that promoted at school (Cherif & F. Wideen, 1992; Tall, 1992). In the new institutional environment students are adults, considered responsible for their decisions, including their choice of the way studying mathematics, moreover they are expected to learn independently (Biza et al., 2014). Using the Communities of Practice framework of Lave and Wenger (Lave et al., 1991) it is shown that there is a powerful interaction between social and institutional issues shaping students' initiation into a new practice of mathematics (Pampili et al., 2018). A "sense of belonging to math" (SBM) scale has been shown to predict undergraduate students' intent to study mathematics in the future (Good et al., 2012). It raises the question about the way the transition from secondary mathematics to university mathematics, affect high-achieving students' sense of belonging to math (Meehan et al., 2018).

A gap is almost always there between school and university mathematics content (Luk, 2005; Kajander & Lovric, 2005). All around the world there are bridging courses offered at many universities. The goal of these courses is to "build bridge" over the gap between the secondary-tertiary levels of mathematics. These courses are necessary, if the educational background of the students are diverse. (Brown, 2009; Panizzon et al., 2014).

In Norway secondary school students do not study sufficient mathematics, and even though the well-paid jobs require studies in mathematics, they still find it "hard, boring and irrelevant" (Hernandez-Martinez et al., 2011). The Norway Schhool system lets students to take most classes of their own choice. Similarly, in England (Noyes et al., 2011) possible factors that contribute to the drop in rate in mathematics among 11-year olds is examined. It is shown that students' attitude changed by their own experiences of their own classes and the way they were taught are the significant factors. The decline in the interest of students in studying mathematics and other science or technology subjects at school is observed in several other countries. In particular it concerns countries like Australia (Chubb, 2012) where the economy relies on the availability of sufficient highly skilled people. The Australian situation is even worse for STEM students (Gordon & Nicholas, 2013).

The transition is of particular interest in case of students who choose mathematics as a major. In fact, for the most part, they are students considered excellent in mathematics during secondary school, they seem to have the cognitive resources to succeed, but, in many cases, they encounter several difficulties during their university experience (Gregorio & Di Martino, 2018). The success and failure of Italian math major students are presented via introducing three groups: expected, unexpected and impotence towards university mathematics.

In this paper we would like to map the Hungarian situation, mostly concerning the gap. To import the international knowledge it is important to know the worldwide situation, thus our results can be useful for researchers of other countries. In Section 2 we analyze the transition problem in Hungary. It turns out that bridging courses are introduced by the universities, levelling tests are written by the students, but the results of these tests do not reflect the mathematics score brought from highschool. In Hungary most bridging courses are offered for prospective students of the fields of science, technology, engineering and mathematics (STEM), but these courses exist for students of economy, as well (Végh, 2012). In Section 4 an experiment is introduced in order to see where the assumed knowledge can be lost. We have investigated the levelling tests of four universities and the scores achieved by the students on these tests. Based on the critically poorly solved problems we created a highschool test. This highschool test is testing if highschool students were ever aware of the mathematical content of these critical problems. The test was written by 279 students in four different highschools. It was written by pupils of all grades to follow that at what age the assumed knowledge is fading away.

The conclusions are drawn in Section 6.

2. The map of the Hungarian gap of transition

Unlike in Germany or Australia or Norway, Hungary has a National Core Curriculum (NCC), by which “School education shall be a uniform pedagogical process within which the NCC defines the pedagogical content of school education broken down by subject areas” (*110/2012. (VI. 4.) Korm. rendelet a Nemzeti alaptanterv kiadásáról, bevezetéséről és alkalmazásáról*, 2018). It is accompanied by a framework that defines the objectives of education, the subject system, the topics and content of subjects, the requirements of the subjects (broken down by grades or two-grade periods), the tasks related to the development of cross-curricular knowledge and ability fields, and the obligatory and recommended time frame available for achieving compliance with the requirements on the basis of school types and phases of education. Thus after every two years all Hungarian elementary and highschool students are supposed to be on the same level of knowledge, skills and competencies.

Higschool studies are closed with a secondary school leaving examination, or shortly a final exam. This exam also serves as an entrance exam for the tertiary level. The score of the final exam counts at the entrance procedure to university. The mathematics final exam in middle school is obligatory for every student. Pupils can choose from two levels (middle or higher) of final exams. We can see that mathematics is "unpopular" by the number of the students who have chosen high level final exam of mathematics (5%). The tasks on the exam are highly predictable. The exam is preceeded by the highschool studies. In the Hungarian system students have to specialize before grade 11. They specialize in two subjects chosen individually. Specialisation comes with a higher level core material of the subjects. Mathematics is one of the most popular subjects in the system pupils specialize on. The standard classes have 3 math classes, the specialized ones have 5-6 math classes per week. The standard material is aiming for the middle final exam. Students can choose between the middle and higher final exam independently of specialisation.

Theoretically, universities' mathematics curricula are supposed to be based on the highschool curriculum. It is traditionally so. The traditions go back to several decades and most universities' curriculum is unchanged for the first few semesters of studies since then. Similarly to the abovementioned countries, in Hungary the mathematical knowledge of pupils exiting secondary education and entering tertiary level started to develop a gap. This phenomena was widely recognized at more and more universities since the early 2000s. This recognition resulted action, and this action was similar at most universities. First, a bridging course was designed. Secondly, a level-measuring test was introduced. The topic of bridging courses varied among the universities. The curriculum of a course was always that part of the NCC that the university required as a preliminary knowledge for its courses. At technical universities it involved mostly the theory of functions: roots, graphs, special functions, etc. For math majors it covered most of the curriculum from combinatorics to modelling problems via the theory of functions. At business schools special accent was put to proportional thinking, optimisation, etc. Hence bridging courses have to develop students' skills to the level of the final exam, and at the same time students have to start studying from that level. There is an obvious contradictions in this procedure. Namely either a student has to re-learn something he knew three months before or he has to start studying from a level he is just about aiming for. To resolve the first type of contradiction the solution of the universities is to introduce a level-measuring test. As its name suggests it is a test designed to decide whether or not the student is on the level to be able to proceed with his studies in mathematics. The result of the test, mostly pass/fail, is an indication to the students whether or not they should take the bridging course. This result is handled differently by different universities. At some places it is optional to take the bridging course, at other universities one has to pass either the level-measuring test or pass the bridging course. The pass/failure rate on the levelling test is very high at every university. This indicates that the theory that university curriculum is a continuation of highschool curriculum does not hold. There is a gap, this gap is universal and exists at every university.

3. Searching for the gap

The mathematics curriculum of universities in most cases are formally based on the NCC. This means, that except a few programs on university math classes the teaching can be considered as a continuation of highschool education. So, the first place to look at is whether or not this formal statement holds in real. The leading subject of our paper is the following: Is it true that university math education is a straight continuation of highschool education? There is a rather obvious way to decide: we look at the requirements of universities and compare it with students' knowledge. As we mentioned, formally the statement is true, students are formally prepared for tertiary mathematics. Our approach consists of several steps

- investigate the levelling tests of several universities,
- investigate the score of students problem by problem,
- find the critically unsuccessful problems,
- find the place of these problems in the highschool curriculum,
- check the knowledge of students on these critical topics,
- check the students' knowledge from grade to grade on these critical topics,
- find the place and time where the knowledge faded away or
- find that the knowledge never existed.

For this we contacted four major universities of Hungary. The University of Szeged (USZ), Budapest Business School, University of Applied Sciences (BBS), Budapest University of Technology and Economics (BME) and Eötvös Loránd University (ELTE). We asked for their levelling tests and their results. Each university kindly gave us all necessary information. We were given tests and problem by problem scores from the Faculty of Science and Informatics of USZ written by 600 students, 700 students from the Faculty of Commerce, Hospitality and Tourism of BBS, 400 students from the Faculty of Mechanical Engineering and Faculty of Natural Scineces of BME, 400 students form Faculty of Sciences ELTE, including math majors.

In all cases we compared the exercises with the NCC's requirements for the middle level final exam. Most problems of the levelling tests belonged to this curriculum, although only the BBS one was fully containing middle level problems. The proportion of problems not belonging to the middle level final exam was low in the tests of the other three universities, as well, and all those problems belonged to the high level final exam curriculum. Yet, students should have easily passed these level exams with their middle level knowledge without solving those high level problems in all three cases. Analysing the results of the tests we selected all those problems where the students scored below 50% as an average. There were several problem types that each university scored below 50%. We selected these problem types and they served as a base of our test. Each of our test problems originated from a problem type on which each university's students scored below 50 %. The surprising result was that all these problems required knowledge, skills and competencies form grade 10 according to NCC and its accompanying framework.

Then we have put together a test to check the knowledge of highschool pupils by the following

- the problems are based on the grade 9-10 NCC,
- the problems are based on the critical problems of the levelling tests,
- the test can be solved in 45 minutes (the length of a lesson),
- most (the first five) problems ask only content knowledge.

The first 5 tasks measured the acquired content knowledge. These problems (see below) were routine tasks that regularly come up when solving math problems, such that without them it would be impossible to solve the particular problems. For all of them very basic knowledge elements were requested. Hence, the grading of these problems in our research was a "yes or no" type of grading. Only perfect solutions were acceptable. The problems are all elementary on highschool level. So, the grading was a 0 or 1 point for each problem and only essentially perfect solutions were accepted. Problem 6 was a relatively easy text problem to check some reading comprehension. Task 7 asked for a proof, arguments. We were mostly interested in the pupils results on the first five problems.

The exercises were the following:

(1) Expand $(1-3p)^2$

(2) Make a product: $-4a-16a^4$

(3) Let $f(x)=-2(x-3)^2+5$

  (a) What type of function is $f(x)$?

  (b) What steps of transformation of function do you recognize and how do they change the graph of the function?

  (c) Draw the graph of the function.

(4) Subtract the following rational fuctions $\frac{4x}{(x^2-1)}-\frac{3}{5x+5}$

(5) Find the domain of $\sqrt{1-7x}$

(6) (a) What are the runs of a 10% and of a 6° slope of rise 100 m ?

  (b) Is the 10% or the 6° slope steeper?

(7) Show that the area of the parallelogram spanned by the midpoints of the sides of a convex quadrilateral is half of the area of the original quadrilateral.

4. Writing the tests

We wanted to find a small but sufficient amount of highschools to write the tests. The leading principle of choice were that the school

- should not be in the top or bottom 10 percent by any rankings of highshools,
- the admission rate to tertiary education is high,
- the math rating of the school is at the average of Hungarian highschools.

Rankings and admission data can be found on the homepage of the Ministry of Human Resources (*Emberi Erőforrások Minisztériuma*). For mathematical ranking of schools we chose the results of the National Competency Test, a test written every year by all pupils of grades 6,8,10 of all schools. In 2016/17 it was written in 2635 schools by 264 546 students, among others 84 957 of grade 10 pupils form 696 highschools (*A kompetenciamérések eredményei*). The same test was written in all schools at the same time. We selected four secondary schools fulfilling the criteria, Nagy László Gimnázium, Babits Mihály Gimnázium, Jedlik Ányos Gimnázium, and II. Rákóczi Ferenc Gimnázium. The sample of schools was not representative in any other means, except that all four were exactly at the Hungarian average at the mathematics competency tests results.

5. Evaluation

The tests were written in grades 10, 11 and 12 of the schools, where the following information was requested from the students:

- school,
- grade,
- type of math program (standard/specialised)
- number of mathematics lessons (45 minutes each) per week
- last year's grade in mathematics (2, 3, 4, 5, 5 the best, 2 the worst)
- highschool type (4, 6, 8 year program, depending at which age shifted the pupil to secondary school)

The test was written by 279 students, 35 of them have not filled in the statistical information. So the evaluated sample contains 244 tests.

Statistical data of the 244 students:

Number of students of grades 10-11-12 were 53, 94, 97, respectively. Number of students by type of program: 80 standard, 164 specialised. The distribution by lessons per week is the following: 3 lessons: 107, 4: 90, 5: 22, 6 lessons: 24. Last year's rating 2: 27, 3: 63, 4: 84, 5: 70. Number of years of training involved, 4: 71, 5: 61, 6: 11, 8: 101.

The χ^2-independency test on each problem showed that the scores on the problems depended on school. In all problems the students of Babits Mihály Gimnázium scored best. The data sheet showed that, unfortunately, the pupils from Babits Mihály Gimnázium were only students of grade 11-12, all participating in the strongest 8 year program and all studying high level mathematics. As in that highschool there was no data on grade 10 and standard level students, we omitted all their data from our analysis. The remaining 213 pupils showed a variety between schools, types of program, etc. No school had a leading score in more then two problems by the Tukey post hoc analysis. The results on the tests can be seen on Table 1. We omitted the scores of problems 3c, 6 and 7. Problem 6 and 7 were rather unsuccessful, they were solved randomly by very few pupils. The answers for 3c were too diverse and too decipherable.

As we wrote before, the remaining problems were given 0 or 1 points depending whether or not the problems were properly solved. Table 1 contains the averages of the scores of the students by grades and levels. The colomns represent the numbers of the problems. The rows represent the grades and specialisation. Specialisation means that the particular class studies mathematics on a higher

year	1	2	3a	3c	4	5
10 standard	0.73	0.54	0.81	0.48	0.12	0.27
11 standard	0.36	0.58	0.73	0.25	0.11	0.22
11 spec	0.50	0.73	0.82	0.55	0.41	0.27
12 standard	0.60	0.79	0.77	0.29	0.25	0.23
12 spec	0.71	0.93	0.93	0.50	0.50	0.79

Table 1

level in grades 11 and 12. They have a stronger, so called raised level curriculum and have 5-6 math classes per week. Standard means the usual curriculum, studying mathematics 3 classes per week. The entry of the table is the average score of the particular age and study group on the particular problem. For example the 2nd line's 5th entry means that problem 4 was solved by 11% of the grade 11 students studying standard curriculum. Note that the averages expected by the National Core Curriculum are close to 1.

The first observation is that all scores except very few are much lower than the expected one. These very few are the 0.93 scores on problems 2 and 3a for the 12 specialized classes. So, we can say that pupils mathematical content knowledge have never even approached the knowledge expected by universities and at the same time required by NCC. Further investigations show by clustering for all six problems' scores that the 12 specialized pupils knowledge is the highest followed by the indistinguishable triple of groups 10 standard, 11 specialized and 12 standard and at last and worst the 11 standard pupils.

To answer our original question about the existence and loss of the mathematical content knowledge we made comparison analysis for the age groups using the General Linear Model of SPSS program package for every problem. There is no significant difference between the six groups on problems 3a and 3c. The students correctly recognized the type of the quadratic function, but less then 55 percent could draw the function at every age group. The scores on Problem 4 on the subtraction of rational functions were below 50 percent at each group, hence we can say that students never handled properly algebraic rational expressions. More group by group analysis is senseless. For problems 1, 2 and 5, where significant difference were found, a Tukey posthoc analysis was done. In problem 1 the results of 10 standard, 12 standard and 12 specialized scored the best, significantly better then the other two groups. In problem 2 the scores were ranked as "expected". Unfortunately all but one groups scored below 80 percent. In problem 5 only the 12 specialized group scored significantly different from the rest, namely 0.79. All other 5 groups scored below 30 percent.

The same statistical analysis was done for the best pupils, the ones whose last year's grade was 4 or 5. Surprisingly the same results were found. Both on the clustering and the post hoc tests. At several places the scores were slightly higher and at a few places lower than the overall score. The scores on problems 4 and 5 remained below 50% and 40% respectively.

6. Discussion

The results of the tests show that in most routine exercises the students' knowledge either never existed or, if existed, it faded away. The track in the change of the scores on problem 1 shows that pupils knew the material at grade 10, when they learnt it, forgot it at grade 11 and then relearned it for the final exam in grade 12. Following the curve it is no wonder that they forgot it again for the first year of their university studies. If they forgot it in a year from grade 10 to 11 then there is no reason to preserve the knowledge form grade 12 to first year university. This phenomena is not new. The number theory material – gcd, lcm, divisors – totally disappear from the mathematical arsenal of pupils from grade 9 to grade 12 (Csányi et al., 2015).

Both problem 1 and problem 2 are typically coming up in problem solving on every level of math studies. The scores on problem 2 do not reach 80 % except for the 12 specialized group.

Problem 3 shows that pupils can recognize the type of a function, but they are not on the level of conceptual understanding. Quadratic functions are typically the first nonlinear functions they meet. Not being able to handle quadratic functions predicts the difficulties with other, for example exponential or trigonometric functions, as well.

The scores on problems 4 and 5 are critically low. These problems come up in several problems as subroutines. Simplification of expressions similar to Problem 4 routinely come up both in algebraic and word problems. To find the domain of a function, as in Problem 5 is obligatory in the analysis of any kind of function showing up in any kind of math question.

Clustering showed that the grade 11 group has a lower knowledge, even in case of pupils achieving grade 4 or 5. The ANOVA method showed that no particular problem caused the clusters more than the others. This means that they scored below of other age groups in overall.

Looking for the reasons several questions can be raised. One question is that why pupils do not know the material if it is in the NCC. Or, how is it possible to obtain good grades if someone does not know the basics? One answer might be that pupils are not taught the full material of NCC. Instead they learn those parts of mathematics that are predictively coming up in their final exam. The scores on the final exam are stressful for every participant of education: pupils carry their scores on the final to the university entrance procedure. Teachers at school are measured by the success of their students on the final. And schools are rated, among other parameters, by the same score. Hence it is a common interest of all parties to prepare for the final exam. The mathematics curricula is retaught and repeated in grade 12, second semester, this is why we experienced a higher knowledge at that age group. In an earlier experiment grade 9 pupils managed to score perfectly on the finals' problems on graphs after a 4 lesson training (Kovács, n.d.2017). As our results show this is not a result for eternity, it is just a short time knowledge.

An other explanation could be that when pupils are taught the material, they achieve a procedural level, where they can write a test appropriately. The prcoedural level is achieved by practicing for the test. There is no possibility, no time for further studies or knowledge-testing. All parties think by a one-time test that pupils know the material. At the same time they do not conceptually understand the material, and the practicing effect is fading away and later diminishes. Later pupils become totally unable to handle these problems. How can it happen?

The answer is very well explained by latest results of memory and brain research. In the Hungarian (and most European) school systems recalling the material happens only at tests that are announced well in advance. This happens usually when the class is finishing and changing topic for example from geometry to sequences or from combinatorics to functions. Then a midterm or test is written. The pupils have a summary lesson and soon after the summary lesson they write the midterm. In this setup fMRI investigations of the brain (M Bradley et al., 2014) show that the knowledge is stored in the short time memory section of the human brain and disappears form there in few (mostly in 2-7) days. This is the same effect when one remembers a phone number or an address, or a waiter remembers the list of orders for a short while and after as the information is not used it is lost. This study method makes the illusion that the student knows the material not realizing that the knowledge is stored in the wrong compartment of his brain. Recalling the material with a retention period helps to put the knowledge into the long term memory. In Cepeda et al. (2008) it was proved, that learning for a test from the point of view of a student's score is the best if he studies right before the exam. At the same time it is not helpful for a long term knowledge. In their experiments they examine the connection of the retention period with the amount of the long term knowledge. Assume a student can study the material twice before the test. Then, for a best score, as we suggested, the best strategy is to study twice right before the day of the exam. For a long term knowledge the situation is totally different. For example, if the student has to recall the material twice, than only one study period should be right before the first exam, the other one much earlier. Results with four study periods are also investigated. Among others it turns out (Kang et al., 2014) that if you write a midterm 30 days from the first study period and an exam 3 months later, then the best strategy is to study on the 1st, 3rd, 9th and 28th day (yes, this is a geometric progression) for a best score. Depending on the study intervals a forgetting surface is described. It is also proved (Kang et al., 2014) that long term knowledge can be assured only by cumulative tests. This means that for example that in a test on functions we put questions a the previous topics, similarly, in grade 11 we ask some grade 10 and a few grade 9 questions, as well. This means that the retention periods can be longer and longer, the amount of the tested material can be less and less, but this method ensures a long term knowledge.

Our results on these unexpected tests are parallel by the above explanations. Pupils can get good grades on tests without gaining long term konwledge. Practicing for the grade 12 final exam recollects the material in the short term memory again. They score reasonably well. So the grade 12 summary of the four year material is just a simple restudy and does not really contribute to a long term knowledge. Thus only a short-lived ability is gained that, as it came, disappears during a summer.

The transition problem is more complex as to answer in Hungary after a curricular investigation. There are several solutions, but first the goal of math education should be decided. If it aims for a long term knowledge, then cumulative problem sheets and cumulative tests should be written. The grading scheme has to be changed, because in this case the short term knowledge decreases to 60-80 % (Kang et al., 2014) and the long term one is increased by far. Textbooks can be reorganized. After every session the practice problems should contain more questions about earlier topics and less about the recent ones. This strategy, if well designed could provide with a predictable and sustainable knowledge of students.

Our few examples show that the origins of the problem exist already in highschool and exist on the curricular level. A next step could be to apply the abovementioned strategies in highschool. A step to investigate the fadeaway math content knowledge could be to see if the NCC is spiral enough. Then to check if the textbooks follow the spiralty, and to see if math teachers in highschools really follow the suggestions of the NCC.

Acknowledgements

The research was supported by the National Research, Development and Innovation Fund of Hungary, financed under the FK 124814 funding scheme.

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(Received August, 2018)