

Essay

# Changes in Mathematics Core Curriculum and Matriculation Exam in the Light of the COVID-19-Shock

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**Abstract:** The new National Core Curriculum came into force in September 2020 in Hungarian schools. The COVID-19 pandemic has had a deep impact on the final stages of its development. In this paper we have selected two areas for analysis: the fundamental principles of mathematics curriculum and the matriculation exam in mathematics. We propose improvements in both fields, further emphasizing the importance of skills in displaying, understanding and processing information, including visual information obtained as a source or outcome of a problem. We argue that representation, interpretation, and critical evaluation of data and information must be essential parts of the mathematics curriculum. In this context, we also propose a new type of task for the matriculation exam: a complex essay task. The ultimate goal is the development of cross-cutting competencies to support students to become citizens who can make responsible decisions based on the data and knowledge available.



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## 1. Introduction

For more than 10 years, family members of the first author have been marking the beginning of spring every year in mid-March with the first child's birthday party. We set a date for this months earlier, the invited families adjusted their other programs accordingly; it has never been missed since 2009. In 2020 we announced the event for 14 March.

The first case of coronavirus was detected in Hungary on 4 March 2020, and on 11 March, the number of confirmed infections increased to 13. On this very day, the government ordered an emergency situation: restrictions were imposed, and the closure of universities, sporting events, and larger community events was ordered. Nevertheless, on 12 March, two days before the scheduled party, I wrote a joking email to those invited, figuring out official information about the precautions to be taken during the meeting.

Finally, on the early morning of 13 March, I found an article [1], read it, and immediately cancelled the party. I also sent the article to everyone to justify my decision. It turned out that the invited families were unsure as well of what the right move was, so my decision was a relief to everyone. Of course, there was still a difficult task left after the cancellation: to explain the background of the decision to my 11-year-old daughter.

That evening, the government ordered the closure of educational institutions and later introduced further strict measures similar to most European countries. The first virus-related death was reported on 15 March. On 10 June 2020, there were a total of 4000 confirmed infected people in Hungary, of whom 550 died. In the beginning of June the strictest restrictions were relieved, the written part of the matriculation exams was held in secondary schools, but life could not yet return to normal.

A crucial question has arisen: how could that particular article convince the reader and help him or her to make the difficult, but right decision? How can other members of society be made to make the right decisions in such acute situations? What could be the role of school and within that the teaching of mathematics in all this? How can we turn this pandemic, tragic situation to our advantage? Should the content and/or form of teaching mathematics be redesigned, and if so, what (new) emphases are needed in the curriculum? Based on the research, we see that the mathematical correctness and interpretation of the news is a clear challenge for society and thus for education [2], especially in the so-called post-truth era [3]. This especially holds for graph interpretation, the classical representation method of COVID-19 data (for a survey, see [4]). It is also known that everyday statistical analysis still does not receive sufficient attention and is inadequately included in math curricula [5].

We would like to address such issues in this paper. In Section 2 we give a brief overview of past and present situations related to the mathematics curriculum and the matriculation exam in Hungary, while in Section 3 we present new ideas and initiatives about these topics, deeply affected by the pandemic.

## 2. Some Aspects of Teaching Mathematics in Hungary

It would be an impossible task to deal with every detail of education, or even within the teaching of mathematics, that will help answer the above questions and that may be affected by the current situation. Therefore, we selected two well-defined and question-relevant areas for our analysis: the mathematics curriculum and the matriculation exam in mathematics. (By matriculation exam—in other words Abitur, matura, baccalaureate, exit examination, final exam—we mean an exam that is organised for those who leave secondary school at the age of 18 or 19.) In this chapter after a brief general overview, we will carry out an analysis of the situation in Hungary in these two areas in order to provide a sufficient basis for our related proposals for the post-COVID-19 period.

### 2.1. Expectations and Reality

The importance of mathematics and the importance of teaching mathematics has been recognized in every era and every culture. Mathematics is a fundamental, important and valued subject, both in terms of the image of culture, its application as a practical tool, and the modern needs for the development of various competencies. This is also the case in Hungary, where mathematics appears already in school readiness tests [6], and later in all areas of public education where some kind of measurement is taken: competency measurement [7]; secondary school entrance examination [8]; and matriculation exam [9]. In addition, a high degree of mathematical knowledge is required in many areas of higher education, e.g., natural sciences, engineering, informatics, economics [8].

Accordingly, there are high expectations in Hungary regarding the goals of mathematics teaching: 'A fundamental goal in the development of students' mathematical thinking is to be able to select and apply models and ways of thinking (analogical, heuristic, estimation-based, mathematical logic, axiomatic, probability, constructive, creative, etc.), methods and descriptions that fit natural and social phenomena. Learning of mathematics can lead to an understanding of its role in the natural and social sciences and in many fields of human culture. It helps to develop the need to prove the formulated connections and hypotheses. This can show the usefulness of mathematics, its inner beauty, its role in human culture. At the end of the process, students reach a certain level of independent, systematic, logical thinking. Students are required to use the technical language in an age-appropriate, accurate manner, and to use the notation system correctly, both in writing and orally. Through problem-solving, the learner can become capable of accurate, persistent, disciplined work.' (Citations from the Hungarian National Core Curriculum (2012)).

However, high expectations are not accompanied by adequate results. Based on the Hungarian and international measurements of recent years, we cannot say that the aforementioned goals have been achieved, even approximately. In 2019, nearly 15% of

students in the matriculation exam in mathematics did not pass the written exam, and more than 40% passed the exam, but received the lowest mark possible [10]. In the 2018 PISA measurement, the OECD average was 489 points in mathematics, with a standard deviation of 91 ability points. With an average score of 481 points, Hungary was 8 points behind the OECD average [11]. However, in the 2015 TIMSS measurement, both 4th- and 8th-grade students achieved above-average results [8]. The difference between the results of the two international measurements can be explained by the fact that the subject of TIMSS is closer to Hungarian mathematics teaching traditions: it places more emphasis on measuring mathematical knowledge than on applying it, which is at the heart of PISA.

## 2.2. Mathematics Curriculum—Past and Present

The Hungarian mathematics curriculum has undergone many minor changes in recent decades [8], but its content has not changed fundamentally and in essence. The last decades have brought some expansion in the topics of mathematics education: the basic elements of graph theory, statistics and probability have appeared in the curriculum and in the examination requirements.

At the same time, it is important to point out that while 100 years ago (in 1920) in Hungary approximately 4% of the 20–24 age group passed the matriculation exam in a secondary school, in 2011 the same proportion was about 60% [12]. This means that we currently have roughly the same (and in some areas more extensive) requirements for the 60% of the population than we previously set for the (presumably best) 4%.

Last but not least, the data show that the number of lessons of mathematics in Hungary has declined by approximately 20% in the last 40 years [13].

As a result of the above, a high tension has developed in mathematics education in Hungary in recent times: more and more curricula have had to be mastered by an ever-widening range of students, in increasingly less time. Therefore, we should not be surprised that, as we have previously stated, there is a large discrepancy between expectations and results. These phenomena also contributed to the development of a new National Core Curriculum started in 2017, followed by the development of new textbooks. The new National Core Curriculum will come into force in September 2020 in certain grades in Hungarian schools.

One of the main goals of the curriculum development work was to reasonably reduce the lexical knowledge, and in parallel to increase the presence of the so-called cross-cutting competencies, in the curriculum. The final stages of the development were strongly influenced by the unusual learning requirements that have characterized the COVID-19 pandemic situation. Several crucial cross-cutting competencies have already been identified in mathematics, or more broadly in STEM education: communicating, investigating, modeling, using tools, understanding and working with data, making sense of problems or phenomena, solving problems, and evaluating ideas or solutions [14]. However, these have appeared to a very different extent in the Hungarian mathematics curriculum so far, and they often played only a marginal role in education. While our mathematics education has clearly shifted in recent decades toward developing the explicit mathematical competencies required by the job market, regular development of these cross-cutting competencies, particularly the basic skills needed to support students to make independent and responsible decisions, understand data, information, and processes has not become an integral part of the curriculum. The need for this is not new: the European Commission has been drawing attention for more than a decade ‘to equip citizens with the tools they need to make informed decisions about their health’ [15]. This argument is still in the forefront of European policy initiatives and communication. The experience of the COVID-19 pandemic has further reinforced the relevance of these cross-cutting competencies and the essential need to develop them. From this point of view the situation in Hungary is special and fortunate in that the pandemic reached the country during the development of the national framework curriculum and the related student and teacher materials. In addition to the core problems, this special situation provides an excellent opportunity to reinforce

the appropriate emphases in the mathematical curriculum. Of course, we are also aware that curriculum reforms always bring a certain amount of anxiety amongst teachers [16].

### 2.3. Matriculation Exam—Past and Present

Before 2004, the matriculation exam after secondary school and the entrance examination required for admission to higher education institutions were separated. In the mathematics matriculation exam the tasks had almost exclusively a purely mathematical content, did not require real modeling, and were not related to everyday life or practice. The mathematics tasks of the entrance exams were prepared in a similar spirit [17]. Clearly, the type of graduation and admission assignments fundamentally determined the content of mathematics education in schools.

In 2005 the matriculation examination system changed. (this was when the new curriculum—implemented in 1998 and characterized by the growing importance of modeling and the application of mathematics—came into practice in schools.) University entrance exams were abolished and a two-level matriculation exam was introduced instead. The matriculation exam is uniform and standardized (students of different secondary school types take the same exam) and students can choose between basic and higher levels for each subject, according to their intentions for further studies. The development of the exam was also accompanied by a high degree of content modernization: the content change of the National Core Curriculum, which reached the level of the classrooms only with little efficiency, could be enforced more effectively by means of educational output control [18].

The detailed examination requirements valid from 2005 introduce new content in the examination (both at basic and higher level): graph theory, mathematical statistics and probability can be considered as completely new elements, as well as the emergence of analysis at higher level, while thinking methods, mathematical logic and combinatorics have become significantly more important than before. In addition: about half of the tasks have to be related to everyday life, and require modeling competencies. The analysis showed that solving the tasks belonging to the new topics did not cause significant difficulties for the students, but we have to mention the fact that these tasks were not particularly difficult problems [19]. For example, statistical tasks usually require only the mechanical calculation of means and standard deviations, the reading of data from simple graphs, and the creation of graphs based on data. Interpretation and evaluation of the data obtained are not expected, and although it is part of the examination requirements for the candidate to be able to compare datasets using the statistical indicators learned, this type of task has been included only once among the basic-level tasks of the last 15 years.

### 2.4. About a Matriculation Exam Problem

A specific example and its solution and the ‘message’ of the tasks are presented below. The task had to be solved by students graduating at higher level in May 2017. Looking back, it seems as if the committee compiling the mathematics matriculation exam in Hungary has seen the future. Task 8 of the 2017 exercises is strikingly closely related to our current life situation in 2020, it consists of three parts, and each part is about a current issue of a fictitious epidemic.

The first part of the task was:

‘During an epidemic 0.2% of the population of a big city became infected by a virus. At one point in time, 80 people living in the city travelled on the same bus.

(a) Calculate the probability that at least one person out of the 80 travelling on this bus is infected. Round your answer to two decimal places.’

Solution: the probability that a randomly selected resident is not infected is 0.998.

$P(\text{among 80 people there is at least 1 infected}) = 1 - P(\text{no one is infected}) = 1 - 0.998^{80} \approx 0.15.$

The message is clear: even if only 2 per thousand of the city’s population is infected, there is still a 15% chance of finding an infected person on a full bus. Therefore, even with

low levels of infection, public transport vehicles should not be allowed to be congested: even if there are few passengers, the frequency of public transport must be maintained.

The second part: ‘Models, describing the spread of the epidemic in the city, forecast that each day the number of people infected will increase to 105% of the number of people who were infected the day before.

(b) How many days would it take until the percentage of the infected population rises from 0.2% to 1%, assuming the epidemic spreads as predicted by the models?’

Solution: denote the number of days by  $x$ , then  $0.2 \cdot 1.05^x = 1$ , of which  $x \approx 32.99$ , so the ratio of infected people would reach 1% of the total population in about 33 days.

The lesson is that even if the spread of the epidemic seems slow at first, the number of people infected will increase fivefold in a month. Similar to the task, the growth rate of infections in most countries was initially exponential. The peculiarity of the exponential function is that the growth, which seems to be slow at the beginning, can suddenly accelerate.

The third part of the task provides the most interesting conclusions.

‘A test, sold in pharmacies, promises users to quickly reveal whether they are infected or not. The description says: The test positively indicates infection at 99% probability for users truly infected. The test is also known to falsely indicate infection in case of users not infected. However, the probability of such false-positive result is only 4%.

(c) It is known, that 0.2% of the total population of the city is truly infected. A randomly selected citizen living in this city is being subject to the above test and the test indicates infection. Show that the probability of the person being truly infected in this case is less than 0.05 (and the test is, therefore, unsuited to reliably indicate infection).’

Solution: suppose there are 2 million people living in the city. According to the text, 0.2% of the population, i.e., 4000 people, are infected and the remaining 1,996,000 people are not infected. If everyone were tested, 99% of the 4000 infected, or 3960 people, would (correctly) test the infection. At the same time, 4% of the healthy population, 79,840 people, would (false) test positive. Therefore, we will have a total of  $(3960 + 79\,840 =)$  83,800 positive tests, but only 3960 of them are actually sick. So in the case of a positive test result, the probability of actual infection is only  $3960/83,300$ , which is approximately 4.73%, so really less than 5%.

The result is almost unbelievable for most students: the test promises 99% accuracy in detecting infection (and also gives a false positive signal in only 4% of cases), yet with a positive test result, the test subject is less than 5% likely to be infected.

Assessing the task and the solutions, we must conclude that, on the one hand, it raises important issues that affect our everyday lives these days, and on the other hand, we cannot be sure that the edifications described after the solutions will be available to those who solve the task. We will return to this question at the end of our paper.

### 3. Opportunities Due to the COVID Shock

In the former chapter, we have reviewed the current situation in Hungary from the point of view of the mathematics curriculum and the matriculation exam, both of which have a great impact on school education. A brief presentation of these was essential for the reader to understand our suggestions below in the same areas.

#### 3.1. Opportunities and Difficulties

As far as the opportunities posed by the COVID-19 epidemic are concerned, this situation can be compared to the so-called Sputnik-shock. It is well known that educational reforms began in the U.S. in the late 1950s as a result of the Soviets launching a satellite in 1957 ahead of them. As Herold shows [20], educational reforms were not only the result of the first satellite launched by the Soviets, there were earlier steps in this direction, but the press and social repercussions of this event gave a political impetus to political leadership that made these processes irreversible.

COVID-19 may launch similar effects. Apart from the tragedies, the epidemic is also an opportunity: in such unexpected situations, former rigid systems can become more easily

transformed. (It is enough to think about how many years, how much money it would have taken for us to systematically change our school education to distance education. The pandemic situation had made it necessary for us to implement it over a weekend, although the implementation was not perfect).

Beyond all that, we also know that standard mathematical tests, whether national or international, may need reform [21], and the pandemic has now created a special opportunity to rethink this.

As for the difficulties associated with the proposals described in the next two sections, these are also numerous. We will highlight only one of these here, but perhaps this is the most important: the technical and conceptual difficulty of introducing any changes to the curriculum. Implementing a well thought-out curriculum change into the public education process that takes into account all possible aspects of education is a very long and complex process. Formulation of the concept of change, compilation of the new curriculum, its implementation, transformation of teaching materials (e.g., textbooks) suitable for the changes, further training of teachers, introduction of the new curriculum to the educational system, adjustment of different exams—this could take overall up to 10 years. A related problem is that the rapid and accelerating change of the world requires the development of a flexible curriculum system that is able to respond more quickly to these changes. Thus the situation caused by the epidemic may transform our attitude towards this difficulty.

A short story presents the difficulties of changing attitudes very well. Due to the new National Core Curriculum (NCC), textbooks and exercise books will also be revised. An important element of the new NCC, is that we expect students not only to solve mathematical problems, but also to answer certain questions in their own words, expressing their opinions. Thus, the revised books also include tasks that begin with turns like this: ‘What do you think of the following question?’, ‘What do you think is the right answer?’, ‘What do you suggest to the person in the task?’. Books revised in this way are reviewed by an expert from the Educational Authority, without whose support, textbooks cannot be published. The expert gave the following opinion on these types of question: ‘The questions should not start with “What do you think” or “What do you suggest”, because in this case all answers should be accepted.’

### 3.2. *What Should and What Should Not Be like the Mathematics Curriculum?*

In general, countries change their mathematics core curricula for two reasons: because of poor student assessment performance in international comparisons [22,23] and/or because young people leaving school are insufficiently prepared for the job market in the interests of that country (see, e.g., [24,25]). Of course, these are by no means the consequences of the curriculum, yet changing the curriculum is a common answer to these problems [26].

We believe that the primary fundamental goal of mathematics education is to satisfy the interests and inquiry of pupils of age 6–18. Thus further economic, political interests, the interests of teachers, school principals, politicians and further policy makers, business people, university professors, parents can be taken into account only after that primary aim when designing the curriculum.

Of course, one of the most important tasks is to formulate what the interests of the children indeed are. In our view, the following goals of mathematics education meet the interests of children.

- (1) The curriculum should give a taste of the nature and occurrence of logical thinking in various fields and circumstances (e.g., in science, during playing games, arguing, when operating a computer).
- (2) The curriculum should demonstrate the role of mathematics in natural sciences, economics, technology and arts. Children need to understand that mathematics is a concise, precise language that may help to describe, understand and articulate human activities in these fields, but mathematics is not equal to these activities.

- (3) The curriculum should provide a taste of problem solving and decision making. Every pupil facing a problem in his/her life should be able to responsibly decide whether he/she (alone or with his/her teammates) can solve the problem with the tools and data available, or should ask for external help.
- (4) The curriculum should give a taste of the limitations of the role, power and applications of mathematics: not everything can be evaluated and quantified through mathematical tools. There can be real-life problems with multiple, perhaps logically contradictory solutions.
- (5) The curriculum should promote the development of pupil's independent, critical thinking, educating them to be citizens who can make responsible decisions based on the data and knowledge available.

We intentionally used the phrase 'give a taste' above. Indeed, perhaps the biggest mistake in Hungarian mathematics education is that we want to discuss the content to be learned 'completely', and by this, most children finish public education in a way that they do not really understand, and do not really like maths.

Accordingly, the purpose of core mathematics education cannot be the following.

- (1) The core mathematics curriculum does not need to contain rigorous axiomatic structure, nor a complete technical discussion of any part of mathematics.
- (2) The core mathematics curriculum does not need to prepare the pupils to study university mathematics, which might be necessary later for an engineer, a doctor, or a scientist. On the contrary: university education needs to be adapted to pupils, and the more specialized university mathematics needs to be adapted to their general mathematics knowledge learned in high school. Admittedly, this means that university mathematics education will start more slowly. Rethinking university mathematics education is beyond the scope of this paper, but from this viewpoint it also contains elements that need to be renewed.
- (3) The core mathematics curriculum does not need to fully satisfy the hunger and aspiration of children gifted with special mathematical interest or talent. The task of different schools is to organize special classes and special forums for such children, but the core mathematics curriculum aimed at mass education has no direct talent support aspect.
- (4) The core mathematics curriculum does not need to satisfy the current needs of politics, economy, such as filling jobs requiring mathematics, or developing technical skills in a narrow sense (fast calculation, statistical estimation, high computer skills). Such needs exist, but should not significantly change the universal view and the actual content of mathematics taught in school: they should not make it more targeted, more job-oriented, and most importantly, they should not increase the material to be learned. Nor is this because we do not know exactly what students will need in 15–20 years.

### *3.3. Processing and Interpreting Data and Information in the New Curriculum—Methods and Techniques*

As mentioned earlier, there were no or just marginal expectations in our previous mathematics education in terms of representation, interpretation, and critical evaluation of data and information. We intend to change this significantly in the new curriculum and in the new textbooks, so when redesigning them, we strive to show the problem of critical processing and evaluation of information and the need to interpret the conclusions and results drawn from the data in as many topics as possible.

The core curriculum so far has focused more on the precise determination of the degree of technical knowledge (calculation procedures, solution algorithms) belonging to each sub-field, as well as on the development of modeling skills.

The new core curriculum declaratively describes only the minimum required level of technical knowledge, but also pays attention to the horizontal appearance of everyday life, not strictly mathematical problems, and to the importance of displaying, processing and

interpreting information obtained as a source or outcome of a problem. We consider the presentation and interpretation of visual information to be an extremely important area in the development of these competencies. The crucial importance of visibility is spectacularly demonstrated by the everyday communication related to the pandemic. Visual information is primary in many media channels, and the article mentioned in the introduction also builds heavily on graphs. Among the COVID-related websites considered authentic, some, e.g., the website of Johns Hopkins University [27], to which the Hungarian government site also refers, contains little textual information in addition to the extremely strong and varied visual presentation of data.

With all of this, our goal is to teach students to accept information from a credible source and to suspect the less credible. Referring back to the specific case mentioned in the introduction: in order to act responsibly in possession of the information, one should be able to understand an article on a pandemic, critically interpret the information contained therein and decide on a specific issue that may be of particular concern to him/her. Moreover, some students might even be able to interpret the available information more thoroughly and write an authentic epidemiological article (of course at his or her own level) based on the data available.

The first step in this is understanding the data and further information. As mentioned earlier, much of this now reaches pupils in the form of visual information. There is a long philosophical and pedagogical tradition of interpreting and examining visual information and visual thinking (for a good overview of the fundamentals of the field see [28,29]).

The importance of pictorial information has been common pedagogical knowledge for decades, and there are even trends that it should be the primary source of information and interpretation, in line with children's media consumption habits [30]. However, this was embraced little by Hungarian and Eastern European mathematics education. The presentation and consumption of information about the pandemic, as well as its interpretation and misinterpretation, points out, above all, that mathematics education must also adapt to this evolutionary turn.

Accordingly, data interpretation and data visualization are introduced as new elements in the curriculum and textbooks, primarily as the discussion of the advantages and drawbacks of different graph types, visualization methods (bar graph, pie chart). A novelty in Hungarian mathematics curriculum is the knowledge of the creation and interpretation of box-plot diagrams, through which we give students a new tool to facilitate the interpretation of data and the comparison of different data sets. Recognition, interpretation and correction of misleading graph errors through concrete examples are also in the forefront of these new initiatives. We approach this problem from two directions, the constructive and the interpretative directions.

The constructive direction is the selection of the appropriate data visualization method for the raw data and its correct implementation, which also helps to deepen the necessary technical knowledge. Thus, it is not enough to perform the calculation correctly and to announce the result briefly and declaratively, but to find and implement the interpretation that best suits the given problem.

We illustrate the change with a simple example. In the teaching of mathematics, the final stage of solving a problem so far has been the correct completion of the calculation procedure, the achievement of the final result in the mathematical sense.

In the case of word problems, we have so far required a brief textual description of the result (typically formulated in a single sentence) and a declarative interpretation corresponding to the original text. As an example, consider the following simple task: 'Alexandra has three apples, Bob has one more, and Cecil has as many as Alexandra and Bob together. How many apples does Bob and how many does Cecil have?' First pupils have to solve the mathematical problem and secondly they have to interpret the mathematical results at the end of the calculation with one sentence: 'Bob has four apples; Cecil has seven apples'. This usually results in two problems. On the one hand, children regularly forget the step of interpretation, after rejoicing at the result of the count. On the other hand,

the typical teacher attitude is that when thinking of this step as ‘non-mathematical’, the instructor does not consider this omission to be a significant mistake. Remaining with the example, if the task is worth 10 points, failure to answer in words will result in a deduction of only 1 point, since the student performed the mathematical calculation correctly.

The new curriculum and textbooks should place a much greater emphasis on displaying and interpreting the result upon completion of the ‘mathematical work’. Students need to be equipped with the right tools to choose the most appropriate method to display the outcome: simply draw three heaps of apples, possibly summarizing the results in a bar chart or just a pie chart while interpreting the quantitative relationships in several sentences.

Here we arrived at the second step, which is the interpretative direction. In this case students have to explain and comment on information coming from various sources: numerical or geometric data resulting from the solution of a task, possibly a data set displayed by a graph or a figure. Moreover, a further crucial aim is to assess the consistency and authenticity of the data and the textual interpretation attached to them. In fact, this does not require new technical and mathematical knowledge compared to what is known by the students, but what they need to possess and develop in particular are the language and interpretation skills related to mathematics and information.

Remaining with the previous example: students should attach different interpretations to the result and evaluate and elucidate them. For example, what about the interpretation that ‘since all three children have only a few apples (under 10) and the difference in the number of apples between any two children is not greater than four, the difference is negligible’? Could we formulate a radically opposite interpretation of the data that just emphasizes the differences?

These types of exercise have so far been lacking in mathematics education in Hungary, although they are excellent for developing both data interpretation and communication skills, as we need to convince our colleagues of the correctness of our interpretation. Central to this is the clarification that there is no perfect, exclusive interpretation, even if the solution is unique in a mathematical sense. Demonstrating the limitations of mathematics, understanding absolute and relative, and emphasizing its importance is a new (and perhaps surprising) key aspect of the mathematics curriculum. This also helps students evaluate consistency and credibility in a critical manner.

The recent Open Science [31] and Open Data [32] initiatives of the European Commission predict that the next generations will already grow up in a Europe where the amount of data and access to them will open up a completely different dimension in citizens’ decisions than it does today. Several directives are declared to support the opening up of public sector information. However, this opportunity can be dangerous if pupils are not properly prepared for this, so it is our fundamental responsibility to prepare children for this danger and opportunity in public education, especially and most suitably, in mathematics education. The new Hungarian curriculum and textbook series are trying to contribute to this.

### *3.4. The Maturation Exam—A Possible Direction of Development*

In the curriculum reform outlined in the previous section the key question is by what means could we achieve that the new elements, ideas and methods become an integral part of education and teachers’ daily practice. As mentioned, one of the tools for this is the rewriting of textbooks, which is an ongoing process currently taking place in Hungary. We have also mentioned that experience shows that one of the deepest impacts on (secondary school) teaching in Hungary is the matriculation exam. While changing other parameters of public education takes a lot of time, effort and money, the transformation of the matriculation exam can be done relatively quickly and easily. Of course, we are not saying that it is worthwhile to achieve radical reforms solely by means of output regulation, but we are convinced that it is worthwhile to use this tool to bring about change.

Due to the needs described in Section 3.3 and to our experience in the COVID-19 situation, we think that a new type of task that has not been included in Hungarian public

education practice so far should be incorporated to the matriculation exam: a complex essay task.

The essence of a complex essay task would be for the student to present an interpretation and express an opinion about an everyday situation based on some given data sources, potentially including newspaper articles and social media. To form this interpretation and opinion, one should be able to use some kind of mathematical knowledge, but in this case it would not significantly exceed the most basic concepts and operations. Therefore, this would be a closed task in terms of its input but open in its outcome. As a later step, the task would be even more complex if the input was also open, so the student would have to gather the information for the given question himself or herself.

The complex essay task could be part of either the written or the oral part of the exam. In this latter case, there would also be an oral exam in mathematics at the intermediate level (that is currently not part of the examination), which could also have a positive effect on the content of mathematics lessons in pre-graduation education. In both cases, after clarifying the relevant technical issues, the possibility of using a computer to solve these tasks also arises. Within this, one of the possibilities is to use spreadsheet and geometry software and further data visualisation tools, but even—in accordance with everyday practice—Internet search engines could be used. Of course, we are aware that using such tools raises additional questions, but we now allow ourselves the luxury of daydreaming, and then rethink the concrete practical implementation later, after the principles have been adopted.

If such a task were part of the oral exam, one could still choose from several options. The task may be given during the exam when oral presentation and explanation skills predominate. But it could also be a project task that students get to know and prepare for months before the exam. The advantage of this is that they can even make a presentation to support their interpretation of the solution, which could also improve a lot of different cross-cutting competencies beyond mathematical knowledge.

Of course, the possibility just described contains only sketchy ideas. Obviously, the inclusion of this type of assignment in the matriculation exam process requires due diligence, lengthy preparation, and the preparation and sharing of an appropriate collection of sample assignments. At this point, we wanted to indicate the direction we consider appropriate to prepare students in a situation similar to the COVID-19 crisis to deal with the overwhelming information.

### *3.5. Case Study: A Matriculation Exam Problem in the Future*

By modifying the specific task presented in Chapter 2.4., we show what types of tasks and what kind of questions we consider appropriate according to the direction described in the previous chapter.

- (a) During the epidemic period, 4000 people in a large city of 2 million inhabitants became infected with the virus that caused the epidemic. Due to the declining number of passengers, the urban public transport company reduces the number of public transport vehicles. What do you think of this measure? Search for the maximum number of people that can fit on a bus. Compare the probability of having at least one infected passenger on a full bus to the probability of the same question with half that much passengers. Based on the result, argue for or against the measure.
- (b) Examining the spread of the epidemic, John prepares a spreadsheet for himself on the number of infections experienced in consecutive days. These numbers are: 4000, 4195, 4420, 4650, 4882. Based on this, it is estimated that the number of infected people increases by 5% day by day from the previous day's value. According to John, at such a growth rate, the number of infected people would only reach 20,000 for a very long time, as counting with approximately 200–250 new cases per day, it would take 70–80 days to reach this number. What do you think about this opinion? Use a computer program to determine when the number of infected people reaches 20,000 under the terms of the task. Explain what was wrong about John's estimation.

- (c) A test, sold in pharmacies, promises users to quickly reveal whether they are infected or not. The description says: ‘The test positively indicates infection at 99% probability for users truly infected. The test is also known to falsely indicate infection in case of users not infected. However, the probability of such a false-positive result is only 4%.’ It is known that 0.2% of the total population of the city is truly infected. Calculate the probability that if a random test of a randomly selected inhabitant shows infection, then the test subject is indeed infected with the virus. Based on the result, argue for or against the rapid test being able to reliably detect infection.

### 3.6. Conclusions

The COVID-19 pandemic has challenged the world, including Hungary, in many ways. This is especially true for the public education system. At the same time, these challenges provided an extraordinary opportunity to rethink fundamental questions about education that we have not asked during our everyday practice.

As a fortunate coincidence, the pandemic in Hungary coincided with the last stage of the development of the National Core Curriculum and new mathematics textbooks, therefore we were able to incorporate our experience into this work. In this paper we presented how the pandemic experience inspired us to make conceptual changes to the mathematics curriculum, and to further develop specific fields and competences, primarily in terms of the presentation, interpretation and critical evaluation of information and data.

As a further outcome, we also made recommendations for the matriculation exam, where we intend to introduce a complex essay task covering these fields. We believe that these improvements will help us to equip students with the competencies that will support them to critically interpret and evaluate information in the mass media, and make responsible decisions in similar situations.

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