Mathematics with Using Information and Communication Technology

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ABSTRACT

Mathematics has an irreplaceable function in human life. Pupils and students at primary, secondary schools and universities have a non-adequate attitude to mathematics. Their imaginations and attitudes are on the scale from high admiration to rejection of mathematics as such. We suppose that the problem is not in mathematics itself but in the way and art of its teaching. In spite of many doubts about its usefulness, many application tasks indicate the fact that without mathematics we would not be able to solve many simple life situations.

Using ICT in mathematics education can help by the solving of these topics.

KEYWORDS

Information and communication technologies (ICT), mathematics education, GeoGebra, Matlab, content reform, real-life problems in education, Slovak National Curriculum ISCED 1, 2 and 3.

1 MATHEMATICS EDUCATION AND ICT

According Lamanauskas in [1] new technologies consistently and rather aggressively have strong influence to the educational practice. It brings emerging challenges both for teachers, students in every type of schools and also in teacher training at universities.

We can identify at least three reasons for promoting the integration of Information and Communication Technologies (ICT) in Mathematics teaching in schools (see [2]):

a) Desirability: The use of ICT stimulate motivation of students and curiosity; encourage and motivate them to develop their problem-solving strategies. The use of ICT may improve efficiency of teachers educational activities, release more time to address students individually, stimulate re-thinking their approach to teaching and understanding.

b) Inevitability: Many fields of publishing have moved from printing to electronic form. This applies to conference proceedings, reference works such as encyclopaedias, webpages, online applications, small-circulation textbooks, special journals, different kinds of tubes etc.

c) Public policy: There is defined in Slovak National Curriculum ISCED 1, 2 and 3 that mathematics as a subject belongs to the group “mathematics and working with information”.

Important aspect of ICT aided education is the visualization. It can bring for mathematics education:

- Effective approach while discovering the results, solving problems and using different kinds of models for the solution of the problem,

- Visualization of relations and functional connections in one model allows to deduce new results in other areas and fields of mathematics and other subjects,

- Supporting of mathematical competence and basic competences in science and technology; digital competence; learning to learn.

The method of generating problems (see [3]) seems to be suitable for this kind of teaching (due to its systematically creating sets of internally connected problems). Student’s activities and instructions have to be regarded as complementary factors in the educational process. These factors both are necessary and must be systematically related to one another so that optimal progress can go forward. The aim of our method is to create areas in which the students may–using the result of guided teaching–move as independently as possible, and in which students develop their own initiatives, activities and own kind of thinking. Students are considering their
own problem and they could ask for help as far as it is necessary. By this way they obtain basis for further work. After a problem has been completely solved and clarified the teacher together with students is thinking about continuation of the problem and generate problems which are related to the problem just solved. Thus the original problem acts as a generating problem; we will call it generator problem (GP). Related problems are obtained by analogy, variation, generalization, induction and deduction etc. The group of all new problems together with their GP will be called the set of generated problems of the GP or the problem domain of GP.

2 THEMATIC AREA GEOMETRY AND MEASUREMENT IN UPGRADING STATE EDUCATION PROGRAM ISCED1

Since 2014 Slovak curriculum for mathematics education for primary level in the State Educational Program ISCED1 has been complemented by an innovative program with performance standards for various thematic areas and various school years. We will focus now to the thematic area “Geometry and measurement”.

In the first year, the teaching process focused on planar geometric shapes: curved line, straight line, open and closed line, circle, square, triangle, rectangle (see [4]). As for the three-dimensional structure, cube, cylinder, and sphere were recommended. Over this year, pupils learn to have orientation in plane and space (right, left, up, down, over, under, in, on, in the front of, behind, beside, between, in the front, in the back). Units of length are taught only on an intuitive level, taking advantage of both historical units (foot, thumb, palm, elbow, another subject – e.g. clip), and comparing dimensional geometric figures (longer, shorter, higher, lower, wider, narrower, longest, shortest, lowest). On propaedeutic level, the pupils are acquainted with identical display - axial symmetry. In the second year, students already get to know the basic geometric objects - point, line, ray, line segment, point belongs (do not belong) to the formation, the point lies (do not lie) on the formation, the endpoints of the line segment. Over this school year, the standard units are introduced: millimeter (mm), centimeter (cm), meter (m) and the length of the line segment in centimeters is determined. Comparison and arrangement of line segments is realized by a strip of paper, measurements and estimates, and are also used instruments for measuring length: ruler, meter, measuring tape. At a propaedeutic level, the pupils are acquainted with identical display - slide. They learn to name polygons: a triangle, quadrilateral and so on and identify their sides and vertices.

In the third year, students determine the length of line segment or dimensions of geometric shapes in decimeters and kilometers. Great attention is paid to the drawing basics: purity and precision of drawing, choice of suitable drawing equipment, hygiene and safety at drawing. In the area of plane figures, the square grid begins to be used: drawing a square and a rectangle in the square grid, marking the tops of square and rectangular by block capitals, zoom in and out of plane figures in a square grid. On propaedeutic level, pupils get to similar structures. In the three-dimensional structure, pupils become familiar with vertices, edges and sides of the cube. They form the building from cubes, the plan of building from cubes (plan structure with the indicated number of cubes standing on each other), rows and columns (for buildings from cubes). In the fourth year, the students learn to convert the unit of length (mm, cm, dm, m, and km), mixed unit of an example of 1 m 10 cm. In the area of plane figures, attention is paid to drawing triangle and polygon - vertices, side, diagonal, opposite and adjacent sides, number of sides and vertices, length of adjacent and opposite sides. Here students will meet with the first construction tasks: drawing any triangle, drawing triangle if the lengths of its sides, the sum and difference of the lengths of line segments are known. Next topics are multiple of side length, circumference of square, rectangle and triangle as the sum of the side length at the propaedeutic level. In addition to these geometric figures, pupils learnt to basic knowledge about the circle, circular line and how they can be drawn by drawing compasses.

The curriculum recommend to use manipulatives and models, some of them is possible to prepare with the educational software.

Figure 1 shows shapes, which are possible to prepare with “Tangram” with software GeoGebra.
Figure 1. Shapes for the game “Tangram” with GeoGebra

It is possible to prepare following figures (see Figure 2 and Figure 3).

Figure 2. “Rabbit” in the game “Tangram” with GeoGebra

This kind of activities supports an interdisciplinary link between mathematics and art education.

Art education is in the primary level of education a subject that through authentic experience gained by art activities develops pupil's personality in its entirety.

Figure 4. “Cat” in the game “Tangram” with GeoGebra

3 MATHEMATICS IN REAL LIFE

Mathematics accompanies us in everyday situations. There exist many abstract mathematical theories, which have later many applications. According Lobachevski (see in [5]) “Each part of mathematics, however abstract it is, will find its model in real life one day. “ One concrete example is using Lobachevski theory of non-Euclidean geometry in Einstein general theory of relativity. But many simple every-day situations is possible to solve with help of mathematic methods. These real-life problems are suitable for school mathematics.

For example, withdrawing money from a bank machine would be impossible without Carl Friedrich Gauss (see [6]). Entering the PIN code in the terminal has to be encoded and subsequently decoded with the help of computer. This action is not possible without coding whose mathematical basis is in the theory of numbers. Mathematics teaches students how to think logically, how to look for the combinations when solving problems. It also teaches us to be accurate. Despite this fact, many people consider mathematics to be their lifelong problem. Primary, secondary as well as university teachers of mathematics frequently have problem to find mathematical applications in every-day life. This question is especially surprising when the university students meet interesting problem solved by visible mathematic method. They should be clear about the importance of mathematics when they choose to continue in their studies of mathematics at the university. Therefore, to motivate students to study mathematics has become a difficult task for many teachers at every kind of school.
They should know how to bring fun and enlightenment of mathematics to the class. Therefore, it is necessary to prepare future teachers of mathematics to teach pupils to discover the beauty of mathematics in everyday-life (for example in [7]). Application tasks serve as a good place, where the confrontations between a human and mathematics are predominantly realized. We can see the application of geometry everywhere, for example geometric patterns on mosaic pavements of European temples. When we look at some fabrics, we also find various geometric shapes – e.g. triangle, square, rectangle or circle. We can observe mirror reflection and look for similar shapes and axes of symmetry. We observe in many areas of our life an interesting mathematical object – a spiral. A group of congruent right-angled blocks forms the spiral. They are joined together longwise and truncated by the plane breadthwise. The plane has an intersection with just one edge of the block or it goes just through one of its vertices. The geometry is just the right topic when it is appropriate to use some suitable mathematical software to improve imagination in pupils. Do our pupils have a good imagination? Are they sufficiently prepared to understand the importance of geometry in practice? The answer is negative. Even students, future teachers of mathematics, have a problem with imagination. One of the reasons is the educational reform that began in 2008. Therefore, it is important and necessary to prepare future teachers of mathematics to teach pupils to discover the beauty of mathematics in our lives.

4 MATHEMATICS IN THE NEW CURRICULUM IN SLOVAKIA

Since 1 September 2008 the Content Reform of Education in Slovakia has been being implemented in accordance with the Act No. 245/2008 on education and training and on amendments and supplements to certain laws approved by Slovakian Parliament on 22nd May 2008 which replaced the original so-called Education Act of 1984. The Content Reform of Education means not only changing of the curriculum content, but also transformation of methods, conditions, forms and manners of education as well as its time organization associated predominantly with a teacher, and financial and legislative changes and sequence of steps.

Every school must prepare his own school educational program. Schools have the responsibility to adapt their specific school educational programs in the range of approximately 30%. That means that in 70% they must respect the State Educational Program. Compulsory content of education and training at schools are defined and specified by the state educational programs. The respective educational program represents a standard for schools but also an aid in the formation of the schools education and training programs. General education program should have replaced current curricula, and educational standards for primary and secondary schools. It should have become a mandatory pedagogical document. After the introduction of the State Educational Program ISCED 2, the number of lessons in individual subjects is determined by the framework curriculum. The content of education was divided into the following educational areas: language and communication, mathematics and working with information, man and nature, man and society, art and culture, man and values, man and the world of work, and health and exercise.

The basic structure of the content of education was based on the key competences defined by the expert group of the OECD in the frame of the project DeSeCo (the acronym of Definition and Selection of Competencies: Theoretical and Conceptual Foundations, see http://deseco.ch/). It corresponds to modern trends used in many developed countries. The success of the transformations in education depends on the fact how the reform of education and training will be accepted by teachers, school leaders and parents, and what importance will be assigned to the education and training by society. New resources can be beneficial for improving teaching and schools (see [8]). However, a good teacher remains a decisive factor in the reform. "Pedagogical work stands and falls on the motivation and skills of teachers. Innovation helpfulness and professionalism must be based on the qualitative new forms of education and training of teachers" (see [9]). We present in the following tables changes in the geometry curricula during the period 1997-2011:
Table 1. Mathematics at lower secondary level from the school year 1997/1998.

<table>
<thead>
<tr>
<th>Year of study</th>
<th>Number of hours per week / per year</th>
<th>Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5/165</td>
<td>angles, triangles, constructions of triangle</td>
</tr>
<tr>
<td>6</td>
<td>5/165</td>
<td>parallelograms, trapezium</td>
</tr>
<tr>
<td>7</td>
<td>5/165</td>
<td>circle, axial symmetry, central symmetry, congruence, similarity, volume and surface of cone and pyramid, constructions tasks</td>
</tr>
<tr>
<td>8</td>
<td>5/165</td>
<td>translation, homothety, dilatation, constructions tasks, goniometry of acute angle</td>
</tr>
<tr>
<td>9</td>
<td>5/165</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Mathematics at lower secondary level from the school year 2003/2004.

<table>
<thead>
<tr>
<th>Year of study</th>
<th>Number of hours per week / per year</th>
<th>Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5/165</td>
<td>angles, triangles, constructions of triangle</td>
</tr>
<tr>
<td>6</td>
<td>5/165</td>
<td>perimeter and area of a square and rectangle</td>
</tr>
<tr>
<td>7</td>
<td>5/165</td>
<td>axial symmetry, triangle, parallelograms, prisms</td>
</tr>
<tr>
<td>8</td>
<td>4/132</td>
<td>trapezium, congruent mappings</td>
</tr>
<tr>
<td>9</td>
<td>4/132</td>
<td>similarity, volume and surface of three dimensional objects, constructions tasks</td>
</tr>
</tbody>
</table>

Table 3. Mathematics at lower secondary level from the school year 2010/2011.

<table>
<thead>
<tr>
<th>Year of study</th>
<th>Number of hours per week / per year</th>
<th>Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3.5/115</td>
<td>point, line, segment, quadrilateral, perimeter of square, rectangle and triangle</td>
</tr>
<tr>
<td>6</td>
<td>4/132</td>
<td>area of square and rectangle, angles</td>
</tr>
<tr>
<td>7</td>
<td>3.5/115</td>
<td>volume and surface of cube and cuboid</td>
</tr>
<tr>
<td>8</td>
<td>4/132</td>
<td>triangle, parallelograms, trapezium, sphere</td>
</tr>
<tr>
<td>9</td>
<td>4/132</td>
<td>circle, axial and central symmetry, similarity of geometry objects</td>
</tr>
</tbody>
</table>

For example, the increased number of lessons for foreign languages, or the creation of new subjects, had the effect of reducing the number of lessons in the subjects of natural science. We as teachers obtain now actual question: In which conditions can we create sufficient time space so that we can efficiently prepare our pupils for life? Since 2008, there are not precisely defined lesson subsidies of subjects for each class.

In 1997 curriculum, approximately 200 lessons were allotted to geometry in the 5th to 9th grades. In the new curriculum (2010), there are about 170 geometry lessons in these grades. It means about a 15 percent decrease as compared to the previous number. It is important according [10] to note that within the meaning of the school law, the number of lessons is defined only for the whole stage of education and not according to grades, as it was in the old curriculum.

The number of lessons in each class is managed by the schools themselves. Although we are aware that the framework curriculum is a living document that need adaption to the conditions, we think, that too frequent changes help not students. The teachers of secondary schools claim the same, when presenting, they have to reduce their...
claims to the students in the course of two decades nearly by 30%. As we mentioned above, State education programme prescribes the compulsory subjects, which are included in various educational areas. These include according [11] the previously mentioned areas of mathematics and working with information and communication.

Mathematics education is not an independent component of the education. Mathematics undoubtedly develops cognition of each pupil, and through its methods and means, is destined to become a tool for the development of the functions of distributing knowledge (see [12]). Most of the technical amenities have its roots in mathematical theories. In spite of these facts, mathematics still ranks among the least favourite and unattractive subjects for pupils. Let us ask the question: Why is it so?

It is generally known that mathematics is rather unpopular and less interesting subject for pupils at primary schools. Today's pupils are used to sitting in front of the TV and listening opinions on mathematics, which are presented by famous media people. These people often do not have a problem, or even a courage to express their uncaring attitude to mathematics in public. Moreover, pupils are listening to these opinions from their parents. Due to their little experience, they are not always able process correctly this information.

On the other hand, we have to say that the teachers who are unqualified often teach mathematics at the lower secondary level. The quality of teachers and their work has a direct impact on pupils’ way of learning, their attitudes towards learning, on their knowledge, as well as on their motivation to learn. The students need to have qualified teachers. What is the reason for their absence? Teachers, who are currently teaching, especially at primary schools, could be separated into two groups:

a) some of them are convinced that their work has meaning and purpose and try to pass on their knowledge and understanding to students as much as possible,

b) the others who could not find work in field of their interest or they have some other reasons.

The second group of teachers is one of the reasons why there is a negative situation in teaching mathematics at primary schools.

But at the same time we must remember that today’s teachers need to develop and complement their education constantly if they want to understand an educational process and also their pupils. Therefore a teacher is expected to use information and communication technologies as didactic devices in their everyday educational, training and teaching process.

5 BORDERS IN USING ICT IN MATHEMATICS EDUCATION

Students with reduced curricula in mathematics education in the secondary school, are not able to choose suitable scale for drawing graphs. It is good visible in the task, in which they are asked to identify some kinds of functional properties. We have experiences in following examples:

We start with the concept of derivative. Let we have a function

\[ f(x)=x^2 + 0.8|x-2| + 0.5. \]

![Figure 3. The function \( f \): The graph drawn with educational program, which look like such a function, which has a derivative at every point](image)

![Figure 4. The Function \( f \): The derivative at the point 2 doesn’t exist](image)
Figures 3 and 4 show that visual representation of some properties of the function depends from the scale by the drawing graph of the function. The second example for this fact is the function 
\[ g(x) = x^4 - 0.02x^2 + 1. \]
The wrong scale show us the wrong number of extrema (see Figure 5 and 6).

We continue with the question of continuity of the function. Let we have a function
\[ h(x) = \frac{\sin x}{x}. \]
This function has a limit at the point 0 with value 1 (see also Figure 7).

The numerator at denominator of the function \( h \) is 0 at the point 0. But we obtain, that
\[ \lim_{{x \to 0}} h(x) = 1. \]
This result is difficult to understand for students.

We repeated these tasks with the software MATLAB. We compare our results.

6 GEOMETRY EDUCATION AND MATLAB
As we know it’s very important to find answer to the question: “How to teach mathematics as such?” At this time it’s already clear that teaching of mathematics should be changed. Modernisation of an educational process includes not only the change of teaching methods and forms but first of all the change of the work style and approach to students. These process would be impossible without the teacher’s strong personality, ability to communicate directly with pupils and students and ability to look for more effective forms of education. But also on the other side the use of information and communication technologies, which have their indispensable place in the educational process, is crucially important; and therefore an informational base enabling students to apply acquire knowledge and skills in practice should be created. The teachers of mathematics can convey to their students a different perspective on how to solve some mathematical problems by using various mathematical programs. We can find various interesting programs that can be used in an educational process. Most of them are connected with geometry teaching. Geometric programs are used in teaching of plane and solid geometry as well as in the dynamic illustration of mathematical terms and relations. We can find...
various type of geometric software. As we already mentioned, GeoGebra as a freeware program is one of them. There exist also mathematical programs designed to facilitate mathematical applications in practice. Although their use is sometimes license tied they are sought after by teachers because they allow creation of other new programs. We can mention for example mathematical program MATLAB (see [18]). In spite of the fact that we know that MATLAB is used especially for performing numerical calculations we have MATLAB choosed, because our university has a Total Academic Headcount (TAH) license for MATLAB, Simulink, and add-on products. As we know MATLAB in its simplest form can be used as a matrix calculator. Its advantage is that all common mathematical operations such as multiplication, division, etc. are noted down on the paper. Thanks to this simple manipulation students with a low programming experience can obtain good results. It was reason why we decided to use these two mathematical programs – GeoGebra and MATLAB for solving tasks about functions \( f(x) = x^2 + 0.8|x-2| + 0.5 \), \( g(x) = x^4 - 0.02x^2 + 1 \) and \( h(x) = \frac{\sin x}{x} \) (see Figure 3, 4, 5, 6 and 8). The main aim was to find out whether the correct solution depend on the scale, it means, at the interval where is the function plotted. For the first time the function \( f \) was plotted in the same interval as in Figure 3, for \( x \in \mathbb{R} \). In program MATLAB the interval was divided by the step 0.001. We achieved the same result as it was by using the program GeoGebra.

Figure 9. The function \( f \): The graph drawn with program MATLAB, which look like such a function, which has a derivative at every point

It was a reason why we repeated the task using the new step 0.0001. But even in this case, the correct result have not been achieved. Therefore the interval has also to be changed as it shown in the Figure 10.

Figure 10. The function \( f \): The derivative at the point 2 doesn’t exist

When the problem was solved by using the functions \( g \) and \( h \) we obtained the same result, as it is seen in Figures 11, 12 and 13.

Figure 11. The function \( g \): three extrema are not visible

Figure 12. The function \( g \): three extrema are good visible

Figure 13. The function \( h \), which is not defined at the point \( C \) and with some chosen point \( A \). Function \( h \) is defined at the point \( A \).

Application this mathematical software in the teaching of mathematics offers students and also teachers a new and creative way of thinking about the solving problems and helps them to develop
independent work and responsibility. Thanks to that, the algorithm of the problem solution which we want the student to learn is presented. It is the clarity and direct and active involvement of the student in the learning process that enables their to become its integral part and logically increases their interest in the subject. The correct use one of various mathematical software in the teaching/learning process improves the teaching of mathematics while at the same time it develops an active involvement of students in the subject matter, which at the same time supports the development of their logical and creative thinking. This is one of the reasons why it is necessary to incorporate the use some kinds of mathematical software in the educational process.

7 TASKS SUITABLE FOR APPLICATIONS

Application tasks is the most important place, when the confrontations between a man and mathematics are predominantly realised. They often play a submissive role in mathematics. Many application tasks are in fact „dressed“ tasks of pure mathematics. They mediate a certain mathematical unit or technique. It is often claimed that people who understand “pure mathematics“ have not any problems with its application.

Typical tasks are so-called motion problems, which are presented with the help of sample exercises. They mediate solution techniques. But is this really the only purpose of motion problems? Let’s state a concrete example – traffic lights accidents whose frequency is dependent on the yellow light and subsequent red light time span (see [13]). Don’t we come across this situation in real life? From a mathematical viewpoint the following questions or working tasks for students arise:

- what the causes of accidents are,
- what counter-measures could be efficient,
- what calculations could be significant for a driver,
- what formulas can be used,
- what recommendations could be given for the problem solution?

Not only motion problems provide us with the possibility of practical mathematical application. Another part of life where mathematics has an indispensable place is music. The most readable influence of mathematics can be seen in musical score. We can find bars, whole and half notes in it. In musical notation one bar is formed by several notes. It means that in a stated rhythm the notes of various lengths have to fit into a concrete bar.

This process resembles looking for the least common denominator in mathematics. Music is also connected with fractions, exponential curves and periodical functions. For example – if we have a string which produces the tone C, then 16/15 of this string’s length (tightened by the same power) produces the tone H. An analogous situation arises also in connection with other tones. We come across exponential curves in piano strings or organ pipes arrangement. Nowadays computers are used for music composition, human voice generating and musical instruments designing. However, these procedures would not be possible without periodical functions. Thanks to them we are able to obtain an authentic electronic musical production. Mathematics helps with the analysis of an ideal sound. History and presence show that not only composers and musicians but also mathematicians and researchers in computer science will be irreplaceable in the process of music composition and reproduction (see [14]).

Application tasks were dominated in the historical mathematics textbooks. Now we continue with two examples from textbook of Václav Posejpal: Aritmetika pre ústavy učiteľské (Arithmetics for Teachers’ Institutes, see [15]). We start with the following quadratic equation with real parameter $b$ from this textbook:

$$3x^2 - (b - 9)x - 3b = 0 \quad (1)$$

Discriminant of this equation is

$$D = (b - 9)^2 + 36b = b^2 - 18b + 81 + 36b = b^2 + 18b + 81 = (b + 9)^2.$$
If \( b \neq -9 \), then \( D > 0 \) and equation (1) has two solutions:

\[
x_{1,2} = \frac{(b - 9) \pm |b + 9|}{6}.
\]

Hence \( x_1 = \frac{b}{3}, x_2 = -3 \).

If \( b = -9 \), then \( D = 0 \) and equation (1) has one solution: \( x = -3 \).

This equation has also geometrical interpretation. Every parabola \( y = 3x^2 - (b - 9)x - 3b \) must obtain the point \([-3,0]\) (see also Figure 9).

Second example is suitable for physics education. We have two pendulums, which simultaneously pass equidistant position at the same time. The period of motion of the first pendulum is \( T_1 = 3 \) seconds and the second pendulum movement period is \( T_2 = 4 \) seconds. What time will the two pendulums pass through a parallel equilibrium? How many oscillations for this time make each pendulum?

Figure 8 shows that the first moment, in which two pendulums pass through a parallel equilibrium, is in our case after 12 seconds. This example connect physics and mathematics education.

8 CONCLUSIONS

We present in our contribution the changes in Slovakian curricula in the field of mathematics education and we also show some consequences from this process to the pupils and students at every stage of schools. Similar trends is possible to see also in science education (see [16]).

Education passes through paradigms, which more or less respond to a broader context, the social and cultural atmosphere. It is therefore necessary to realize that education and training, like human society, are carried out in complex conditions. These conditions are constantly improving, resulting to their change. The above development is associated with both the past and the presence, but the future as well.

Against the background of increasing connection among human beings and the present globalization problems, we should not forget the connections of processes of education and training with the rest of the world around us. It is connected with a wide range of problems requiring not only a beneficial solution towards the perspective of the man and his humanity, but also advice of innovation in education and training. It serves us ICT in mathematics education (see [17]).

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