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THE ROLE OF ICT IN THE TEACHING AND LEARNING OF MATHEMATICS IN ELEMENTARY EDUCATION

Abstract

Technology is an essential aspect of everyday life, thus the growth and integration of information and communication technology (ICT) in learning and teaching is expected. Beginning with the origins of technology based on mathematics as a science, we narrow our focus in this scholarly study on the use of ICT in the teaching and learning of mathematics in elementary education. We focused on studying the impact of ICT on the teaching and learning process, as well as the usage of ICT tools in the development of knowledge in mathematics. The goal of this systematic analysis is to show the benefits of integrating ICT into mathematics teaching and learning, as well as the constraints and challenges that elementary school teachers and students encounter.

Our comprehensive analysis of pertinent theoretical and empirical findings led us to the general conclusion that teacher proficiency with the new technology plays a major role in the integration of ICT. The positive impact of ICT on mathematics teaching and learning is undeniable, because technology reduces logistics in the planning and implementation of instruction, increases interaction in the classroom, and encourages mathematics learning through the visualization of abstract concepts and processes, while also allowing for independent study.

Keywords: *ICT, teaching process, learning process, mathematics, elementary education.*

Introduction

Consulting domestic or foreign literature, we often come across texts that write about the relationship between technology and science, not emphasizing the relationship between technology and mathematics. Modern technology would be unthinkable without mathematics. It is safe to assume that the relationship is reciprocal (Hansson, 2019) because technology also needs mathematics for its faster and more modern development. From a practical standpoint, mathematics is a human activity that has existed since the beginning of written history. Through abstraction and logical reasoning, mathematics once evolved from counting, calculating, measuring, and the systematic study of the forms and movements of physical objects (Joshi, 2017). Based on mathematics as a science, we now study the development of technology through numerous basic concepts and algorithms. As a consequence, computer science employs various mathematical logic and number theory to construct data structures and computer algorithms.

Defining ICT as a combination of devices and technological resources, that are used to manipulate and correlate information (Kaware and Sain, 2015), we mean the wide application and influence of ICT in the educational process. In other words, ICT has become an integral part of education, revolutionizing the way mathematics is taught and learned (Duan et al., 2020). The digital era in which we live today requires appropriate pedagogical changes that are "in step" with the latest technical-technological trends and demands. In this context, the importance of carefully integrating technology into school curricula is highlighted to achieve the desired learning outcomes. Today, mathematics is used all over the world, finding its application in a large number of fields: natural sciences, medicine, engineering, social sciences, and others.

Mathematics as a scientific discipline is integrated into elementary education as a compulsory subject, starting from the first educational cycle. The subject of mathematics is one of the most represented teaching subjects in the curriculum according to the lesson fund. Considering that every individual acquires his basic habits, knowledge, and skills during elementary education, it can be said that school institutions are the right place to develop key ICT skills and mathematical knowledge. Integrating ICT tools into the mathematics curriculum aims to improve student engagement, conceptual understanding, and overall academic achievement in mathematics by transforming existing teaching and learning processes. Taking mathematics as a basic segment of any technology, in the following text, the role of ICT will be considered through the prism of teaching and learning mathematics in elementary education.

The impact of ICT on the teaching and learning processes

Globalization and technological changes have created a new direction for the development of the economy, led by technology through its databases

and knowledge. As a result, the development and potential of ICT have become a vital issue, which should fulfill the educated needs (Chao, 2015). Relying on technology, society becomes more and more advanced, and thus the integration of technology in the classroom becomes inevitable (Sokku and Anwar, 2019). Expectations are high, beginning with the fact that ICT is a tool that facilitates learning and promises new solutions to existing teaching and learning challenges (Oduma and Ile, 2014). Linking the use of ICT in a mathematical setting, it is indisputable that learning new information and facts, together with honing our skills, makes it possible for us to arrive at new mathematical truths more quickly and effectively. ICT not only supports traditional teaching methods but also encourages interactive learning, through inquiry. Under the influence of ICT, pedagogy is changing, responding to new educational trends and societal needs. According to the results obtained from the review of studies aimed at the pedagogical model of teaching with ICT in the period from 2008 to 2018 by Hardman (Hardman, 2019), the positive impact of ICT in the teaching of mathematics in elementary education is highlighted under the condition of using constructivist pedagogy.

The actual integration of ICT in the classroom appears to be more difficult than first assumed. Difficulties in implementing ICT are often pointed out, starting from the need for the development of specific software and other ICT tools that can be included in the teaching and learning process, not leaving out the game as a paradoxical traditional and spontaneous activity, up to the need for professional training of teaching staff and the development of digital competencies among students during elementary education. Several frameworks, self-assessment tools, and training programs have been produced and continue to be developed at the international and national levels to aid in the process of upgrading teachers' competencies. Through the European Digital Competence Framework for Educators (DigCompEdu), teachers are enabled to determine their level of competence in the digital area (one of the six areas) and thereby determine their individual need for additional training (Redecker, 2017). On the other hand, analyzing the framework of separate competences developed by the European Commission and the key competences for lifelong learning from the European reference framework, we realize that the importance of the area of digital literacy is also highlighted in the national standards for elementary education. This field focuses on the active integration and implementation of technology in modern society. The competencies that students need to gain during elementary education refer to the correct, ethical, and safe use of ICT, skillful and effective usage to solve problem situations, new ideas, communication and collaboration inside and outside the school, creating digital content, and so on (Национални стандарди за постигањата на учениците на крајот од основното образование, 2021).

The impact of ICT on the teaching process is expressed through the role of the teacher in the classroom. Before the implementation of ICT in the teaching process, teachers had the dominant role as distributors of knowledge, infor-

mation, and facts. The teacher's role gradually shifts to that of a guide/mentor, coordinating the learning and knowledge acquisition process through instructions on how to use the necessary ICT tools. ICT allows the teaching process to become more rational, reducing the necessary logistics of work. In practice, the use of ICT in mathematics usually refers to the interaction between the student, the computer, and the knowledge, which explains the disparity between potential and actual integration. Since the very beginning of the integration of ICT in schools, several researchers have analyzed the factors influencing the acceptance and use of ICT by teachers in schools (Capan, 2012; Dudeney, 2007; Virkus, 2008; Zhang, 2013). They show that the main barrier to the integration of ICT were the teachers because they are the same persons who lead the teaching process in the classroom. In other words, the integration of ICT depends to the greatest extent on personal factors, defined as self-perception. According to students' positive attitudes and high expectations of ICT integration in the educational process, the key barriers to ICT integration in schools are confidence, competence, and teacher attitudes, which reduce the percentage of ICT application (Chien, Wu and Hsu, 2014). Based on the attached research, we see that the role of teachers in the process of integrating ICT into teaching is becoming more and more important, especially when it comes to the use of ICT in pedagogy and the achievement of new educational goals. Teachers are required to create creative, interactive, and fun learning (Beaver et al., 2015). We found that the successful integration of ICT in the teaching of all subjects (in our case, the teaching of mathematics) depends to a considerable extent on the professional development of teachers and their digital (ICT) competencies.

To be able to develop the integrated approach of ICT in teaching, in the domain of acquiring mathematical knowledge, it is necessary that ICT moves from an additional activity to a basis for developing the concepts and connections of the mathematics curriculum, rather than isolating itself from other curricula. Here is the request to adjust the curricula, according to the new transformational trend (Vanden Eng et al., 2015) and continuous monitoring of positive practices. The system of planning and creating the curricula needs to direct its attention to specifying the formative changes and the implicit forecasting of the changes. Any planned activity must have clear and concise goals so that students can further focus on specific mathematical goals.

On the other hand, we consider the impact of ICT through the learning process, that is, the students. Students can explore and grasp mathematical concepts through a range of mathematical exercises and real-world applications, which makes learning more meaningful and relevant (Tachie, 2019; Valverde-Berrocoso, Acevedo-Borrega, and Cerezo-Pizarro, 2022). In the learning process, a wide range of resources and technological tools are offered, adapted to the individual needs and abilities of students (Razali, 2019; Tomljenović and Zovko, 2016), supporting the process of independent learning and progress at their own pace. Using ICT for calculations, drawing graphs, and solving complicated mathematical problems improves the quality of content learning and

develops critical thinking (Das, 2019). The capability of ICT is much more than performing number operations, creating graphs, and similar functions. Linking ICT knowledge, mathematical concepts, and processes leads to metacognitive knowledge about one's speed and accuracy with numerical techniques and routines. Developing the ability to use ICT directs students to think at a higher level so that they can effectively apply the appropriate ICT tools. In this way, students begin to gradually develop their problem-solving skills, through logical and analytical thinking. Students are frequently assigned mathematical problems that include a huge amount of data and requirements for solving the problem situation. Through the way students solve, the skills to combine mathematical knowledge with ICT can be easily recognized. In the solving process, students first consider the type of calculation they will use, provide an estimate of the answer, select work methods, and arrive at the correct calculation using a traditional method (pen and paper), a calculator, or an electronic document in which the data are arranged in rows and columns of a table (for example: an Excel table in which the data can be easily manipulated and ready-made formulas can be used).

From all this, we realize that, actually, in the ICT integration process, personal, pedagogical, school, and technological factors have the greatest influence.

In the study of Ghavifekr and Rosdy (2015), it is pointed out that technology-based teaching and learning is more effective compared to the traditional classroom. The inclusion of ICT in mathematics teaching allows teachers to engage students in teaching interactively and dynamically. The integration of ICT, in itself, allows teachers and students to adopt innovative approaches to learning, which are considered to prepare students for future success (Al-Ansi, Garad and Al-Ansi, 2021). The goal is to stimulate the development of students in the era of modernization through the use of technological achievements for the acquisition of higher-quality and more permanent knowledge. We confirm this by the fact that today's teaching and learning process is more inclined towards innovation activities with the help of sophisticated technology. Technology is expected to enable the new generations to more easily realize their potential, interest and talent (Sugiyanto, Kartowagiran, and Jailani, 2015). In other words, ICT plays a key role in the overall modernization of education through the transformation of the traditional classroom into a dynamic and interactive learning environment. The main goal of educational policies and reforms in each country is to develop its education sector following international standards (Tlepbergen, Akzhigitova, and Zabrodskaja, 2022). Hence, the main goal of competent institutions for creating educational policies is to provide means for improving the use of advanced technologies in the teaching and learning process in school institutions.

Application of ICT tools for acquiring mathematical knowledge

Familiarity with mathematics as a science, its basic principles and concepts, mathematical operations, solving simple and complex mathematical problems, etc., begins during the first and second educational cycles of elementary education. The process of acquiring mathematical knowledge is based on the basic didactic principle - from simple to complex, starting with the simplest mathematical concepts and operations, making them more complicated according to the age and developmental abilities of the students. Mathematics is one of the subjects that receives the most attention during elementary school, for the sake of the proportional cognitive development of students and, thus, the development of logical and analytical thinking. It is well known that students acquire permanent knowledge through interactive-visual learning, and the use of ICT tools makes this possible with a single click from a computer, tablet, mobile phone, and so on. We are witnessing new life trends, where the traditional game is increasingly being replaced by the computer game. Computer games are increasingly used in schools to achieve certain goals, which enable students to learn in a fun way. Computer games can only be utilized in schools if they suitable the needs of teaching and learning and the basic prerequisites for their application are met, such as proper equipment, educational software, and prepared teaching staff (*Делчева-Дизд*аревиќ, 2020). Along with the advantages offered by the technology, there is always the concern of negative effects. Learning through the use of technological equipment must be supervised because it is obvious that almost everything is good only when used positively.

In this section, we will elaborate in more detail on the application of ICT tools in the process of acquiring mathematical knowledge, and we will give a brief overview of several studies conducted in the last few years that, in different aspects, study the application of ICT in the process of learning mathematics in elementary education.

Table 1: Overview of research

Reference	Research interest	Conclusions
(Gamit, 2023)	Perceptions of the integration of ICT in teaching and learning, with a focus on mathematics (forming a foundation for understanding numbers)	Positive results of the integration of ICT: improvement of the quality of teaching, increased motivation to learn and help in acquiring new skills and competences
(Gutiérrez Zuluaga, Aristizabal Zapata and Rincón Penagos, 2020)	Educational software	Emphasis on visualization, because it is the most important in the process of acquiring knowledge and memorizing it
(Lara Nieto-Márquez et al., 2020a)	Smart platform – Smile and Learn, with more than 4500 educational activities for children/students aged 3 to 12 years	Further development of activities offered by the platform, expanding the spectrum of activities through the integration of different fields with the help of a game
(Contreras García et al., 2019)	Using resources that demonstrate randomness and the use of probability. Suggestion of the most commonly used virtual tools that can be used in the formal teaching of probability	Deepening the knowledge of concepts with the help of virtual tools, showing the relevance of properties and procedures, as well as overcoming difficulties in this process
(Zaranis, 2018)	Directed learning with the help of ICT in the acquisition of knowledge in the field of geometry	An interactive process that has a positive influence and effect on learning and acquiring knowledge, due to the pictorial and dynamic display of geometric mathematical concepts

As can be seen, the application and impact of ICT tools for the acquisition of mathematical knowledge is a well-researched field with important theoretical and practical outcomes, owing to the problem's scope and ongoing change. The ICT tools that are applied during the teaching and learning of mathematics as a compulsory subject in elementary schools can be divided as follows:

- **Interactive smart board -** In the classroom, during the teaching process, it is almost inevitable to apply the so-called interactive smart boards, which allow teachers to include multimedia elements on certain topics during the realization of the objectives (videos, simulations, and interactive games), presentations, as well as annotations and manipulation of the contents in real time. The school environment becomes much more interesting and active for students because greater flexibility in the teaching and learning

process is enabled. Using interactive smart boards keeps students' attention and improves their understanding of math concepts.

- **Online platforms –** They reached their "popularity" with the beginning of the pandemic caused by the coronavirus. The platforms offer a wide range of resources and can include: interactive content, tasks to practice knowledge, quizzes, forums, questionnaires, verification tests and so on. In the review of the used literature, we noticed the positive influence of online platforms in the process of learning and acquiring new knowledge of elementary school students (Kliziene et al., 2021; Lara Nieto-Márquez et al., 2020b; Marbán et al., 2021).
- **Education software –** They represent a set of various ready-made computer programs, which help guide learning and meet teaching needs (Стојановска, 2012). There are some educational software that can support, enhance, and make interesting the teaching and learning of mathematics in the classical classroom. Based on previous knowledge and our monitoring of educational trends, we will review the most often used software in the teaching and learning of mathematics in elementary school: SketchUp, GeoGebra, and Microsoft Mathematics.

1. SketchUp

We find the beginnings of SketchUp since 2006 under the name Google SketchUp - three-dimensional (3D) software designed by Google to enable the display of items and, in general, the total display of cities on their satellite maps (Liveri, Xanthacou and Kaila, 2012). SketchUp can be used for modeling simple 3D shapes to creating complex 3D objects. This program can encourage and stimulate students' creativity and curiosity, thereby awakening their interest in design. This program's application in mathematics teaching can be invaluable to geometry topics and contents. In mathematics curricula, geometry as a subject begins to be studied in the first grade. The practical experiences of the teachers so far show that the students initially have difficulties in distinguishing the shapes, due to the imaginative visualization of some 3D shapes. SketchUp can facilitate the work of teachers and increase the effectiveness and efficiency of mastering the intended content in the geometry section. The functions offered by this program can be reviewed and applied in more detail by downloading it at the link: https://www.sketchup.com/en.

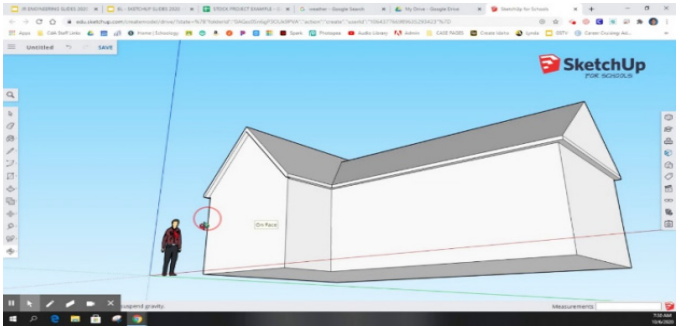

Figure 1: Example of SketchUp application in school – creating a house

2. GeoGebra

GeoGebra is a dynamic math software/interactive application that has the ability to bring together topics from the math curriculum (geometry, algebra, statistics, as well as working with data through graphical and tabular display). It is suitable for the teaching and learning of mathematics in elementary education, up to higher university education. Unlike SketchUp (a program oriented towards 3D design), GeoGebra is distinguished by the visualization of mathematical concepts. A number of educational software applications have been created for geometric constructions and solving analytical and algebraic problems, but this is one of the best computer applications for visualizing mathematical concepts and illusions (Majerek, 2014). GeoGebra can be downloaded from the official website: https://www.geogebra.org/, which allows easy and quick involvement of students in the learning process.

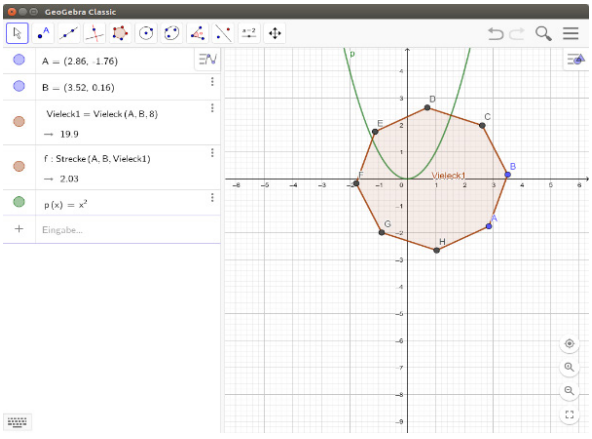

Figure 2: Example of application of GeoGebra in school – recording of coordinates

Yohannes and Chen (2021) conducted a review of papers from the Web of Science database from 2010 to 2020. Most studies have focused on topics related to geometry and analysis, investigating students' learning performance, their higher-order thinking, and their attitudes, opinions, and perceptions. The review of the studies shows that learning mathematics is based on strategies that include activities and tasks for the implementation of GeoGebra.

3. Microsoft Mathematics

Microsoft Mathematics is used to solve problems in the fields of linear algebra, statistics and trigonometry. It is a free software of Microsoft Corporation. It operates based on mathematical expressions and employs an asymbolic computer system. In the study of Oktaviyanthi and Supriani, we discovered favorable opinions regarding the usage of Microsoft Mathematics (Oktaviyanthi and Supriani, 2015). It is shown that this software includes the new motivation of students to actively participate in the process of inclusion, enriching it, as well as better understanding of the material being learned. This ICT tool can be downloaded from the following link: https://microsoft-mathematics.en.uptodown.com/windows.

Microsoft Mathematics can be used to illustrate mathematical concepts, just like the previously stated SketchUp and GeoGebra applications. The only difference is that Microsoft Mathematics can measure the area under curves and has higher graphical representations of algebra and calculus. Microsoft Mathematics, in summary, can be described as mathematically sophisticated software due to its ability to depict a wide range of abstract and symbolic representations. This indicates to us that this software is suitable for use later, that is, in the second educational cycle of elementary education, because prior knowledge and representations of mathematical concepts are needed.

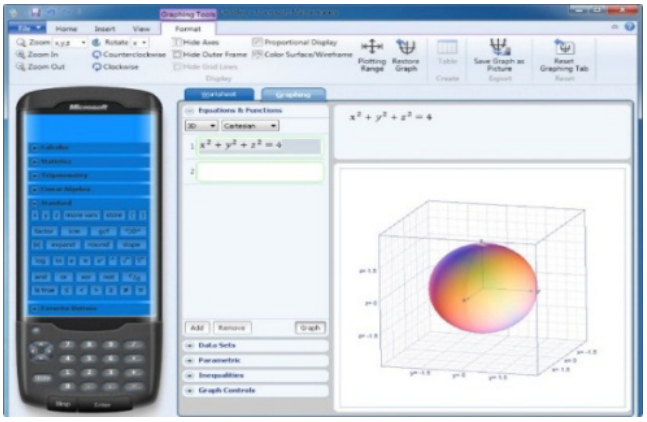

Figure 3: Example of application of Microsoft Mathematics in school – equations and functions

Conclusion

Based on a synthesis of the literature read, we have concluded that the use of ICT in the teaching and learning of mathematics in elementary education has a positive impact on the acquisition of students' mathematical knowledge. According to our findings, an interactive and more flexible approach to knowledge acquisition enhances interest and motivation to learn mathematics, improves current performance, and supports constructivist learning and critical thinking. The use of ICT tools, such as SketchUp, GeoGebra, and Microsoft Mathematics, enables the visualization of mathematical concepts and problem situations so that the acquired knowledge can become permanent and applicable.

In contrast to the positive experiences that prevail among students in the learning process, we noticed that teachers in the process of ICT integration in the teaching process face certain limitations and challenges, such as changing the functions performed by the teacher in the planning process and realization of teaching, insufficient training for working with ICT tools, and inadequacy of the curriculum.

In order to improve the further integration of ICT in the teaching and learning of mathematics in elementary schools, we will highlight several recommendations that can serve as a good basis for future theoretical and practical research on this extensive issue:

- Enrichment of initial education through non-formal and informational education, because the time we live in, with all its dynamism, rapid changes, and technical-technological challenges, expresses the need for other types of education apart from the formal one. The person needs to acquire new knowledge, skills, and techniques, which will enable self-improvement for better career development as well as meeting needs in everyday life.
- Placing an emphasis on the professional development of teachers, allowing them internal and external trainings (according to individual needs) to improve ICT competencies. ICT, i.e., digital competences, belong to the group of specific competences that are acquired by the teaching staff and have a great influence on the competences that students need to acquire during elementary education. Focusing specifically on the problem that has been elaborated in this scientific paper, we actually want to highlight the need for a coordinated and parallel development of digital competence and competence for mathematical sciences, technology, and engineering, which are included in the eight key competences for lifelong learning. The development of these competencies among teachers contributes to a large extent to helping elementary education students acquire the transversal competencies related to certain subject areas (digital literacy; mathematics and natural sciences; technique, technology, and entrepreneurship) contained in the National Standards for elementary education.
- Adaptation and improvement of the mathematics curriculum.

- Using new teaching methods, tools, and techniques according to new educational trends, as well as creating a larger number of digital learning materials, educational software, and online platforms.
- Equipping all schools with modern computer equipment and tools.

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