Technology-based Interdisciplinary Approaches to Accelerated Learning of Mathematics

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Keywords: Mathematics Learning, Interdisciplinary Approaches, Technology-based Learning.

Abstract: As technology enters everyday life more quickly and purposefully, the education system is also becoming more accessible and efficient. In 2020, during distance learning in Latvia general education schools, based on a survey of the Latvian Ministry of Education and Science, 18 main problems were identified that most directly relate to learning mathematics and require a change in teaching strategies and approaches. These problems raised much debate and led to think about the need for a more efficient education system in the future, where close cross-sectoral cooperation with an interdisciplinary approach can make a new contribution. The research question is: What interdisciplinary digital technology-based approaches stimulate students' interest in learning maths, motivate them and improve attitudes in the long term? The aim of the study is to point out to educators, policy makers, industry entrepreneurs and researchers the necessity for collaborative and interdisciplinary approaches for accelerated learning in mathematics in general schools. In the future this will contribute to the development of AI solutions and a quality support system for mathematics teachers. The study identifies and describes eight technology-based interdisciplinary approaches to accelerated learning of mathematics that can make mathematics a more accessible and meaningful subject.

1 INTRODUCTION

We live in a rapidly changing world and face increasingly global and complex challenges on a daily basis, such as income disparities, environmental problems, migration issues, organized crime and more. These complex problems cannot be solved in isolation from the perspective of individual sectors. Complex problems require an interdisciplinary approach. We are living in an unprecedented period of history, when the Covid19 pandemic is demanding rapid changes in many aspects of our lives, and this is especially true in the education sector. In March 2020, schools were closed almost overnight and till now were available mostly online. And it became clear that in the age of Artificial Intelligence (AI), with the faster and more targeted entry of technology, the education system will change radically in the future and will never be the same again. These changes have raised much debate and led policymakers, researchers and educators to think together about the necessity for a more efficient education system in the future that meets the requirements of the Fourth Industry, providing students with tomorrow's jobs and eliminating any inequalities.

One of the most sensitive and important subjects in schools is mathematics, which is the basis of many professions. If students are well acquainted with mathematics, then in the future they will have better access to many fields, such as finance, economics, engineering, IT, medicine and others. Mathematics must keep pace with technological advances such as AI, robotics, virtual reality, big data analytics, 5G data transmission, 3D modeling, genetic engineering, and more. Today, technology is developing much faster than general education, leading to uncertainty and social tensions, also known today as the digital gap. Only when the curve of the general education system intersects the curve of technological development, social tensions will decrease and the well-being of society increase (OECD, 2019).

2 PROBLEM STATEMENT

It is written in the research of Professor Zanda Rubene of the University of Latvia that the current

Cunska, A.
Technology-based Interdisciplinary Approaches to Accelerated Learning of Mathematics.
DOI: 10.5220/0010473901140121
In *Proceedings of the 13th International Conference on Computer Supported Education (CSEDU 2021) - Volume 2*, pages 114-121
ISBN: 978-989-758-502-9

target audience of schools is “Generation Z” or digital age children born between 2001 and 2015, whose everyday life is fully merged with modern technologies that read little printed text, have visual world perception, accept AI solutions, have insufficient social skills, are sensitive to criticism, are over-cared for and grow up in a child-centered society (Rubene, 2020).

Our challenge is to create a digitally based education system and support so that social tensions do not increase. Therefore, outdated books, uninteresting environment and inert teachers will not seem attractive to the younger generation. Researcher A. Persico has pointed out that the strategies and methods of teaching mathematics that were popular several years ago are now being replaced by more effective research and Big Data-based methods aimed at making mathematics a more accessible and meaningful subject (Persico, 2019).

During distance learning in Latvia general education schools in 2020, based on information in interviews and media, focus group discussions and a survey of the Latvian Ministry of Education and Science (IZM, 2020), the author identified 18 main problems most directly related to mathematics and changing strategies and approaches, and supporting technology, in particular AI:

→ Lack of computer equipment and data transmission for both schools and households,
→ Lack of digital skills for both teachers and students,
→ Disproportionate involvement of parents in ensuring the learning process,
→ Different effects on urban and rural schools, on talented and less able pupils,
→ Lack of a unified methodology for the use of technology in the teaching process of mathematics,
→ Lack of a unified system and digital platform for communication and solving various tasks,
→ In the effort to ensure quality, part of the topics of mathematics remained untaught,
→ Inability to plan time, anxiety and stress for both students and teachers,
→ Lack of motivation, encouragement and support for both students and teachers,
→ Lack of patience for students to read and understand math problems independently,
→ Teachers’ suspicions about students' honesty in solving math problems independently,
→ Lack of explanation by teachers for especially more complex mathematical tasks,
→ Lack of socialization for both students and teachers,
→ Too much time for teachers to provide feedback and correct work,
→ Overloading of teachers in preparing for digital online lessons, looking for more creative tasks, creating more options and correcting students' work,
→ Lack of interdisciplinary approaches and activities in nature,
→ Passive lifestyle at home and lack of sports activities,
→ Lack of cooperation between education and IT professionals to create innovative solutions and reduce the tensions created by digital technologies.

Teaching higher mathematics to students of the Faculty of Engineering of Vidzeme University of Applied Sciences in a 3-year period (2018, 2019 and 2020), the author surveyed 253 students to find what their main interests are, which occupy a large part of their lives and make their daily lives happier and more creative. Students were able to provide answers in a free-form form, and the summary provided a daily student profile (Figure 1) that accurately demonstrated the necessity of interdisciplinary approaches to learn math with interest and pleasure as a creative and multidimensional subject.

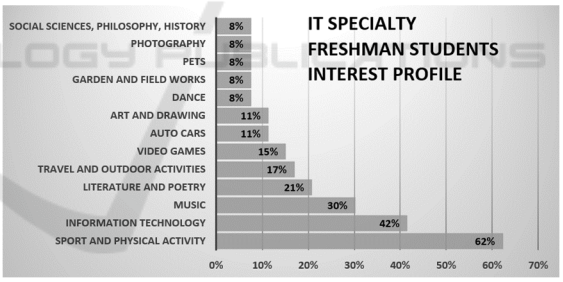

Figure 1: IT specialty freshman students interest profile.

As shown in Figure 1, 62% of students are interested in sports, 42% of students are interested in Information Technology, 30% of students are interested in music, 21% of students are interested in literature and poetry, 17% of students are interested in traveling and outdoor recreation, 15% of students are interested in video games, 11% of students are interested in cars. Students are also interested in art and drawing (11%), dance (8%), garden and field work (8%), dogs and cats (8%), photography (8%), social sciences and history (8%). Other student`s interests include: handicrafts (6%), logic puzzles (4%), films (4%), cooking (2%), languages (2%), theaters (2%), self-improvement (2%).

The research question is what interdisciplinary digital technology-based approaches stimulate students' interest in learning math, motivate them and improve attitudes in the long term?

The aim of the study is to point out to educators, policy makers, industry entrepreneurs and researchers the necessity of collaborative and interdisciplinary approaches to accelerated learning in mathematics in general schools. This will in the future contribute to the development of AI solutions and a quality support system for mathematics teachers to stimulate the emergence of innovative learning approaches and enable mathematics to be taught as a creative and multidimensional subject.

3 METHODOLOGY

The study is a compilation of current information and many years of experience with an interdisciplinary approach, and the methodology includes:

→ 3-year student survey (2018, 2019 and 2020) of 253 first-year students of Vidzeme University of Applied Sciences, who come from the whole Latvia;

→ Compilation, analysis, comparison of the survey results and creation of a student's daily interest profile, which shows the necessity of interdisciplinary approaches;

→ A selection and brief description of eight technology-based interdisciplinary approaches based on experience, 30 years of mathematics lessons, teacher success stories from around the world and expert advice;

→ Qualitative research methods (observations, semi-structured interviews, focus groups, secondary research) to explore the views and experiences of pupils, teachers, students, parents and industry professionals during distance learning through daily conversations, information in the media, success stories, social media profiles;

→ Primary data, so as to reveal the problems of distance learning, the Ministry of Education and Science of Latvia (IZM) in cooperation with the company Edurio surveyed 4662 teachers, 8352 parents, 10177 students in May and June, 2020 (IZM, 2020).

4 THEORETICAL FRAMEWORK

4.1 Interdisciplinary Approach

In the field of education, the word "interdisciplinary" has been around for years. Several studies (Kim, 2020; AldertKampAdvies, 2017; RSE, 2020) indicate that interdisciplinary learning is innovative, attractive and exciting, as well as driving 21st century education reforms. Interdisciplinary learning is a way of learning and thinking that is based on several disciplines in order to acquire new knowledge and skills. For interdisciplinary training to be effective, researchers (McPhee et al., 2018; RSE, 2020) emphasize the following framework conditions: 1) interactivity of different fields, 2) teamwork and cooperation between people, 3) internship in relevant fields in the workplace, 4) breadth of knowledge and skills, 5) creativity and curiosity, 6) constant access to knowledge and lifelong learning, 7) changes in school curricula , 8) support for teacher education and development, 9) digital and social skills.

4.2 Accelerated Learning of Mathematics

Our brains are adaptable, and when students learn or change their approach to learning, incredible developmental results can be created. In recent years, a new science has developed, neuroplasticity, which specifically studies improvements in brain function and emphasizes that brain function can and should be improved at any age (Boaler, 2019). Based on research (Accenture, 2018; Area9, 2020; Boaler, 2019; Duval, 2019), seven basic principles can be identified that significantly improve and accelerate the learning of mathematics:

→ For growth to take place, the learning process must be regular and continuous;

→ Mistakes and error correction improve the long-term sustainability of mathematical skills;

→ Positive communication from parents and teachers, which inspires faith in the student's strengths, is especially important for promoting growth;

→ Applying an interdisciplinary approach activates neural pathways and learning in general;

→ Open and creative math problems are important, which promote deeper learning and retain attention;

→ Meaningful collaboration and exchange of ideas accelerates neuronal flow and improves learning.

That's why group and project work is so important in math lessons.

→ There is a strong correlation between memory and time, and by repeating the subject, students are able to learn mathematics much faster.

Neuroscientists (Boaler, 2019; Duval, 2019) point out that the knowledge we currently have about brain function is so important that it should change the way we teach students and run schools. Our brains have a tremendous ability to grow and change at any stage of life. This is demonstrated by a study of black cab drivers in London, which showed that extensive and complex spatial training has led to a significant increase in the amount of brain hippocampus in humans, which is important for all spatial and mathematical perceptions (Maguire et al., 2000). Taxi drivers in London must undergo extensive training, learning how to navigate between thousands of places in the city. This training is colloquially known as "being on The Knowledge" and takes about 2 years to acquire on average. To be licensed to operate, it is necessary to pass a very stringent set of police examinations (Maguire et al., 2000). Similarly, neuroscience researchers (Coyle, 2009; Duval, 2019; Moser et al., 2011) confirm that the best time for brain growth is when people work on challenges, make mistakes, correct them, fight, and move on. But teachers usually do their best to make students' work easier by breaking down problems into smaller tasks, or by giving answers in front of them, or by facilitating the content of teaching. As another important piece of evidence for neuroscience, researchers (Boaler, 2016; Boaler et al., 2016; Menon, 2015) point out that five impulses act on the brain when working on math problems, two of which are related to visual perception (Figure 2). This leads to the conclusion that brain connections will be much more productive if mathematical tasks if they are designed as visible interdisciplinary combinations of numerical expressions and images.

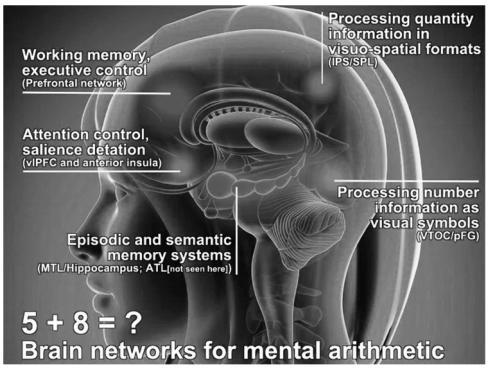

Figure 2: Brain networks for mental arithmetic (Duval, 2019).

4.3 Artificial Intelligence

A study (Guo & Han, 2020) indicates that AI is a cross-disciplinary discipline that encompasses several disciplines, such as neuroscience, psychology, mathematics (including statistics), information science, and computer science. Today, AI, represented by deep data-based learning, is developing rapidly and is widely used in many fields. It is believed (Southgate et al., 2019) that AI algorithms have existed since the late 1970s, but their widespread use with the available computing power in the world and modern AI chips began only 5-7 years ago. AI is a term used to describe a set of computer systems and computer programs that use human-like thinking features to perform tasks. AI systems are able to analyze images and videos, listen to sounds, understand and synthesize language, predict exchange rate fluctuations, predict electricity consumption and perform many other tasks that only humans have been able to do so far. If more and more new AI solutions appear in production (for example, in Latvia company Balticovo the quality of eggs is analyzed with the support of AI, before the eggs reach the final tests), then in school education AI is still at an early stage of development.

5 FINDINGS

Based on the identified problems during distance learning, neuroscience research and pedagogical success stories, the following technology-based interdisciplinary approaches to accelerated learning in mathematics can be suggested:

5.1 Contextualizing: Mathematics through the Prism of History

Research (Nikitina & Mansilla, 2003) indicates that contextualization is a review of mathematics and science in history. It shows the connections between the theories of science and mathematics and their historical and cultural roots. The historical foundations of a particular mathematics topic can serve as a core for a better understanding and more effective acquisition of the topic. In the lessons, it is valuable to create a link between the natural sciences and the humanities by creating an interdisciplinary link. For several years now, in the course of studying applied mathematics with students, studying specific topics, we look at the history of the origin of this topic.

A good example of this approach can be seen by studying the topic of solving systems of linear equations with the Gaussian method, when students find the answers to many mathematically mediated questions: Why is the ingenious German scientist Karl Gauss called the King of Mathematicians and the Innovator of Science? How can I count the numbers from 1 to 100 the fastest? How to divide a circle into equal parts using a circle and a ruler? How did number theory become science? How can astronomy solve complex mathematical problems? What are trigonometric or Gaussian sums? How did the surface theory for the development of geodesy come about? How did the unit of measurement "gauss" in physics come about? The example shows that in one lesson, mathematics can successfully meet history, science, art, astronomy, astrology, geography and physics to stimulate students' interest in real applications of mathematics. The strength of this approach is the creation of a cultural-historical reference, which forms a strong basis and support for the development of students' personal knowledge of mathematics.

5.2 Problem-Centering Approach: Applying Math and Science to Solving Real-World Problems

Research (Biccard & Wessels, 2011) indicates that problem-focused approaches give students the opportunity to explore mathematics for themselves and offer sensible solutions. All attention in the classroom is focused on the problem to be solved, as a result of which there is an active discussion both among the students and between the teacher and the students. In addition, these types of classes can take place in nature, outside classrooms, using digital technologies and other aids (maps, tape measures, rulers, compasses, measuring instruments, thermometers, etc.).

The strength of this approach is personal involvement, which increases motivation and interest. Leading a math group for 3rd to 7th grade students during the Covid19 pandemic, when distance learning was identified and students mostly learned from home, we developed 10 sets of tasks that encouraged students to go to nature to find the information they needed and make calculations independently.

For example, one of the tasks was as follows: A number is called symmetric if it can be read equally from the right and the left. There has been one important symmetrical year in the development of the Kalnamuiža park territory. Find this year on the information board of the park territory. Name the next symmetric year. Calculate the difference between the two symmetric years. Is the difference a symmetric number? If not, can the digits make a symmetric number and which one?

5.3 Visualization: Combinations of Mathematical Numbers and Images

It is said that a picture is worth a thousand words. This is especially true in mathematics, where an image or some other type of visual model can be useful in describing a mathematical idea (Tenannt, 2006). Over the last twenty years, with the development of computer visual imaging capabilities, a new field of mathematics called visual mathematics has emerged. Especially for younger students, it is important to work with constructions and colors. In this way, students can better see how planes and three-dimensional shapes are formed and how formulas work. Today, many students have a visual perception. They learn the substance best when they can see what is happening, and a non-visual approach can even hinder their efforts to solve the problem.

A good example of a visualization strategy for learning mathematics is the famous Königsberg "bridge walking" problem, which can be easily explained by creating a graph diagram as a visual representation of the situation.

5.4 Active Approach: Mathematics in Step with Sports

Parents, educators and health professionals have pointed out that today's children do too little exercise, which is further exacerbated by distance learning at home. It is well known that without movement a child cannot grow up healthy. The more and different movements a child has, the more active the brain is and the more intense intellectual development takes place. The movement creates emotional well-being and improves perception. Pre-school and primary school teachers in particular have given a lot of thought to developing an interdisciplinary approach between sports and maths lessons.

But the most innovative solution has been created by the Canadian technology company LÜ (https://play-lu.com/). It has developed an interactive area that uses light, sound and video effects to transform any gym into an engaging and comprehensive learning environment. LÜ is a smart space that understands the behavior and interaction of the people in it in real time. Using information from ceiling-mounted 3D cameras, students can learn math from wall-mounted tasks in sports.

5.5 Parallel Approach: Mathematics in Combination with a Foreign Language

In Latvian schools, English is mostly studied as the first foreign language and German or Russian is chosen as the second foreign language. Taking into account that teachers often lack digital mathematics tasks and worksheets in Latvian, they search for them on the Internet in foreign languages. In this way, an interdisciplinary approach is promoted while learning mathematics and a foreign language. Open tasks can be mastered in this way especially productively. A study (Pehkonen, 1999) indicates that tasks are considered open if their starting or target situation is not specified. Open problems usually have more than one solution and can be accomplished in more than one way. This leaves students free to tackle the task and allows them to use different ways of thinking. The approach works very well in mixed classrooms, where the level of knowledge of the students is from the lowest to the highest, because everyone can provide answers according to their knowledge and skills. The teacher has the opportunity to find tasks, the simplest of which are possible for all students in the class, but higher levels of difficulty challenge the abilities of the most talented students.

A good example of an open problem strategy in mathematics lessons is the task: 10 participants come to the seminar, and each shakes hands with each other exactly once. How many handshakes have occurred? There is only one answer - and it is 45, but there are at least seven methods of solving: looking at all possibilities, with the help of graphs, with the help of visualization, with the help of a table, with the method of mathematical induction, with combinatorial formulas. Finally, students can be asked to find a general case for the task.

5.6 Modeling: Math Applications

Not all students love math at first glance. To some it may seem tedious and complicated, especially if only theory, formulas and methods are taught. Math lessons can be made more interesting and digitally engaging with apps that can be found on the Internet for free and for different ages.

The following applications, for example, will provide an interdisciplinary and visually appealing approach between mathematics and technology lessons: Mathspace (https://mathspace.co/us), Buzzmath (www.buzzmath.com/en-us/), CK 12 (www.ck12.org), Shapes 3D (www.mathsisfun.com), Khan Academy (www.khanacademy.org), Photo Math (photomath.app), GeoGebra (www.geogebra.org), etc. In turn, the application of mathematics and modeling will be helped by more professional programs, such as MATLAB (www.mathworks.com) or Wolfram | Alpha (www.wolframalpha.com).

5.7 Coding and Programming: Math through Logic and Algorithms

Coding and programming are great helpers and powerful methods for students to better understand mathematics. For example, first-year students of the Faculty of Engineering learn applied mathematics much more quickly and train algorithmic thinking if, in parallel with theoretical lessons, the functions of the mathematics math module of the Python programming language are mastered. Primary school students, on the other hand, become much more interested in mathematics and develop logical thinking more deeply if they attend robotics lessons and are able to write working codes for robot movements without errors.

5.8 Artificial Intelligence: Synergy of Mathematics and Neuroscience

The highest point of the interdisciplinary approach is AI solutions that promote socialization, quick feedback, interactivity, involvement, multiple repetition, generation of different tasks according to each student's individual abilities. Research in the new field of neuro-education (Bidshahri, 2017; Wilson & Conyers, 2013) emphasizes that, in collaboration with AI, individual brain activity data can be used in the future to understand each student's strengths and weaknesses and make math learning much faster, deeper and more personalized. AI and mathematics have the strongest synergies, as AI is based on mathematics (linear algebra, statistics, probabilities, logic, etc.) and AI-based solutions can be successfully used to learn math faster.

Researchers (Perera & Aboal, 2019) describe an example where an online adaptive learning solution called “Mathematical Adaptive Platform” (PAM) has been developed in Uruguay, the content of which is adapted to the national mathematics curriculum. PAM provides personalized feedback according to each student's skill level, based on an analysis of the student's experience. PAM provides assistance to students through more than 25,000 differentiated tasks and 2,800 feedbacks to explain the solution to each task.

6 CONCLUSIONS

As technology enters everyday life more quickly and purposefully, the education system is also becoming more accessible and efficient. And teaching of mathematics in general schools must keep pace with technological advances, with the result that our task is to create a digital technology-based education system that does not increase social tensions and inequalities.

In order to make school mathematics a more accessible and meaningful subject, technology-based interdisciplinary approaches are needed, which are clearly indicated by the following trends:

→ the current target audience of schools is "Generation Z" or children of the digital age, born from 2001 to 2015, whose everyday life is fully merged with modern technologies and AI solutions (Rubene, 2020);
→ former teaching methods are being replaced by more effective research and Big Data-based methods (Persico, 2019);
→ currently (especially during distance learning in 2020) technologies have different effects on urban and rural school students, talented and less able students;
→ distance learning points to the necessity for interdisciplinary approaches that promote sports and outdoor activities;
→ distance learning points to the lack of cooperation between education and IT professionals in order to create innovative solutions and reduce the tensions created by digital technologies;
→ the student's daily interest profile modeled in the research (Figure 1) indicates the desire to learn mathematics in a modern way, with interest and joy as a creative and multidimensional subject;
→ neuroscience researchers (Boaler, 2019; Duval, 2019) point out that the knowledge we currently have about brain function is so important that it should change the way we teach students and run schools. Brain connections will be much more productive if mathematical tasks are designed as visible interdisciplinary combinations of numerical expressions and images;
→ one of the most beautiful aspects of mathematics is its many facets, when ideas, problems and solutions can be represented in several visible ways, for example, with numbers, algorithms, codes, visual images, tables, models, graphs, etc.

A study (Guo & Han, 2020) indicates that AI itself is an interdisciplinary discipline that combines several disciplines, such as neuroscience, psychology, mathematics, big data analytics, and computer science. If more and more new AI solutions emerge in production, AI in school education is still at an early stage of development. Mathematics is one of the most rewarding subjects where AI solutions can be successfully used to foster collaboration and individual approach, to speed up task correction and feedback, to generate more and different tasks, to relieve teacher time and respond to student emotions. AI education is a feature of intelligence, and schools need to keep pace with the times, make changes, innovate and change the roles of teachers / students to adapt future populations to the "age of artificial intelligence" (Shen, 2020).

The most important questions in the near future will be the following: Are today's teachers ready to develop the leaders necessary for tomorrow? Will educators be able to be active and collaborate with industry professionals to improve mathematics teaching in general? It is extremely important to look for interdisciplinary collaborative solutions, because:

→ An important task is to reduce the technological tension caused by the discrepancies between the pace of technological development and people's ability to apply it. And the education sector alone will not be able to cope with it;
→ The task of the state is to create support and preconditions so that every student and teacher is not excluded from the development of digital technologies;
→ As digital technologies take over everyday life, the most important task is to create an appropriate and flexible education system with the opportunity to acquire more new skills;
→ During the Covid19 pandemic in 2020, significant paradigm shifts have taken place, such as no direct contacts, no traditional services, information needs to be prepared in advance to be passed on, etc.;
→ We must not lose value and the quality of teaching, nor unduly reduce the content of teaching.

ACKNOWLEDGEMENTS

The research is carried out within the framework of the postdoctoral project "Artificial Intelligence (AI) Support for Approach of Accelerated Learning of Mathematics (AI4Math) (1.1.1.2/VIAA/ 3/19/564)" at Vidzeme University of Applied Sciences with the support of ERAF.

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