Maria-Cristina Popa (coord.)

E-Book: Transforming Math Education through Blended Learning in Primary School

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BL with Robotics

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TABLE OF CONTENTS

INTRODUCTION

The development of technologies in various fields leads to the development in the same direction of the training process. The world's education system seeks to keep up with the new innovations that appear, and especially what can be applied in education. New teaching-learning methods and new strategies based on information technologies are emerging, with the latest and most appropriate tools, to prepare new generations for permanent changes in the field of digital technologies. A series of researches appear that indicate not only the necessity of studying and applying digital technologies in the training process, but also the major importance of combining technologies with the theoretical and practical content of information from the national school programs of each country. Educational Robotics has a special place in modern training, which can be applied at any age. Namely, the application of educational robots to the combined learning of mathematics in primary education.

This volume comprises a close collaboration between 5 partners in the project "Blended Learning to Increase Math Success through Robotic Applications (BLwithRobotics)", grant agreement no./ Grant agreement 2021-1-RO01-KA220-HED-000023025.The volume's chapters focus on the latest information related to the Application of Educational Robots in blended mathematics teaching and future trends in this direction.

The experts who contributed to the writing of the chapters made an analysis of the specialized literature regarding the teaching-learning of mathematics in primary classes with combined teaching techniques – Blended Learning and using Educational Robots as a basic tool. In particular, those ideas were pursued in which the application of educational robots would reduce anxiety in mathematics, a current and much highlighted problem among students of different ages. The entire volume is based on the role of Educational Robots in reducing anxiety, conducting a pleasant classroom management with the application of Robots both in teaching and in assessing knowledge, applying a blended teaching (Blendead Learning) in mathematics classes, with guidance and suggestions for the application of Educational Robots.

The topics analyzed in the chapters were developed based on the most important ideas derived from new research in the field, with the opinions of teachers in training and experienced teachers in primary education, taking into account the official school curriculum of all partner countries.

This volume can be a good guide for teachers in training and with experience in primary education, when teaching mathematics through blended learning, it can also be helpful for the training and continuous development of teachers in the direction of new teaching methods. It can also be useful for middle school and high school teachers as an example of the application of combined learning with Educational Robots.

CHAPTER 1.
INTRODUCTION TO ROBOTICS IN MATH EDUCATION

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Anna Bogacz – Społeczna Akademia Nauk

1.1 THE ROLE OF TECHNOLOGY IN MODERN EDUCATION

In the rapidly changing education landscape of the 21st century, the pervasive influence of technology is observed. Teachers and students are struggling with the rapid changes taking place in the sphere of learning, and technology is becoming a fundamental driver of transformation. We will delve into the multifaceted role of technology in modern education. We will explain its far-reaching effects, the emergence of personalized learning, and the challenge of the digital divide.

The digital revolution in education means not only the integration of technology into classrooms, but rather a multifaceted transformation of the entire educational reality. The Internet, mobile devices, and an extensive repository of learning software and platforms have changed the way we teach and learn. This profound change includes the following aspects:

- **The Pedagogical Paradigm Shift** – a radical transformation of conventional teaching methods once anchored in the physical classroom. Instructors are no longer the only guardians of knowledge, but are beginning to act as guides, encouraging students to discover knowledge on their own. Technology enables students to access a wealth of information and learn independently by interacting with digital content (Kivunja, 2014);
- **The Democratization of Knowledge -** at the core of digital transformation is the democratization of knowledge. The Internet is an expansive, limitless repository of information that students can access, regardless of geographic location, socioeconomic status, or age. Universal access to information fosters equity in education and frees learning from the physical constraints of textbooks and classroom walls (Holbrook, 2019);

- **Personalized Learning Environments** - the use of technology to enable a personalized learning environment. Adaptive learning platforms, data analytics, and intelligent algorithms for organizing the educational process adapt instructional content and learning pace to the individual needs of students. Such adaptation of education to the individual needs and abilities of the student is particularly beneficial in teaching mathematics (Alamri and all, 2021);
- **The Digital Classroom** – the use of a digital classroom to extend learning beyond the traditional classroom. Use virtual learning environments, online discussion forums, and digital libraries to enrich the learning experience, allowing students to network, collaborate, and learn from anywhere in the world. Technology blurs geographical boundaries, fostering global education (Michaelsen, 2020).

The democratization of knowledge, made possible by the introduction of digital technologies into education, transcends socio-economic barriers. As access to information becomes more equitable, educational disparities resulting from economic differences can be reduced. This universal access highlights the importance of digital skills, ensuring that all students have the necessary skills to harness the power of digital technologies.

In the traditional classroom, teachers are challenged to address differences in learning ability. The traditional approach often leaves some students behind, while others may lose engagement due to a lack of challenge. Technology provides a solution to this problem by personalizing education. Computer algorithms can assess student performance, identify strengths and weaknesses, and tailor educational content to specific needs. This dynamic, flexible approach can foster a deeper understanding of mathematical concepts and engage students at their unique skill levels. The incorporation of technology into education generates a wide wealth of data. Educators can use this data to gain insights into student outcomes, identify areas where additional support is required, and optimize teaching strategies. By collecting and analyzing data, instructors can ensure that no learner is left behind, bridging their learning gaps. The digital classroom, although an integral part of modern education, does not fully replace valuable direct interaction between the teacher and the student. Blended learning, which combines face-to-face and online learning, offers students the best of both worlds

(Hrastinski, 2019). In real-world classrooms, students can engage in discussions, collaborate on projects, and benefit from immediate teacher support. Technology complements these interactions by allowing students to access a wealth of resources to enrich their learning experiences.

Despite the many benefits that technology brings to education, the digital divide continues to be a challenge that cannot be ignored. This divide is due to differences in access to technologies such as computers and high-speed internet access. This can significantly affect a student's educational capabilities. Bridging the digital divide is a constant priority in modern education, requiring investment in infrastructure, technical resources and digital skills programmes to ensure that all students have equal access to the educational benefits offered by technology. The role of technology in modern education includes a pedagogical paradigm shift, the democratization of knowledge, personalized learning environments, data-driven insights, and the ongoing challenge of the digital divide. It is important to understand how these changes are impacting the field of mathematics, and more specifically, how robotics, combined with blended learning, can revolutionize mathematics education.

1.2 ROBOTICS AS A TOOL FOR ENHANCING MATH EDUCATION

In the growing choice of educational methodologies, the application of robotics is a concept that stands out as a remarkable tool to revolutionize the way we learn mathematics. The incorporation of robotics into mathematics education breaks down barriers between abstract mathematical concepts and their real-world applications (Benitti, 2012). Next, we'll take a closer look at the multifaceted role of robotics in math education, discussing its ability to explain mathematical principles, develop problem-solving and critical thinking skills, and how it supports student engagement and motivation. Mathematics, with its abstract formulas and theorems, is often challenging for students who have difficulty understanding their actual meaning. This is where robotics leads the way, as it brings mathematical concepts to life through real-world applications. When students work with robots, they can see firsthand how mathematical principles are applied in practice. For example, they can observe how trigonometry is used to calculate the angles of a robot's movements, or how algebra is used to create navigation algorithms. Robotics transforms mathematics from an abstract discipline into a concrete, real-life experience. When students can physically manipulate robots, experiment with programming, and witness the results of their mathematical calculations, it deepens their understanding of abstract concepts (Ke, 2014). Tangibility makes mathematics more accessible, and lessons learned from the use of robots often have a lasting impact, as students can relate these concepts to real-life scenarios. Applications of robotics require students to take a problem-solving approach. Students must identify problems, solve them, and optimize robot movements. These exercises are rich in opportunities to solve mathematical problems. Whether it's determining the most efficient path for a robot to navigate a maze or calculating the angles at which a robotic arm can grab an object, these challenges encourage students to apply mathematical knowledge to real-world tasks.

Robotics is inherently interdisciplinary. It incorporates elements of science, technology, engineering, and mathematics, known as STEM. This interdisciplinary approach serves as a powerful tool in mathematics education in several ways. The first one can be described as **Seeing the Connections**. With robotics, students can see the connections between math and other STEM subjects. For example, by programming a robot, they may realize that geometry is necessary to calculate spatial coordinates, while physics comes into play to understand the mechanics of the robot's movements (Bernard and Mazur, 2009).. This interdisciplinary perspective fosters a holistic understanding of STEM subjects, emphasizing how they work together in real-world applications.

The second aspect is **Encouraging Career Exploration**. Robotics introduces students to potential career paths in fields such as various branches of engineering, computer science, and robotics itself. This early exposure can spark interest in a career in STEM and motivate students to further their education in related disciplines. Robotics competitions and challenges provide a platform for students to showcase their skills and explore future career opportunities.

One of the most fascinating aspects of robotics in mathematics education is its ability to captivate and motivate students. The excitement of designing, building, and controlling robots can be a powerful catalyst for engagement. Robotics evokes students' enthusiasm for learning mathematics in a variety of ways. It offers hands-on learning opportunities. Students don't just read or listen, they actively create, experiment, and solve problems. This hands-on engagement can lead to a deeper understanding of mathematical concepts. When students successfully build and program robots, they experience a natural sense of accomplishment. This sense of achievement can boost their confidence and enthusiasm for math. They begin to understand that they can apply mathematical principles to solve real-world problems, making math seem more relevant and rewarding. Robotics emphasizes practical applications of mathematics in the real world. Whether it's manufacturing, healthcare, or autonomous vehicles, mathematics plays a key role in the functioning of modern technologies. By working with robots, students see how mathematics is used in a variety of industries, making the subject more utilitarian and inspiring career aspirations.

1.3 ADVANTAGES OF BLENDED LEARNING

Blended learning is a dynamic and innovative approach to education. It combines traditional teaching with the use of digital resources (Clark, 2018). The integration of these two learning methods offers many benefits, making it an attractive model for modern education. We will further explore the benefits of blended learning, discussing its flexibility, the ability to learn at your own pace, collaborative learning, and broad access to resources that enrich the learning experience (Bonk & Graham, 2005).

Blended learning brings a level of flexibility to the educational process that is very valuable. This flexible approach takes into account different learning styles, paces, and life situations. At a time when students are engaged in a variety of activities, blended learning fulfills the need for flexible learning structures. Flexibility in blended learning means that students can customize their learning paths. They have the freedom to decide when and where they engage with educational content. For example, if a student is particularly productive in the evening, they may choose to study math during those hours. This level of personalization is a significant advantage for students. Blended learning supports students who need to juggle work or other responsibilities with their education. By providing opportunities to learn at their own pace, it relieves the pressure of adhering to rigid schedules and enables students to maintain a balance between different activities.

One of the main advantages of blended learning is the self-contained nature of the online component. Students can revise and practice math concepts as many times as needed until they achieve mastery. This self-paced approach fosters a deeper understanding of mathematical principles. Learning to a master's level is a core concept in self-paced blended learning. It ensures that students fully understand a topic before moving on to the next one. If a student encounters difficulties with a particular mathematical concept, they can return to it as many times as necessary until they feel confident, making sure that no gaps in their mathematical knowledge are left. The ability to revisit and practice mathematical content over time increases the durability of the acquired knowledge. When students can reinforce their learning through consistent practice and repetition, it solidifies their understanding of mathematical principles, leading to more long-term retention of knowledge.

Digital tools in blended learning environments generate a wealth of data that can be used to assess student progress and tailor teaching to their needs. This data-driven approach is particularly beneficial in math education, where understanding each student's strengths and weaknesses is critical. Blended learning platforms offer real-time monitoring of student performance. Teachers can observe student progress, pinpoint areas where they may be struggling, and quickly provide targeted support. This approach to education ensures that students receive help when it is needed most. The data generated by blended learning can also be used to adjust the learning process. Teachers can tailor the curriculum, materials, and teaching methods to the specific needs of individual students. This personalized approach optimizes the learning process and is especially valuable in mathematics, where students often have varied learning requirements.

Blended learning does not replace traditional classroom interaction, but rather complements it. Face-to-face working in blended learning environments provides students with the opportunity to collaborate on projects, engage in discussions, and benefit from face-to-face interactions with peers and teachers. Collaborative projects and group activities encourage peer interaction, which can be especially valuable in math education. Students can work together to solve math problems, share their experiences, and learn from each other. Collaboration nurtures a sense of community and shared learning experiences.

Face-to-face interactions in the classroom provide students with an immediate opportunity to get support from their teacher. When students encounter difficult math concepts or require additional explanation, they can seek help directly from their teachers. This personalized support ensures that students do not face unnecessary obstacles in their educational path.

The blended learning online work component provides students with access to a wide range of resources. Interactive simulations, video tutorials, educational games, and online textbooks are just a few examples of materials available to students. This access to a wide spectrum of resources makes math education more engaging and dynamic. Interactive simulations offer a unique way to learn about mathematical concepts. Students can experiment with mathematical principles by visualizing abstract concepts in action. For example, they can manipulate variables in a virtual physics experiment to understand mathematical relationships. Video tutorials provide alternative explanations of math concepts. Different teaching styles and approaches can help students who may not be able to absorb concepts through traditional methods. Video tutorials also allow students to come back to the explanations as many times as needed. Educational games make learning math fun and engaging. Students can engage in gamified experiences that challenge their math skills while providing instant feedback and rewards for their progress. These games transform math into an enjoyable adventure.

The undoubted advantages of blended learning include the flexibility it offers, the self-paced learning it promotes, data-driven insights, collaborative learning, and broad access to resources that enrich the learning experience. Blended learning is a multifaceted approach that tailors education to individual needs and encourages interaction with peers and teachers.

1.4 CURRICULAR AND INNOVATIVE APPROACHES

In the field of mathematics education, the inclusion of robotics has opened the door to innovative and dynamic curricular approaches. Next, we will follow strategies for developing a curriculum that uses technology and robotics. The importance of alignment with educational standards, the value of hands-on learning, the role of project-based learning, and the importance of teacher training and support in ensuring the effective integration of robotics into mathematics education will be discussed (National Research Council, 2007; Jonassen and al., 1999).

1.4.1 MEETING EDUCATIONAL STANDARDS

The foundation of any effective educational program is alignment with educational standards. Mathematics curricula must be carefully designed to meet these standards, ensuring that the content taught through robot-based approaches is both relevant and comprehensive. Educational standards define the key educational objectives and competencies that students should achieve at each level of education. It is essential that robotics-based math education adheres to these standards, ensuring that students are exposed to the necessary math content and skills. Alignment with educational standards also ensures that the curriculum remains up-to-date and applicable. The integration of robotics should improve students' understanding of mathematical concepts and their ability to apply this knowledge to real-world situations.

1.4.2 PRACTICAL LEARNING

A key feature of robotics in mathematics education is hands-on learning. Students should have plenty of opportunities to build and program robots, applying mathematical concepts in a hands-on way. This face-to-face experience improves comprehension and retention. Manipulating robots and observing the direct impact of mathematical principles on robot behavior deepens students' understanding. Hands-on learning is particularly effective at justifying real-world applications of mathematics. When students are involved in constructing and programming robots, they can see how mathematical principles are applied to technology and industry, thus reinforcing the importance of mathematics in everyday life.

1.4.3 PROJECT-BASED LEARNING

The inclusion of project-based learning in the curriculum encourages students to work on real-world math problems. Robotics projects challenge students to solve complex mathematical puzzles, which promotes a deeper understanding of mathematical concepts. Robotics projects often require students to solve complex problems (Krajcik and Blumenfeld, 2006). They must develop solutions that involve applying mathematical principles to real-world problems. This approach fosters problem-solving skills, which are integral to mathematical proficiency. Project-based learning encourages critical thinking. Students are tasked with making decisions, optimizing robot movements, and adapting to unforeseen situations. These scenarios require students to think creatively and improve their math skills.

1.4.4 TEACHER TRAINING AND SUPPORT

Teachers need to be properly trained and supported so that robotics can be effectively incorporated into mathematics teaching. Professional development programs and resources are essential to help educators become proficient in using these technologies. Teachers need comprehensive training in robotics and its applications in mathematics teaching. This training should cover not only the technical aspects of robotics but also pedagogical strategies for effectively teaching mathematics using this innovative tool. Support for teachers should be continuous. Educators should have access to resources, mentors, and communities of practice that can provide guidance and solutions to problems. The field of robotics and technology is constantly evolving. Teachers need support to stay on top of new developments and incorporate them into their curriculum. This ongoing professional development is critical to maintaining the effectiveness of robotics in mathematics education.

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CHAPTER 2.
TEACHING PRINCIPLES AND METHODS

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2.1 BASIC PRINCIPLES OF ROBOTICS LEARNING

The period up to 2030 is described as Europe's "digital decade", where the digital strategy aims to ensure that both citizens and businesses benefit from the digital transition (European Commission, 2021). As part of the "Digital Decade", the European Commission has developed a Digital Education Action Plan (2021-2027), which sets out a shared vision for the European Union for high quality, inclusive and accessible digital education in Europe and aims to support the adaptation of Member States education and training systems to the digital age (European Commission, 2021). The European Year of Skills 2023 aims to promote the development of digital skills in society in line with labour market needs (VIAA, 2022), with the launch of the European Digital Skills and Jobs Platform, which offers information and resources on digital skills (European Commission, 2022). The Digital Skills and Jobs Coalition Platform underlines that basic and advanced digital skills will be essential to strengthen our overall performance as a society (European Commission, 2023) and the digital transformation in Europe implies the need for digital skills development across society (European Commission, 2023; Tumase, 2023).

The World Economic Forum is increasingly talking about the skills needed in the labour market of the future: while humans do 71% of work but 31% of work is done by technology in 2018, it is predicted that in the next five to seven years, more than half of human work will be done by "machines". This means that many professions will disappear, replaced by new ones that do not exist today. Several thousand new professions and job roles are expected to emerge in the next 10 years. Already around 2022, the most needed people will be those who can work with large amounts of data, managers of large jobs, technology training specialists, software and application developers and analysts, sales and marketing professionals, digital transformation specialists, as well as organisation development specialists and information technology services. In contrast, there will be a decline in demand for data entry clerks, accountants, customer information and customer service workers and many other occupations. As occupations change, so will the competences needed in the labour market and in everyday life? Analytical thinking, active learning and new skills will be needed, as will technology skills, which means that creativity, originality, initiative, critical thinking, attention to detail, and flexibility in solving complex problems will be essential (World Economic Forum, 2018; Skrastiņa, 2019).

To this end, it is necessary to assess what knowledge, skills, attitudes and values children need to acquire in education to be successful and competitive in the labour market. Some of the most important skills for the future could be analytical and creative problem solving, adaptability, critical and logical thinking, technology skills, patience, reflection, communication and global thinking. The ability to use and adapt knowledge and skills in changing contexts will also be important in the future (OECD, 2018; Skrastiņa, 2019). In order to foster learners' ability to manage technology proficiently, several OECD countries have seen efforts to include technology in the education sector from pre-primary level. However, in many countries, technology literacy in pre-primary education is still integrated into other areas of learning rather than being assessed as a stand-alone learning area, resulting in learner outcomes not being separately assessed as technology learning outcomes.

Five key competences to be assessed for learners in ICT:

1. finding, evaluating and managing information and data;
2. information exchange;
3. digital content creation, transformation;
4. problem solving in a digital context;
5. knowledge and skills related to safety and risks in the context of ICT (OECD, 2018).

It is essential to promote the integration of technology literacy in pre-primary education in order to create long-term interest and foster the technology literacy skills needed for later stages of education (Avsec & Sajdera, 2019). Many children around the world are first exposed to digital technologies before the age of two (Dardanou et al., 2020). It is therefore also necessary to follow this general development trend and include educational robotics in mathematics content learning.

The proficient use of digital technologies can also be effective in promoting child development by improving memory, visual thinking, logical reasoning, mathematical thinking, etc. (Segal-Drori & Ben Shabat, 2021). Several of the opportunities provided by technology are viewed positively if they have a meaningful purpose, adult support (i.e. communication, monitoring activities, promoting healthy technology use habits, etc.), and if limited time is provided through regular physical activity and consistent sleep patterns (Morgan et al., 2021). The main benefit of using robotics in the learning process is the ability to solve problems practically – through experimentation – even when failing, the ability to see the interconnectedness of things, and to think creatively and innovatively to reach a solution. Skills such as group work, creativity and problem-solving skills were also developed most in the learning process (Eguchi, 2013).

However, it is important to remember that too frequent use of online technologies, more than 1 hour a day, can be detrimental to a child's development, as it fills the time they should be doing other more age-appropriate activities - interacting with an adult (parents, teachers), exercising, getting regular sleep, etc. Engaging in online activities several times a day has a negative impact on children and young people's social skills and physical activity levels (Morgan et al., 2021). Risks arise when access to technology and the internet is unrestricted, where you can do whatever you want, with no one monitoring the process and for several hours a day. For younger children this could be online videos, cartoons, aimless gaming on a phone/tablet, while for young people it could be the problems associated with wandering around the networks offered by the internet. For example, a statistically significant correlation was observed for young people between time spent online and problems such as anxiety, depression, withdrawal and emotional reactivity, but problems affecting sleep quality, attention span or aggression did not show a statistically significant correlation with time spent online. Excessive screen time contributes to emotional and behavioural problems in 5% - 20% of children under five years (Bagarić et al., 2021), and increases the likelihood of childhood obesity and delayed physical development. Therefore, it is recommended that children spend no more than one hour a day in front of the screen, if an adult is involved in explaining and discussing the content (Maziah et al., 2012; Tumase, 2023).

There is a view that school, and life, should be more like pre-school. To thrive in today's fast-changing world, people of all ages need to learn to think and act creatively, and the best way to do this is to focus more on imagination, creation, play, collaboration and reflection, just as children do in traditional pre-primary settings (Villarejo, 2019). In today's society, everyone needs creative thinking skills, which can be fostered through the idea of creative learning or the "4 P":

1. *Projects.*
2. *Passion* – when people work on projects they care about, they are willing to work longer and harder.
3. *Peers* – creativity is a social process in which people collaborate, share and build on each other's work.
4. *Play* – supporting playful experimentation as a pathway to creativity, encouraging young people to take risks and try new things (Resnick & Robinson, 2017; Weinberg, 2022).

There are several approaches to robotics learning:

1. *Theme-based.* In this learning process, each lesson selects a topic to be taught and integrates the content of the lesson (presentation of information, construction) around it.
2. *A project-based learning approach.* In this approach, students work in groups and are presented with a real problem for which they work together to find a solution. This learning approach requires long-term engagement and can also take place outside educational institutions.
3. *A goal-oriented approach* where children compete to find solutions to different problems. This learning approach also requires long-term engagement and can take place outside educational institutions (Eguchi, 2010; Skrastiņa, 2019).

2.2 STRATEGIES FOR APPLYING ROBOTS

When planning a lesson, it is important to keep in mind the prerequisites for a successful learning process: balanced physical and mental activity, time for rest, teacher support and presence, feedback and challenges. Educational robots are one way of engaging children in a playful and active way in the learning process. Robotics naturally builds active learning experiences while generating interest and fostering motivation (Metin, 2022). The inclusion of educational robots in the learning process in pre-school has a positive impact on children's developmental progress. For example, the independence of 5-6 year olds in completing tasks increases, as learners become more willing to work individually (initially in groups) after repeatedly working with educational robots in the classroom, as their confidence in their own abilities and understanding of the given tasks increases (Lin et al., 2020; Tumase, 2023). Developing self-efficacy or confidence in oneself and one's abilities, communication, collaboration and motor perception skills, learning about culture, and developing motivation and cognition can all be used during mathematics learning:

- Lego Education robotics kits (WeDo2.0 and Mindstorms EV3);
- Robots, programmable robots (KIBO robotic kit, Bee-Bot, Dash&Dot, TurtleBot, Codey Rocky, Micro:bit);
- Programming sites (Stratch, Strach Jr., Dr. Stratch, Scalable game, Python, MATLAB, Logo, Sketchpad, etc.);
- Apps and interactive games such as Microsoft Kinect games, Scalable game, Bee-bot Ipad app, Hour of code, Lightbot (ShiauWei&Chee-Kit&Weng Kin&Mi Song, 2023).

At least four coding apps – Kodable, Lightbot, Daisy the Dinosaur and ScratchJr – tested and safe for teaching (Papadakis, 2021; Tumase, 2023).

Planning and organising activities that promote pupils' learning is the most important challenge of a teacher's job. The planning of the learning process can be based on a model of teaching that includes experience, reflection, generalisation and analysis, application (Kolb, 2000). Aspects of effective planning can be supported by a description of the planning cycle in terms of the principles of active learning (see table 2.1).

Table 2.1. Aspects of curriculum design (Watkins, Carnell, Lodge, Wagner, Whalley, 2002)

Learning cycle	Active learning	Collaborative learning	Responsible learning	Learning about learning
Do	Challenges for the student, not the teacher	Tasks to be carried out in small groups to build up an overview	Students make choices, plan their approach	Pupils are encouraged to observe aspects of learning when they carry out tasks

Evaluate	The pupil values what is significant, important	Students collect ideas and analyse how the group works	Students monitor progress and follow an action plan	Students analyse their learning, review its goals, strategies, feelings, outcomes
Learn at	New insights and understanding	Explain to the whole group or to other groups	Identify factors affecting progress and develop new strategies	Richer ideas about learning are expressed, further improvement is promoted
Plan	Evaluate, plan for the future, taking into account the known and unknown	Further opportunities for group learning together are considered	Plans are revised to adapt to the situation	Learners plan to analyse and experiment more with their approach to learning

When planning activities with smart toys and educational robots, there are a number of prerequisites to consider:

- the activity is in the form of a game/play (playtime),
- activities should be fun/entertaining,
- clear objectives for the teacher and clear tasks for the children,
- easy-to-use, easy-to-understand technology for communication,
- regularity and structure in the terms of reference,
- the tasks are graded according to difficulty,
- a sense of achievement that motivates children,
- the challenges include a challenging, problem-solving aspect,
- include social interaction with peers,
- the background of the whole lesson includes a common theme/story (Lin et al., 2020; Tumase, 2023).

In pre-school, educational robotics is seen as a kind of playground, providing additional opportunities for expression, participation, communication and exploration of technology, where problem-solving skills play an increasingly important but secondary role (Odgaard, 2022). Children prefer to do tasks in groups when they start activities with educational robots, as this creates a sense of security, which in turn inadvertently develops children's cooperation and communication skills (Lin et al., 2020).

It is important to be aware that children have different perceptual characteristics, distinguishing between two types of perceptual characteristics in the learning process. Some are able to be more analytical, detailed and visual in their learning (field independence learners), while others view learning content more generally, in a global context and less strongly based on visual information (field dependence learners). Differences in perceptual characteristics are also strongly influenced by problem-solving skills related to technology. Children who perceive and process information based more on visual material, and who pay more attention to detail, perform better in tasks involving educational robotics (Kyriakoula & Charoula, 2019).

In addition to individual support, a sequence of tasks should be followed, where, in the Educational Robot sessions, children can be asked to initially draw the path on paper, then plan it with the help of direction cards, and in the final phase program the robot to perform the actions without aids. By using a variety of approaches and methods, there is an optimal chance that learners of all perceptual types will acquire knowledge and skills. Diverse approaches to learning mean that the same goals are pursued through different pathways, i.e. using a variety of approaches. For example, games have already provided basic knowledge of directions, sequences, etc. In addition, the skills learnt in robotics lessons can be practised in advance with other technological solutions such as apps. In order to give children a full experience of the world of programming and to give them a broader view and more versatile skills, it is possible to combine the programming of the educational robot with different programming apps.

However, there is also a need to develop teachers' competences to use digital technologies in a proficient and targeted way to promote the acquisition of new knowledge and skills (Segal-Drori & Ben Shabat, 2021; Tumase, 2023). The educator plays a facilitating role where they create the environment, create the problem and then help to discern the problem and potential solutions. Without the educator's involvement, children solve problem situations in simpler ways, without using the technologies offered, and thus without respecting the conditions of the task, e.g. moving a robot by hand rather than by programming. On the other hand, the teacher's attempts to control the situation too much, to dictate the pace of the work, the pace, the schedule, can cause children to become frustrated and frustrated because there is not enough time to correct the mistake, there is a rush, and the next task follows (Odgaard, 2022). Children face different challenges when they start activities with educational robots, as it is not their usual environment and way of playing. Mistakes and problems in programming lessons are often caused by understanding the direction when the map and the educational robots are from the opposite point of view of the child. If the educational robots and the child are looking at each other in a mirror image, then the actions must also be programmed in the mirror image, which often causes difficulties. It has also been observed in research that children feel confused when a lesson concept is transferred to a new environment, e.g. a different room, an outdoor activity, a different activity mat or map, etc. (Critten et al., 2022; Tumase, 2023).

For example, Lego Robotics is based on a curriculum developed by Lego Education. Since 1980, Lego Education has been developing programmes and methods to teach subjects such as computer science, physics, mathematics and science – the sciences.

The programme aims to:

1. To create an exciting and inspiring learning environment where children develop critical thinking, creative problem-solving skills and knowledge on a wide range of topics (insects, machines, techniques, animals, etc.),
2. To provide knowledge of the technique and its basic principles in the form of games. Through modelling and construction, the child learns to think logically and creatively. The basic knowledge of programming gives confidence in the ability to solve problems without adult help, both in the classroom and in everyday life,
3. Promote cooperation and communication. It is mostly aimed at children aged 4 to 14-15 years (Lego Learning Institute, 2014).

For the very young (4-5 year olds), there are large Lego bricks (e.g. Lego Duplo, Lego Strech, etc.). At this age, through LEGO Education, children learn counting, develop language skills, and develop social and emotional skills (Lego Learning Institute, 2014).

Later in their education, children start to learn and experiment with how technology works what science is, and develop thinking that is more critical, creativity and problem-solving skills. Learning is based on "learning through play", using Lego bricks, digital devices and simple software. Lego Education's learning approach is based on the "4C" – connect, construct, contemplate, continue – framework, which guides the lesson and encourages students to experiment, collaborate and discover new things:

1. Associating/Connecting (Connect) is the first stage of the lesson. Students are introduced to the topic of the lesson, the task, discussion, questions about the topic.
2. Construct. The second stage of each lesson is Construct. Lego constructions are built according to a given scheme.
3. Contemplate. After the construction, the next step is to refine and modify the construction, using the knowledge gained in the first phase of the lesson.
4. Continue (Lego Learning Institute, 2014).

Each task ends with a new task that builds on what has just been learned. The teacher plays a very important role, as the 4Cs learning process requires a balance between the complexity of the tasks and the pupil's skill and ability to complete them. If the task is too easy, it leads to boredom, and if it is too difficult, it then leads to anxiety (Lego Learning Institute, 2014; Skrastiņa, 2019). Children who integrated Lego robotics into their daily learning for a year were shown to have significantly higher scores in mathematics and technological areas. Through building structures, the small muscles of the fingers are well developed and through physical and active learning, the brain is stimulated and the quality of learning is improved. People think and learn primarily through the experiences they have had rather than through theoretical knowledge, calculations and generalisations (Memet, 2013; Skrastiņa, 2019).

As part of her final work, Kandavniece (2021) exhibited robotics games for children. The main aim of the educational robotics games is to expand vocabulary in the field of mathematics.

1. The game "Robo bees digits" (Kandavniece, 2021)

Number and digit. Relationships between quantities. Grouping (Count five in a volume, recognise the number corresponding to the number). To extend vocabulary with concepts such as: one, two, three, four, five; choosing the appropriate number (1-5) to denote, as well as grouping objects.

Achievement expected: In a practical activity, identify the number of objects in a volume of five; choose an appropriate number (1-5) to represent the number. Groups objects

Message to the child: number 1 has one Robo Bee, number 2 has two Robo Bees!

Pervasive skills: critical thinking and problem solving. Figure out how to use the Robo Bee algorithm to go from a card with a given quantity to a number card.

Resources: robo bee, sandpaper number cards (1-5), number cards (1-5) and picture cards, basket with objects.

Brief description of the activity: number cards (1-5) are placed on the floor of the room. Children roll a sandpaper number over it with their hand and name it (see Figure 2.1).

Figure 2.1. Sandpaper figures (1-5) (Kandavniece, 2021).

Invites the children to name what is in the basket, paying particular attention to the number. Explain that the children's task will be to group the objects in the basket as they see fit. Once they have grouped them, they choose the appropriate number card for each group. (see Figure 2.2).

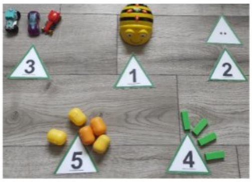

Figure 2.2. Grouping objects with number cards (Kandavniece, 2021).

The children are asked to group the card material with numbers, dots, ladybirds, flip-flops and counting sticks. By grouping the pictures according to the same patterns, the child shows interest in adding the corresponding number cards (see Figure 2.3).

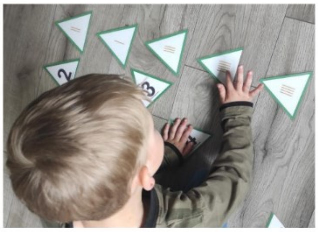

Figure 2.3. Grouping of card material by selecting the appropriate number (Kandavniece, 2021).

The Robo Bee playground is prepared together with the child. The teacher discusses and demonstrates the safety rules for working with the Robo Bees, letting the children tell how we will work with the Robo Bees! Before the Robo Bee starts its task, the children discuss how it works, which arrow (↑ →↓←) will make the Robo Bee move in which direction. If necessary, the children try out the arrow cards to make a path. There are number cards and picture cards on the play area. Explain that the children's task will be to programme the Robo Bee's path to the required square, e.g. if the Robo Bee goes to the number 2, then the Robo Bee will go to the card with the two pictures. The children try different ways to get from the number card to the picture card (see Figure 2.4), (see Figure 2.5).

Invites each child to pick up their Robo bit, carefully turn it upside down and switch off the three buttons. Together, they tidy up the Robo Bee playground (Kandavniece, 2021).

Figure 2.4. Robo bee prepared area (Kandavniece, 2021).

Figure 2.5. A child creates an algorithm to get the Robo Bee to the desired square (Kandavniece, 2021).

2. Formula Searching for Figures (Kandavniece, 2021).

Geometric shapes. Orientation in space (Recognises geometric shapes and figures circle, triangle, quadrilateral, finds corresponding objects in the environment. Identifies the location of an object in space by naming the terms above, below, near, behind, beside, and performs actions according to them).

To expand vocabulary with concepts such as: shape (angular, round), colour (green, red, etc.), figure, circle, triangle, quadrilateral, corner, edge, behind, beside, under, above

Achievement expected: Identify geometric plane figures (circle, triangle, quadrilateral), notice similar figures in the surroundings and describe their shape.

Message to the child: I can also find a circle, a triangle and a square in the Lego box.

Intermediate skills. Critical thinking and problem solving – independently compare similar shapes and tell what they are like. Creativity and Entrepreneurship – Finds similar geometric shapes in a Lego box and purposefully compares them.

Resources: Lego Education Early Simple Machines set, board, Montessori metal inserts.

Short description of the activity: at the beginning of the activity, the teacher tells the children that today we are going to work with Lego boxes, but in order to do that, they have to guess a riddle. “It has four sides. It has four corners. It is black. There is a little button on the side that we can use to turn it on. What is it?” (Planchette). Repeat the puzzle again, pointing to - edge, corner. Safety rules are discussed, children tell how they will work with the tablets to keep both children and tablets safe. The formula will be constructed according to the instructions (instructions are on the tablet) (see Figure 2.6). The children start to construct the formula. The construction process is carried out by talking about the shape of the Lego bricks, the colours, the position (above, below, next to, behind, in front of).

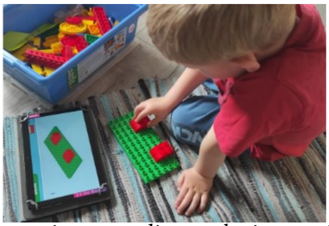

Figure 2.6. Formula construction according to the instructions (Kandavniece, 2021).

Invites the children who have finished constructing to switch off the tablets, close them and put them on the table. Invites the children to create a track for the formula runs. A formula challenge is set up at the track Explain that when the formula stops at a shape, name it and find a similar shape in the Lego box (see Figure 2.7).

Figure 2.7. Name and find the same shapes (Kandavniece, 2021).

Figure 2.8. Metal inserts (Montessori), Lego figures (Kandavniece, 2021).

Invites children to compare and find similar geometric shapes in the Lego box. Each child shows and names the shapes found in the Lego box (see Figure 2.8) (Kandavniece, 2021).

1.3 PEDAGOGICAL AND TECHNICAL RECOMMENDATIONS FOR THE APPLICATION OF ROBOTS

The educational robot must be used under conditions that are appropriate for the pedagogical process, as well as under technical conditions. Tumase (2023), as part of her final work, developed recommendations for educators in educational robotics (Tumase, 2023), providing recommendations for both the pedagogical process and the technical conditions in educational robotics.

Pedagogical recommendations (Tumase, 2023):

1. Before and alongside the educational robot, offer students other forms of tasks that help them practice analytical-algorithmic thinking – games with numbers, sequences, logic, directions, plane orientation, problem solving, etc.
2. Before starting to work with the educational robot, it is advisable to familiarise yourself with the concept of "arrows and direction". Before doing any tasks with the educational robot itself, try path planning with arrow cards, where special attention is paid to understanding turns.
3. In the preparation phase, it is important to discuss with the students the "language of the robot" or how robot communicates and interacts. Making the students aware

that any robot is guided/controlled by a human using a technology (in this case a tablet) and that the robot will not perform any action that is not instructed – programmed – by a human.

4. Include clear instructions in the terms of reference: what needs to be done and how it needs to be done. Often, students, looking for an easier way out, perform the task in a way that the teacher did not anticipate, thus, as it were, avoiding full compliance with the task conditions. Sometimes an unforeseen (creative) solution by the learner is justified and desirable, but sometimes it does not achieve the objectives and the result of the lesson. In order to achieve the objective of the lesson or task, the steps that learners must perform must be defined – they must be illustrated and age-appropriate (e.g. with pictures).
5. It is necessary to differentiate the task according to its difficulty level. During the sessions with the educational robot, the progress of the learners varies enormously. Some learners quickly acquire basic skills and knowledge and crave longer and more complex tasks, while some learners need to linger at the same difficulty level for a long time.
6. With the Educational Robot, adapting tasks to different levels of complexity in the pre-school phase is quick and easy. For example, for those who do better:
   - offer more objects on the pitch,
   - more obstacles,
   - a longer section of the planned route,
   - more turns,
   - additional task conditions, where part of the task has to be solved before or after the robot action, etc.

1. Suggestions for planning a lesson for children who need more time to learn robot tasks:
   - before using the educational robot in the learning process, familiarise yourself with the carpet on which the robot will operate and plan the different paths with the help of the direction cards (arrows);
   - repeatedly offer the same solution (stay at the same difficulty level);
   - allow enough time for everyone to develop the ability to calculate the exact squares/paths required and to

understand the relationship between the real and the virtual square;
- offer the opportunity to initially “walk” the robot on the robot mat
- initially, place the robot on the carpet in the same direction as the learner sees it on the tablet/app so that they are facing the same direction when planning the path.

2. Multi-step tasks, where several sequential task conditions have to be performed, require visualisation of the actions to be performed. For example, learners are given the task to plan a path, add sound blocks, add light blocks, count objects. Often learners take a long time to complete one part of a task independently and forget what to do next, so it is very important to have a reminder where everyone can check their progress.
3. The emotional background to the Educational Robot sessions is mostly positive, with a sense of accomplishment in every session, but it should be noted that increasing the complexity of the tasks too slowly or too quickly leads to a decrease in concentration.
4. In a technology-enriched learning process, the presence and emotional support of the teacher is very important for students. Although students enjoy and are enthusiastic about the lessons where they have the opportunity to learn about and work with different technologies, they are sometimes scared of new environments (lack of confidence). The tasks with the educational robot are an unusual operating environment, so some learners need to be reassured by the teacher during the task that everything is correct. In the first moments of the session or after a long break, the learners are very eager for the presence of the teacher and for reassurance that everything will work out and that “nothing can be broken”.
5. In addition to emotional support, learners need intensive help at the beginning of the technology learning phase, but once they have mastered it, they are eager to work independently. It has also been observed that learners prefer to work in pairs at the beginning, but as they learn the first basic skills, they want to work individually.

6. It is not always easy to transfer acquired knowledge or skills to a "new environment":
   - Just because learners are good at putting a puzzle together in a tangible form doesn't mean that transferring those skills to another format will go as smoothly. For example, in the case of an interactive puzzle, it is difficult to grasp the essence where it is not possible to physically pick up the puzzle pieces and place them where they are needed, as would be the case for a tangible puzzle.
   - Changing the environment in which educational robots operate can sometimes be confusing for learners, so it is preferable not to change the environment (room, type of carpet, etc.) before getting to know and master the new technology properly.

Technical/organisational recommendations (Tumase, 2023)**:**

1. Always check that all devices are in good working order - charged, connected, etc., so as not to disrupt the lesson time and students' work process with technical problems.
2. When using educational robots (different types of technology), it is useful to establish "healthy technology habits" from the very first lesson, i.e. certain rules about what can and cannot be done in such activities. These can be devised together with the learners, a poster or defined by the educator and an infographic that is then prominently displayed and updated before the lessons involving technology activities.
3. In order to have a full and conscious process of learning to use technology, it is recommended to develop a ritual, i.e. a specific sequence of actions at the beginning and end of the lesson, which learners can eventually master and start working independently. For example, switching the robot on/off, opening an app, connecting the tablet to the robot, choosing the type of interface they want.
4. When initially planning the Educational Robot lessons, it is recommended to divide the students into several small working groups (depending on the number of robots available) to allow the teacher to focus on each student in a qualitative way, as well as to divide the students according to the difficulty level of the task.

5. If a task has to be explained repeatedly (to several groups of students), it consumes a lot of time and energy for the teacher, so to save resources it is possible to not only visualise the tasks, but also record their conditions in audio or video format before the lesson.
6. The Educational Robot tasks are cognitively demanding, so it is advisable to plan physical activities after the Educational Robot task - games, etc.
7. The optimal number of learners per educational robot is 2, provided that both learners are engaged in the task.
8. Technical problems can have a negative impact on learners' motivation, for example, if the path is planned correctly but the robot is not positioned exactly in the middle of the field, or if there are other objects on the field (carpet), the robot can get caught on one of them, which can result in the whole path being incorrect as the robot starts to go more and more crooked and inaccurately (Tumase, 2023)

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CHAPTER 3.
CLASSROOM MANAGEMENT WITH ROBOTICS

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3.1 CLASSROOM MANAGEMENT

The rapid advancement of technology has significantly impacted virtually every sector of society, prompting increased investments by countries to stay competitive in this ever-evolving landscape (Şimşek et al., 2008). In today's "Information Age," where knowledge is power, the pace of information doubling every seven years is a testament to the rapid progress in science and technology. Innovations in fields such as laser and optical systems, biotechnology, nanotechnology, and robotics have not only transformed daily life but also revolutionized work processes, making them more efficient and sustainable.

Recent technological developments, including 3D printing, mobile devices, renewable energy technology, the Internet of Things, and virtual reality, have ushered in the era of Industry 4.0. These developments are fundamentally reshaping our lives. In this dynamic century, it's clear that new generations need to acquire competencies to harness technology effectively, nurture critical thinking, and respond to problems with gradual, solution-oriented approaches.

In an age where millions of new contents are produced every minute, the ever-changing landscape of information, data, tools, and users demands adaptability and resilience. Technologies like artificial intelligence, autonomous vehicles, smart systems, and robotics are no longer just concepts; they are increasingly integrated into daily life. Nations that actively engage with these technological developments and contribute to their growth often have more influence in the global arena (Tatlısu, 2020).

As technology evolves at an unprecedented rate, it has become evident that the traditional education system and conventional teaching models are ill-suited to these advancements. There is a compelling need to reorient education systems to align with the evolving technological landscape and integrate technological activities into teaching models.

The importance of educating individuals who can adapt to technological developments and innovative technologies, thereby enhancing the quality and effectiveness of education, has never been more pronounced. This transformation is not attainable through traditional methods and strategies alone.

Recognizing the inadequacy of traditional approaches to address the challenges in today's education field, one of the most effective remedies lies in harnessing information technology and robotics, along with the opportunities they bring (Kayabaşı, 2005). Education stands out as one of the domains most profoundly influenced by advancements in information technology and robotics (Özer and Gelen, 2008).

Education and Technology: The emergence of the novel coronavirus in Wuhan, China, in 2019, quickly evolving into a global pandemic with millions of fatalities, necessitated a rapid shift to online teaching via digital platforms. This crisis underscored the vital role of digital literacy skills and the importance of teachers' technological competencies. To ensure effective education and sustainable learning during this period of distance education, teachers began exploring learning models that integrate technology, such as blended learning and flipped learning. Web 2.0 tools played a crucial role in supporting these models. Teachers who experienced the benefits of these tools continued to utilize digital educational tools and innovative teaching models even after the pandemic.

The winds of change sweeping through the new millennium have significantly altered the educational paradigm. While the traditional education model prioritized knowledge acquisition, the contemporary educational system emphasizes the ability to access and utilize information effectively in daily life (Oktay, 2010). In this context, teachers are expected to possess a broad range of knowledge and skills, including understanding educational program objectives, curriculum development, student developmental characteristics, teaching material design, time management, familiarity with contemporary teaching methodologies, receptivity to new methods and techniques, and proficiency in measurement and evaluation (Ekici, 2014).

In the age of information and technology, societies aspiring to remain influential equip their generations with not only fundamental knowledge and skills but also 21st-century competencies. These skills encompass critical thinking, creativity, innovation, communication, collaboration, information and media literacy, and problem-solving. Coding skills have also taken on a significant role among these competencies (Sayın and Seferoğlu, 2016).

As technology rapidly evolves, individuals' purposes for using technology have also evolved. Robotic technologies, in particular, have become increasingly integrated into daily life, and their presence in educational environments has made learning more efficient. This growing reliance on robotics underscores the importance of educating individuals who possess coding and robotics knowledge. In this context, coding and robotics knowledge are indispensable components of education. Technological elements, when aligned with curriculum requirements, positively contribute to course management. Teaching materials and technologies play a vital role in ensuring the sustainability of learning because the more sensory organs a teaching activity engages, the more lasting and traceable the learning experience, and the slower the rate of forgetting. Educational robotics applications captivate Generation Z due to their engaging nature and numerous application opportunities (Eguchi, 2014). Members of this new generation, also known as Generation Z, are not only avid consumers of technology but are actively encouraged by leading information technology companies to create their own games, software, and robots. This encouragement aims to cultivate a society that actively produces information technologies. In an era where original ideas hold immense value, transforming such ideas into products necessitates well-planned education that focuses on developing 21st-century skills (Tatlısu, 2020).

Programming, a vehicle for acquiring computational thinking skills, is considered a fundamental skill that every 21st-century student must possess. Many countries worldwide offer programming courses, either as a compulsory subject or an elective activity within their curricula (Mannila et al., 2014). In the developing world, young people are increasingly expected to develop cognitive skills that support their cognitive development, including problem-solving, critical thinking, and algorithmic thinking skills. Countries seeking to integrate programming into their curricula employ various terminologies such as "coding," "programming," "computer programming," "algorithmic applications," "algorithmic problem-solving," and "algorithmic and robotics."

3.2 ROBOTIC IMPLEMENTATIONS

Among the developing technologies, one of the things we often hear about is robot technology, which is becoming increasingly widespread. Today, robot technology is used in many areas such as health, education, communication, and automobile production. With the recent use of robotic applications in educational environments, they have become the subject of research (Tatlısu, 2020). Educators and scientists, realizing that it is very important for students to go through science, technology, and engineering education at the very beginning of their education life, that is, in the preschool and primary school periods, have endeavored to research more carefully and deeply the effects of using computers and robotics in education in order to provide them with these skills (Bers, 2007).

Sayın and Seferoğlu (2016) discussed coding education as one of the 21st-century skills that individuals must have in order for countries to keep up with the developments in the world and to train the manpower to meet the economic needs of the age. Looking at the research conducted around the world, it is seen that the importance of coding education, especially at an early age, is increasing (Demirer and Sak, 2018).

Educational robotic applications are also used as a tool in teaching programming under the name "robotic coding." Robotic coding activities concretize the programming steps, which are an abstract process, and offer students the opportunity to directly observe how the codes they write work with hardware (a robot). Concretization is a widely preferred way of teaching programming (Tatlısu, 2020). Robotic coding can be seen as a new approach that will allow students to concretize the information they have learned (Ersoy, Madran, and Gülbahar 2011). While coding improves individuals' computational and mathematical skills, individuals also learn problem-solving learning methods and algorithmic thinking skills while engaging in coding activities. Coding competencies are a skill that individuals must learn, not only for field experts but also for every individual (Wing, 2006).

Robotics constitute a broad section covering concepts related to mechanical materials, motors, sensors, and programming. Today, with the increasing popularity in the field of robotics, the concept of educational robotics has emerged. Robotic studies with educational robotic kits have begun to become widespread at all levels, from primary school to high school (Rogers, Wendell & Foster, 2010).

Educational robotic studies allow students to be together with concrete objects. Thus, students are introduced to real-life problems. In addition, one of the biggest advantages of educational robots is that robots give feedback to the other party in a short time (Üçgül, 2017). It is thought that robotic applications that will be integrated into the educational models offered will contribute to learning by experience and concretizing events. The aim of projects where robotic applications and education come together is to offer educators educational curricula that combine science and technology, and to ensure that learning is more permanent and meaningful by combining robotic applications with education (Wood, 2003). Educational robotic applications increase students' interest and curiosity in the course through fun activities (Eguchi, 2010).

Robotic applications add value to the development of students by providing a different environment against the mediocrity in formal education, single-level approaches, rote, and repetitive education approaches (Silik, 2016). Educational robots provide students with the opportunity to work with concrete tools. In this way, students are introduced to problems they will encounter in real life. Another advantage of educational robots is that robots provide immediate feedback, and this motivates students (Üçgül, 2013). It is obvious that students are more interested in technological devices decorated with concrete experiences in their games. However, studies on robots have shown that the use of robots in education has positive effects on the cognitive, language, social, and moral development of students (Kozima and Nakagawa, 2007).

Nowadays, when educational robotic applications are becoming widespread, these applications can be encountered at all levels, from preschool education to university. Teaching robotic systems to young children using the right educational approach may make sense to help them gain many skills such as critical thinking, algorithmic thinking, and interdisciplinary perspective, especially problem-solving skills, which are one of the 21st-century skills. Educational robotic applications can be a tool that can help make abstract ideas more concrete, as the child can immediately see the behavior of the robot he designed (Kazakoff et al., 2013).

One of the most important features of educational robotic applications is that they are suitable for an interdisciplinary teaching approach (Catlin, 2016). Therefore, robotic applications provide a rich environment for students to learn many aspects of mathematics, science, engineering, and computer science (Stripling and Simmons, 2016). When we look at developed countries, we see that they have reduced coding education to the preschool age group in these countries and are providing science, technology, and engineering education from an early age thanks to educational robot sets (Sullivan and Bers, 2018). Robotic kits, which can be coded and used by students, integrate with education and make learning more meaningful and permanent (Berland and Wilensky, 2015).

Those who use robotics education consciously and systematically for education in their own countries around the world use training sets in their robotics courses. A robot built with an educational robot can be coded by a person who is not trained in traditional programming languages. It resembles a puzzle with its indentations and protrusions on the pieces. Therefore, it can be said that educational robots not only improve the manual skills of people in younger age groups but also their engineering and mathematical skills (Fidan and Yalçın, 2012).

The use of robotics in education can be considered from two different perspectives: the design of robots and the programming of robots. Adapting these differences to student needs and creating classroom activities in line with these differences is important for education (Ferreira et al., 2018).

Robotics should be an integrated material in education systems, and any negative situations that may make it difficult to include it as a course in schools should be taken into account. These include the high cost, the need to train teachers in the use of technological resources, students' digital competence, and the need for teachers' pedagogical training (Takacs et al., 2016). Lack of necessary educational and technical equipment is one of the biggest reasons why robotic applications cannot be implemented sufficiently. In addition, the expense of designing robots brings with it some problems. However, when the experiences that students will gain thanks to the designed robots are considered, the uniqueness of these robots is once again understood.

3. In recent years, the use of educational robotic tools has become an indispensable practice in developing students' mathematical and engineering skills (Cameron, 2005). Robotic

applications positively affect the development of students' collaboration, critical thinking, problem-solving, technology use, and higher-order thinking skills (Costa and Fernandes, 2005).

3.3 CLASSROOM MANAGEMENT AND ROBOTICS

Class- it is not a fixed picture consisting of a student, desk, book and board, but a simultaneously complex structure that requires continuity, where the teacher is always on the stage, requiring immediate response and reaction, where multi-dimensional, unpredictable situations are encountered. Any factors that may occur in this structure called class must be managed successfully. Teachers' effective management of this complex structure called the classroom will be possible with the classroom management skills they have (Güneş, 2016). In its simplest sense, the classroom is "a common living space where educational activities are carried out." Teachers and students have different roles in this living space. The most important role of the teacher is to plan experiences in this area of life (Gülşen et al., 2010). Classroom management is a term that encompasses various factors that include the action of the teacher to develop a supportive learning environment for learners' academic skills as well as their social-emotional skills. (Evertson and Weinstein, 2006). Classroom management skill is an important element in the success of a teaching career and the impact of it is vital to the teacher and student's interaction (Jones and Jones 2004). Greater responsibility is placed on the teacher in balancing the ability to influence the environment with teaching and learning. These come in the form of the teacher having an upper hand over their teaching styles, knowing how to physically set the class, and checking the energy that emanates from the class to suit learning (Gyimah, 2023).

The purpose of classroom management is not to control students, effective classroom management is to support students to do their own activities individually and manage themselves through learning (Bailey et al., 2012). Classroom management is not just about the behavioral aspect. It consists of processes such as organizing life in the classroom, arranging the teaching process, using resources efficiently, benefiting from the environment in a positive way, guiding the student in the process, and preventing possible problems that may arise.

Classroom management also includes improving teaching conditions, making physical arrangements, using time effectively, drawing and organizing the space in relationships, establishing positive communication, and supporting students throughout the process (Karip, 2002). In this era of globalization and changes in technology, there has been a high expectation from human resources not excluding the context of educational institutions. In the education sector, there is a higher demand for teachers to properly manage their classes effectively so that a maximum level of school activities can be benefitted from students. Classroom management involves the methods exercised by teachers to improve and maintain students' attitudes and traits in the classroom setting and managing these traits like a director (Woolfolk, 1995). Over the past few decades, classroom management has become increasingly vital and a concern of teacher education programs (Hicks, 2012).

The fundamental reason for this is that effective teaching and learning cannot take place without very good classroom management (Marzano, Marzano, and Pickering, 2003). With the effect of developing technologies and the easier accessibility of robotics, educational robots have begun to be used more and more in education, and robotic coding has started to make a name for itself in almost all educational levels. In this context, it is thought that the necessity of robotic coding education is no longer a matter of debate and the focus should be on the skills that this education will provide to students.

The main purpose of educational robotic applications is to increase learners' motivation, desire to learn about science and technology, and problem-solving skills. The roles of teachers who are responsible for raising the new generation are also changing with developing digital technologies. The classroom management process, which means planning the teaching process, managing the factors affecting the teaching process, and increasing the quality and permanence of teaching, must adapt to developing and changing information technologies.

Today, teaching processes are supported by technological developments in line with course outcomes as well as theoretical knowledge; It has become a necessity to include developable and sustainable digital applications. It is seen that students take a more active role in the education process supported by technological tools, the acquired knowledge is transferred more easily to different learning areas, and the teaching and learning process becomes more enjoyable (Bal, 2019, 48). Wing (2006) defined computational thinking skills as a basic need and skill for people in the developing and changing world order and mentioned that it is an important quality just like reading and writing skills. Raising individuals who go beyond the concept of literacy beyond the act of reading and writing and question why and why they read, who know for what purpose and how to use the information obtained, and who analyze and evaluate what they read is possible with a planned and programmed classroom management. In effective classroom management planning, it is necessary to take into account the variables that affect classroom management. These variables are listed as the physical conditions of the classroom, teaching materials, curriculum activities, the competence of the teacher and the readiness of the learner (Ada, 2000).

Robotics studies conducted around the world show that students provide more decisive and practical suggestions for problems related to their daily lives. At the same time, it improves your problem-solving skills and brings great success in both group and individual work. Some countries that are interested in robotics and include some space for it in their curricula are at the top of the lists where education standards are determined. By integrating technological developments into education in the modern classroom management approach, students willingly participate in teaching activities and ensure permanent learning by applying what they have learned. The active participation of the student in the learning activity prevents negative behaviors that may occur in the classroom and allows the learning process to be completed efficiently. With developing technologies and updated curriculum, the skills expected from students also change. Students are expected not only to achieve academic success but also to achieve success in the 21st century. They are expected to be individuals who question, research, follow technological developments, think algorithmically and have problem-solving skills, which are called skills (Göksün & Kurt, 2017; Lai & Viering, 2012).

Motivating students in line with the objectives of teaching before starting the learning activity will reduce the negative effects in the teaching environment and increase the efficiency of the teaching activity. The important thing here is that the student willingly participates in the learning activity. The people who will awaken this desire in the student are the teachers, who are the main actors of the educational activity (Fidan, 1985, 6). Undoubtedly, for teachers, applications such as robotics are helpful treasures that will motivate students to study. Group studies with robotic applications also increase students' interest and motivation.

Studies in the literature have revealed that robotic activities give better results when done with group work (Bruciati, 2004; Kapa, 1999; Liu et al., 2013). Classroom management has an important role in establishing an ideal classroom environment, effective teaching, and social learning of students. From a general point of view, classroom management involves establishing and maintaining order, designing effective instruction, responding to the individual needs of students while dealing with students as a group, and mastering discipline in the classroom (Emmer & Stough, 2001). In this context, educational robotics can be applied as a material in a variety of educational settings, including curricular and extracurricular situations.

Currently, there are two variables that play an active role during robotics training: the student and the teacher. Because while the student plays an active role as a designer and programmer, the teacher must also be a guide. For this reason, robotics in education, not with robots, it seems to be more related to human, robot and computer interaction (Tellioğlu, 2022). To ensure success in classroom management, a teaching method appropriate to the content, purpose and individual characteristics of the student must be selected. Since there is no single method that can be used in every teaching environment, choosing the method appropriate to the learning environment will be effective in ensuring classroom management. In order for education to be successful, the teacher must maintain order in the classroom and create a positive classroom climate by motivating students to learn. This situation can only be achieved with effective classroom management (İlgar, 2000). In an effectively managed classroom, negative student behaviors decrease, students feel safe, and a relationship based on respect is established between the teacher and the student (Turan, 2008). According to Yüksel (2020), there are three communication methods that a teacher often uses to establish communication in the classroom. These are communication made through verbal, non-verbal and technological tools. Robotics is becoming a preferred technique that increases student motivation by adding the element of fun to learning processes.

The use of various design principles and game mechanics also encourages students to participate in in-class activities. Robotic learning environments increase students' academic performance and motivation, prevent undesirable behaviors in the classroom and help create a positive classroom climate. Since technological tools and applications appeal to students' interests, their use in learning makes education more permanent. With technology in education, classroom adaptation is increased and thus contributes to classroom management. Since the technological applications used in the course attract the attention of the students, their motivation for the course increases. These practices help reduce undesirable behaviors in the classroom. The teacher who controls the classroom thus spends more energy on education and training.

3.4 IMPLEMENTING ROBOTICS IN CLASS MANAGEMENT: A MULTIFACETED APPROACH

The integration of robotics into classroom management represents a promising avenue for modern education. Robotics offers educators a unique set of tools to enhance the learning experience, foster engagement, and improve overall class management. This academic discourse explores the key aspects of implementing robotics in class management, focusing on its benefits, challenges, and pedagogical implications.

Classroom management is a critical aspect of effective teaching, and its success greatly influences the overall learning experience for students. In recent years, the integration of robotics has gained momentum as a means to enhance class management strategies. This study explores the implementation of robotics in class management, highlighting the multifaceted benefits, potential challenges, and best practices for educators.

a. Enhanced Engagement and Personalized Learning

One of the primary advantages of incorporating robotics into class management is the ability to enhance student engagement. Robots can be used to create interactive and hands-on learning experiences, capturing students' attention and fostering active participation. Moreover, robotics can facilitate personalized learning by adapting to individual student needs. Customized challenges and activities can be tailored to suit students' learning styles and abilities, promoting a more inclusive and effective educational environment.

b. Improved Classroom Discipline

Effective class management often requires a well-structured and disciplined classroom environment. Robotics can serve as discipline-enforcing tools by setting clear rules and expectations.

For instance, a robot can be programmed to remind students of the classroom rules, offer instant feedback, and maintain a consistent and impartial presence, reducing disruptions and promoting self-regulation.

c. Skill Development and Problem-Solving

The integration of robotics into class management can serve as a platform for the development of critical skills, such as problem-solving, critical thinking, and teamwork. Students can work collaboratively to program and control robots, solving challenges and tasks that require creative problem-solving. These experiences not only enhance their academic understanding but also prepare them for future careers in fields such as STEM (Science, Technology, Engineering, and Mathematics).

d. Challenges and Considerations

Despite the numerous advantages of implementing robotics in class management, there are challenges that educators must address. Initial costs, teacher training, and the need for technical support are significant considerations. Additionally, maintaining a balance between the use of robots and traditional teaching methods is essential to ensure that robotics enhances, rather than hinders, the learning experience.

e. Best Practices

To successfully implement robotics in class management, educators should follow a few key best practices. Firstly, clear learning objectives should be established to ensure that robotics align with the curriculum. Secondly, teacher training is essential to provide educators with the necessary skills to incorporate robotics effectively. Regular assessments and feedback mechanisms should be in place to monitor the progress and adapt the use of robots as needed. Finally, a culture of inclusivity and diversity should be promoted to ensure that all students benefit from this technological integration.

The implementation of robotics in class management presents a promising avenue to transform the educational experience for students. Enhanced engagement, personalized learning, discipline enforcement, skill development, and problem-solving opportunities are among the numerous benefits. Nonetheless, educators must be aware of the associated challenges and follow best practices to harness the full potential of robotics in class management, ultimately improving the quality of education and preparing students for the demands of the 21st century.

3.5 CONCLUSION

In the 21st century, the competition among developed countries in the realms of production, innovation, and technological advancement has significantly escalated compared to previous years. This intensifying competitive landscape has prompted nations worldwide to invest in science, engineering, and innovative technologies, necessitating a reevaluation of their educational systems and the pursuit of substantial improvements (Aydın, 2011).

It is evident that individuals can comprehend the technological advancements surrounding them and convert them into innovative ideas through training in "coding and robotics." In the contemporary digital age, where technology permeates every facet of life, early childhood education in coding and robotics yields fundamental achievements such as critical thinking, problem-solving, adaptability, cooperation, leadership, and information acquisition and utilization (Wagner, 2008). The skills acquired by children at a young age significantly shape their future prospects. As such, it is imperative to nurture children as individuals capable of facilely adapting to innovations, possessing problem-solving and critical thinking skills, and introducing them to science and technology from an early age (Tatlısu, 2020). Robotics has garnered heightened attention in today's educational landscape, resulting in a surge in the inclusion of robotics in curricula, especially in developed countries. This move is deemed crucial to prepare future generations to become technology producers.

The integration of robots from the field of engineering into our educational framework is believed to concretize abstract educational concepts, boost students' interest and motivation in their coursework, and dispel any negative perceptions they may hold regarding their studies (Koç & Böyük, 2013). Negative emotional responses to lessons are among the factors that challenge classroom management for educators. By incorporating robots into education, science and technology are fused with practical lessons, rendering learning more meaningful and enduring (Wood, 2003). As educational objectives take on tangible form, teachers can enhance the classroom environment's efficacy, facilitating students' achievement of their goals.

Conventional approaches and methods in school education are often perceived as ineffectual and uninspiring by many students. Despite educators' persistent efforts to explore new and contemporary approaches and methods, it is acknowledged within the education community that today's schools grapple with substantial issues related to student engagement and motivation. Addressing the motivation dilemmas faced by Generation Z necessitates an exploration of their everyday interests and the provision of solutions grounded in those interests. To avert undesirable classroom behaviors and enhance the success of educational scenarios, various techniques and methods can be explored. In this regard, strategies aimed at increasing student motivation have been a consistent focus of research for years, with educational circles continuously seeking innovative ways to reverse this situation, augment student participation and commitment, and foster an effective classroom environment. Among these strategies, gamification has emerged as one of the most significant.

While harnessing evolving technology in education is crucial, it is equally vital to educate teachers who can effectively utilize these technologies (Şimşek, 2002: 215). Thus, it is imperative to provide training opportunities for both prospective teachers and current educators to harness the potential of information technologies effectively. This will not only empower teachers to engage and educate the students of the 21st century but also contribute to the overall enhancement of education systems on a global scale.

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CHAPTER 4.
PSYCHOLOGY OF LEARNING AND ROBOTICS

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4.1 THEORETICAL APPROACHES

Educational robotics is a powerful and innovative approach to teaching aiming to integrate robotics into the educational environment in order to enhance learning and cognitive, socio-emotional and motivational development. The idea of using robots in the classroom is not new. Constructivist theories are the foundation of using educational robotics (ERs) in education as a teaching approach in which students use robots with teacher supervision. A systematic literature review (Jung and Won, 2018) showed that there is a current trend in using educational robotics as instruments for STEAM education and other disciplinary fields. Toh et al. concentrated on the effects of robots on education and young children and acknowledged the psychological benefits of using them in teaching with young students. In another review of 119 studies on the use of educational robotics in STEM education, it was shown that there are meaningful benefits of robotics for learning (Tzagkaraki, Papadakis and Kalogiannakis, 2021) but also specific benefits for knowledge transfer, socio-emotional learning, motivation and cultural competencies, creativity and enhancing diversity and inclusion (Bascou and Menekse, 2016).

In order to deeply understand the psychological benefits of robotics, the present chapter aims to provide a comprehensive overview of the cognitive, socio-emotional, and motivational aspects of learning with educational robots. Theoretical frameworks and practical implications of robotics for learning processes are discussed. The chapter is structured as follows: (1) the overview of the impact of robotics in learning from different theoretical perspectives, (2) cognitive development and the use of educational robotics, (3) socio-emotional and motivational benefits of robotics and (4) highlights of the psychological benefits of using educational robotics.

4.2 THE IMPACT OF ROBOTICS IN LEARNING- DIFFERENT LEARNING FRAMEWORKS

The impact of using educational robotics in cognitive learning and development can be explained from different contemporary frameworks on learning as Knowledge-Learning-Instruction (KLI) (Koedinger, Corbett, & Perfetti, 2012), Situativity Theory (ST) (Brown, Collins, Duguid, 1989) or Self-Determination Theory (SDT) (Ryan and Deci, 2000). We will briefly present the relation between using robots in instruction for building learning within the frameworks mentioned above.

Knowledge-Learning-Instruction (KLI) framework emphasizes the hypothesis of the "knowledge dependency". This theory refers to the idea that the cognitive nature of learning and educational goals determine the instructional approach. As a broader approach of learning experiences and processes, the KLI framework proposes three components (Figure 4.1.).

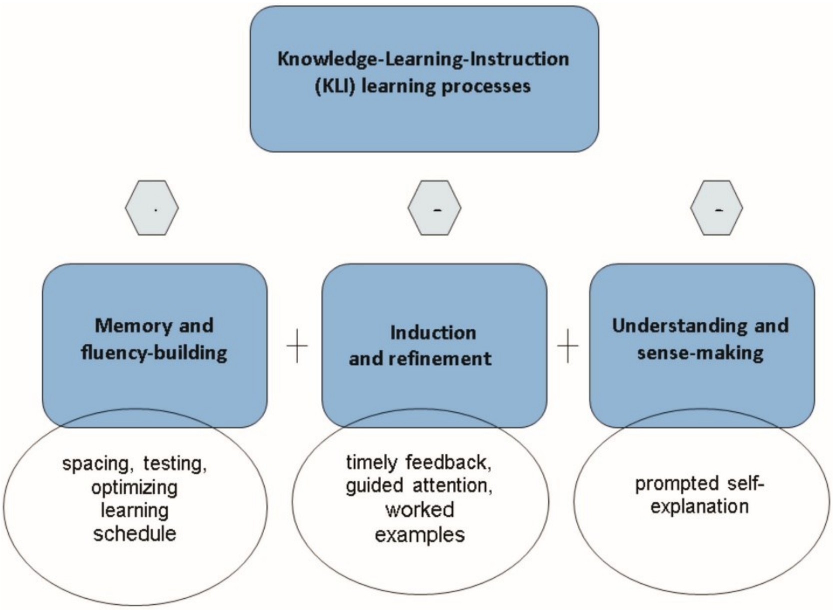

Figure 4.1. Knowledge-Learning-Instruction (KLI) learning processes taxonomy

The first component is Memory and fluency-building processes which involves implicit learning processes that enhance memory and automatic categorical knowledge. Fluency refers to making connections resistant to interferences and enhancing knowledge connections. The second component is Induction and refinement processes related to learning. Those processes include categorization, schema organization, induction, generalization and discrimination. Those are variables that constitute conditions between input and output and refine the knowledge components. The third processes are related with understanding and sense-making processes of knowledge. This is the verbal and more conscious component of learning related to explanation, discovery and rule mediated deduction. Under circumstances involving experimental control, learning occurs as unobservable events that can be deduced from performance and appropriately assigned to instruction events.

KLI involves also a taxonomy of types of knowledge based on the function of learning events, applications and conditions. There are knowledge contents that are applied constantly (e.g. paired-associates) and other variables (e.g. under rules conditions) (Fig 2.). Also, there are contents that are variable, such as information from mathematics and others that have a single value, such as facts (e.g. the capital of a country). The facts require the declarative component of the memory system and should be retrieved verbatim. On the other hand, mathematical knowledge requires variable responses because there are many different problems that need the same equation or may be applied across different situations. To go further, we can affirm that math skills require generalization and building connections.

The KLI paradigm further indicates causal relationships between instructional principles (e.g., "retrieval practice," "worked-example study") and changes in learner knowledge by tying the kind of Learning Event and the related learning processes to the type of knowledge being taught. Facts and memory and fluency processes are more relevant for simple constant knowledge content. On the other hand, induction and refinement procedures are more pertinent for changeable knowledge domains like talents. Various instructional strategies, such as practicing retrieval of knowledge and examining examples of abilities, will maximize distinct learning processes. Different knowledge components would therefore interact with various Instructional Principles to produce various learning.

Situativity theory was developed from cognitive psychology. According to situativity theory, information, thinking, and learning are all situated in experience. They are a product of the people involved, the culture in which they are embedded, and the actual physical setting in which they take place (Bredo E. 1994.). The concept of non-linearity, which argues that the result might be greater than the sum of its parts, is embraced by situativity theorists. It is due to the dynamic and ever-changing interactions between the environment, culture, and individuals. Furthermore, the idea that a participant's capacity to transfer knowledge from one context to another being severely restricted, is tackled by situativity theory in relation to the problem of transfer. Offering concerns regarding the way the environment and interactions with others affect learning, a situated approach offers potential solutions for enhancing transfer. Lave & Wenger (1991) explain that teaching and learning is interconnected with many social processes. An important role of a teacher is to build upon those processes and to maximize their positive effects on learning outcomes. We propose the idea that cognition and learning for an individual (or group) can be non-linear, or greater than the sum of the parts, when we view these interactions as possible "signals" rather than "noise." For instance, learning may not occur when a relatively tired student interacts with a less engaging teacher. Significant learning could happen if any one of these components were missing; in this scenario, learning loss is non-linear and multiplicative rather than just additive. Furthermore, this viewpoint suggests that in order for students to generalize their knowledge across a variety of contexts, we ought to emphasize more on the authenticity (i.e., approximation to "real life" or outside-of-class experience with the topic being covered) of the educational environment (Resnick, 1991).

In this view, learning skills involve figuring out which pieces of information are relevant for encoding and which are not. When learning facts, all provided information is essential and should be encoded. However, when acquiring skills, only a fraction of the presented knowledge is relevant to building a successful generalized skill. Nowadays, especially when speaking about teaching, it is used the term embodied cognitions (Robbins & Aydede 2009). It states the importance of sensory inputs in cognition. More, it is about the cooperation between cognitive processes of perception, thought and action as being dependent one to each other.

In the discussion about using robotics to teach different disciplines, we should add the perspective of the model of distributed cognition, which is a significant part of todays' research in situativity theory. From a distributed cognition perspective, learning is a part of micro and macro social context, and the interactions of the learner with those contexts lead to developing knowledge and learning. The main focus of this model is on the way individuals engage in cognitive activities in relation with material and social contexts (Salomon,1995). The most important idea about the value of educational robots for teaching is that they enhance learners' cognitive abilities through the interaction of the students with the robot. Moreover, if we embrace the distributed cognition perspective, we must see learning as a process embedded in a large and complex system (Fig 2). The components of the system can be: teachers, learners, all the environment artifacts and characteristics.

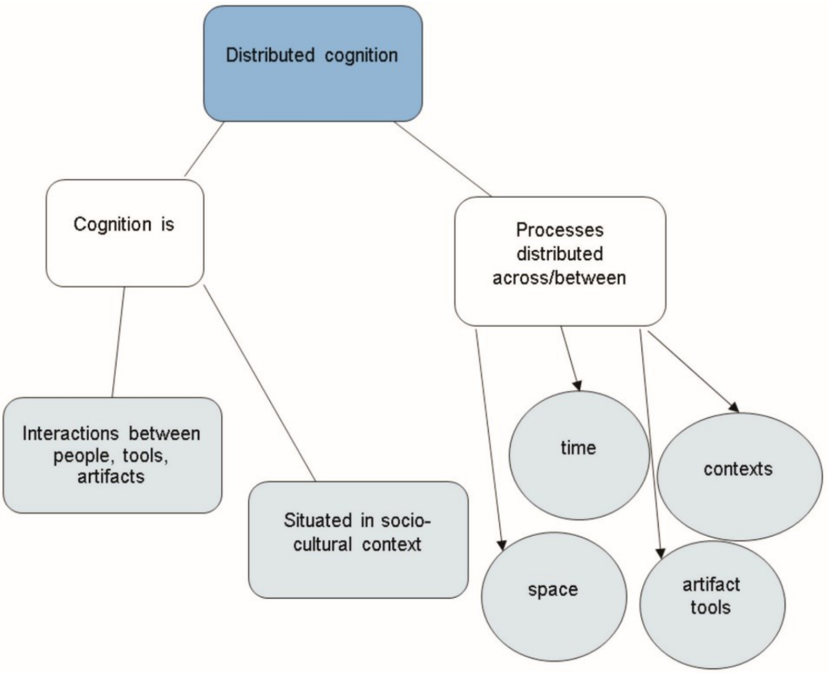

Figure 4.2. Distributed cognition theory explained

Adding robots to the system of learning may be an effective method of enhancing the interaction of the learner within the system. The robots also contribute to building computational thinking in an embodied cognition perspective. For example, adding a scenario with educational robots may shape the interaction of the students with the task, between them and also with the teacher. The robot is an educational tool that helps the construction of meaning in learning. All the interactions in the system through the process of learning scenarios with robots are representing a distributed learning system. As in any system, in a distributed learning system, the student needs to learn how to solve hands-on problems emerging in the processes. Implementing scenarios with educational robots is putting the student in the middle of many interactive processes which require the development of multiple strategies to handle uncertainty, to solve the task, to manage emotions, relations, to listen to instruction etc. A teacher who adopts the didactic strategy of building learning experiences through robotics, will facilitate the knowledge transfer. Second, will create a more authentic context and situation by paying attention to all the factors in the process and the relations between them: the competency building, the well-being of students, the motivation, the social context, the executive processes such as attention span, inhibition or working memory etc. From a situativity perspective, educational robotics would craft the learning through all the factors, not only focusing on transferring the knowledge. Moreover, they augment and scaffold student attention and motivation to refine the learning experience. Adopting a situativity approach, building lessons with educational robots encourages instructors to think about a variety of contextual aspects that can influence teaching and learning in addition to the information being presented. Situativity differs from various other instructional design theories , through its focus on the various components of the setting and how they can affect teaching and learning (Anwar, et al, 2019).

In addition to the concepts discussed, the following section explores the value of self-determination theory for the topic. Self-determination theory emphasizes the importance of building intrinsic motivation for learning. The underlying mechanism is creating learning experiences which allow students to fulfill the need for competence, autonomy and relatedness. This theory focuses on the contextual conditions that can facilitate learning, self-motivation and self-regulation in every human situation through addressing the psychological needs (Ryan,, & Deci, 2000). The need for competence is a need to feel effective and capable to accomplish certain actions, to develop and apply your competencies. The need for autonomy refers to the need of feeling in control and of having the confidence that you can choose your actions. The need of relatedness is a need for social authentic connections and of building meaningful relations and experiencing a sense of belonging and community. The effects on building educational environments that can meet the need for autonomy, competence and relatedness is the significant increase in students and teachers' well-being. By involving robots in instructional practice, educators contribute to the designing of the classroom experiences that support students' psychological needs and give them a greater sense of mastery in learning processes. We will talk extensively on the impact of robots in motivation and socio-emotional learning later in this chapter.

4.3 COGNITIVE DEVELOPMENT AND EDUCATIONAL ROBOTICS

Using educational robotics in teaching can have a positive impact on the cognitive development of primary school students. Cognitive development refers to the growth and maturation of a child's thinking, problem-solving, memory, and other mental processes as attention span, inhibition, analytical skills, mental planning etc (Kálózi-Szabó, Mohai, Cottini, 2021).

In primary schools, cognitive development is related with the increase of working memory capacity, which allows children to hold more information in their minds at the same time (e.g. multiple strategies for solving problems or keeping a plan for solving a problem by keeping goals in mind). Second, children become more effective in using diverse strategies of organizing information, elaboration and clustering, as metamemory (knowledge of how memory works and how it can be improved) develops. At the same time, attentional focus visibly increases after age of 8 and also children become greater in inhibitory control. This ability helps them eliminate irrelevant or interfering information from their minds and maintain their focus on a task while ignoring distracting environmental factors. One important developmental task related to using robotics for improving learning is the speed of mental operations. The primary school years are characterized by the greatest increase of this ability. It is related to the fact that certain structures became specialized for solving certain types of problems; as children are confronted with one type of task more than once, they become quicker and easier to solve (become automated). Children use a variety of strategies in problem solving and this variability supports learning (Siegler, 1999). In this period, children are testing different problem-solving strategies in order to learn when to engage a particular one. This is an ongoing process in this developmental period and one strong argument for using educational scenarios with robots. It is a helpful tool to help students learn the most effective cognitive problem-solving strategies (Cardoso, 2019).

Integrating educational robotics into instruction strategies can significantly improve students' cognitive development through contributing to the enhancement of thinking, analytical, problem-solving skills, creativity, computational competencies (Binkley et al, 2012). There is a growing body of research showing that educational robots are the main tool in building computational thinking skills. The ability to use logical and algorithmic reasoning and to break complex problems into smaller parts in order to find the right solution for solving them are some of the main cognitive skills discussed by scholars (Almisis, 2013). There are specific characteristics of instruction strategies based on scenarios with robots, especially in teaching mathematics. Algorithmic thinking and problem solving are the basis of teaching mathematics with educational robots. They often require students to break down larger math problems into smaller, more manageable subproblems that can be addressed one step at a time and to write sequences of instructions (algorithms) to control their movements and actions (Highfield, 2010). This process encourages students to think step-by-step, considering the logical order of commands, which is fundamental to computational thinking. At the same time, scenarios may involve the pattern recognitions which are closely related to geometric competencies fostering students' capacity to develop spatial reasoning and analogical transfer in thinking. Regarding logical reasoning, programming robots requires understanding the cause-and-effect and the relationships between commands and anticipating the robot's behavior. Students must use critical thinking and logical reasoning to figure out how to make the robot accomplish specific tasks, which enhances their problem-solving abilities. This is a complex cognitive skill for life and a key aspect for encouraging students to evaluate their strategies, explore more efficient ways to solve problems, making improvements and reinforcing computational thinking skills (Nardelli, 2019). . Abstraction and creativity are also implied in the process of learning through scenarios with robots. It is related to the multiple variables, statements and loops that are versatile and encourage abstract thinking in the context of mathematics. (Chevalier, Giang, Piatti, and Mondada, 2020). The executive functions are enhanced significantly through manipulating robots. Students use math concepts, such as measurements, angles, and geometry, to program robots and achieve objectives and the activity involves understanding and manipulating three-dimensional space (Di Lieto et all, 2017). This promotes attention and mental planning. Also, students must remember and recall the steps they've programmed to guide the robot. This promotes memory and strengthens the ability to follow sequences. Immersing students in those scenarios plays an active role in cognitive development by helping them actively process the information and acquiring the computational thinking competencies. (Moschella & Basso, 2020).

An important variable of cognitive development is related to interdisciplinarity which is enhanced through using robotics to teach math because it helps students see the connections between mathematics and other subjects. It may also offer the opportunity to apply mathematics in a real-world context and to gain a deeper understanding of the concepts, making the subject more engaging and relevant. Integrating robotics into different subjects (e.g., math, science, and technology) encourages students to make connections between various areas of knowledge, promoting holistic cognitive development (Bers, 2018).

4.4 SOCIO-EMOTIONAL AND MOTIVATIONAL BENEFITS OF ROBOTICS

While the previous section highlighted the cognitive benefits of robotis, the next part of the chapter focuses on the socio-emotional and motivational implications of robotics for learning.

The socio-emotional learning is a set of key competencies for primary school children. The main tasks needed to be developed in these areas are related to recognizing ones and others' emotions, emotions regulations, developing cooperation, empathy, and building frustration tolerance. Social and emotional competencies are facilitated in the hands-on activities with robots. Students need to continually adapt their strategies and make adjustments to their mindset and actions. This enhances their ability to cope with diverse situations and foster resilience and capacity to overcome obstacles to learn frustration tolerance and to adopt a growth mindset. During the implementation of instruction activities with robots, students need to collaborate, to work together and to regulate their emotions related to the task and to the interaction with their peers. Those factors will foster social skills and emotional competence making children understand the rules of social and emotional life (Alam, 2022). If we go further with the interaction with robots, it is valuable to mention that students with social and emotional deficits have benefits from interacting with colleagues, but also from interacting with robots because they create a safe, low-risk environment for practicing social skills and communication. (Mayer, Salovey and Carusso, 2011).

Regarding the development of language and vocabulary, it is important to acknowledge the meta-language as a skill to acquire. Being exposed to learning assisted by robots, can help communicate their ideas, understand the way others think and internalize social rules. Moreover, as children consider other people's reactions to their own behaviour and compare themselves to external standards, feelings of: pride, shame, guilt are reinforced. From this point of view, the scenarios with robots can contribute to better emotional regulation. They also enhance the development of a better understanding of how to control impulses in a social context. It can be an opportunity to develop voluntary control and the ability to express emotions appropriate to a given social context and have lower intensity negative emotions.

Due to the typical design of learning activities with scenarios, children learn to control impulses and to gain delay gratification as they have to have patience to take their round. More than that, being exposed to failure is a valuable strategy to learn to accept it as a part of the process and to regulate fear, shame, guilt or anger, but also to observe and learn from peers' reactions and strategies. Socially competent children are those who persevere in their attempts to be accepted by others, by adopting strategies that increase their chances of success (e.g. imitating the behaviours of group members), which can be facilitated by the teamwork required in the tasks with educational robots. Few recent studies showed that using robots in education can contribute to inclusion, the integration of students in groups and reducing prejudice and discrimination (Panayiotou, Humphrey., & Wigelsworth, 2019).

Engaging in activities with educational robots can lead to increased motivation to learn and explore STEM (Science, Technology, Engineering, and Mathematics) concepts (Giang et al, 2020). As we mentioned before in this chapter, there are three main psychological needs that can improve internal motivation for learning- the need for autonomy, need for competence, need for relatedness. Through hands-on learning, robotics allows students to collaborate and encourages teamwork. Many sceneries are group-based which may build communication, sharing responsibilities and to achieve common goals (Benitti, 2012). Those characteristics are responding to the need of building meaningful and positive relationships with peers. The need for competence refers to children needing to feel confident in their abilities to handle reality. Being involved in learning activities assisted by robots, may help them successfully completing projects and easily understand complex math concepts. Also, the challenges can boost students' self-esteem and confidence in their problem-solving abilities (Morris & Rohs, 2021). Motivation is also sustained by exposing students to learning sceneries where they can develop a growth mindset due to the fact that they persevere and iterate their solutions (Chen, Park, and Breazeal, 2020). The growth mindset is an important asset in building motivation and engagement. Last but not least, teaching robotics-based scenarios increase students' autonomy by giving them opportunities to choose the strategy to approach the problems, how to collaborate and how to manage different steps in the learning process. Having a feeling of competence is one of the main factors impacting motivation and engagement for learning. The need for competence is closely related to self-efficacy, which is the main factor that helps build motivation and engagement for learning (Bandura. 1986). We will provide some arguments for the importance of scenarios with robots in increasing self-efficacy for math. First, hands-on involvement means children have opportunities to have positive experience with learning tasks by demonstrating their ability to apply math concepts and skills to complex scenarios and situations (Yang, Lai, and Wang, 2023). Moreover, trial and error experiences help students familiarize with experimentation and failure and allow them to learn. Second, the sense of mastery that students gain through the interaction with the robots is essential to their belief that they are able to learn and to apply the skills acquired. Third, peer learning and modeling is a powerful tool when it comes to boosting self-efficacy through shared success and support. Fourth, effective guidance and constant feedback from instructors impact self-efficacy because it helps students understand their areas of improvement and learning.

In terms of student engagement, using robots to teach conceptual knowledge in primary education is both intellectually and creatively stimulating through putting children in scenarios that enhance exploration, connect learning with daily life experiences (D'Amico, Guastella, and Chella, 2020). Moreover, building scenarios with robots on students' interest may be another positive point of teaching with robots (Wei, Lee, & Chen, 2011). When designing the scenarios, teachers can incorporate topics of interest for students, but also materials and strategies that can be effective in accommodating a wide range of individual and developmental differences, skills, needs, interests and cultural artifacts.

4.5 BENEFITS OF DESIGNING LEARNING EXPERIENCES WITH ROBOTS

In light of our previous insights, the following section synthesizes the information by highlighting the most powerful benefits of designing learning experiences with robots.

To summarize, the main benefits of designing learning experiences using educational robots are the following:

- The scenarios with robots offer alternative strategies for solving a problem and to encourage children to discover their own solutions.
- Children benefit from the involvement in active activities, building on their real-life experiences and interests.
- The scenarios are self-explanatory learning strategies where children can easily understand why a certain strategy is correct, what the principles behind the procedure are, why a certain strategy is wrong and can improve their strategies fast.
- Due to the fact that children often fail to learn some content because they do not have effective learning strategies, the scenarios with robots propose new methods of processing information and solving problems. Children learn better because they are given the opportunity to rehearse new concepts by applying them to different situations, tasks, or by relating them to previous knowledge.
- The impact of concrete examples, the manipulation of objects and the active involvement of the child in building computational knowledge is an effective way to help students learn and make connections.

- Instruction strategies with robots fundamentally contribute to the retention of knowledge and to the transfer to new situations.
- The scenarios with robots contribute to the development of a growth mindset where success at school is due to the quality and quantity of effort put in, not to a fixed intelligence quotient. This can help students easily overcome failures and persist more in future tasks.

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CHAPTER 5.
ANXIETY AND MATH IN THE CONTEXT OF ROBOTICS EDUCATION

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5.1 THEORETICAL APPROACHES

Individuals' academic achievements in a field are generally tried to be explained by taking into account learning in the cognitive field. However, the impact of a person's affective characteristics related to any field on their cognitive domain skills is often overlooked. Negative affective characteristics negatively affect motivation and interest in the field and reduce the quality of learning in the field. Positive affective features related to the field increase interest, make the person willing and active, and make the learning process more qualified and efficient (Çelebi & Su, 2022). Negative affective characteristics, on the other hand, prevent the person from turning his true potential into performance. One of the most important reasons for these obstacles is anxiety, which is an affective feature.

In a mathematics class, the teacher introduces a collaborative learning approach, encouraging students to work in small groups to solve problems and discuss concepts together. This approach addresses math anxiety by fostering a supportive and cooperative learning environment. Students can share their ideas, ask questions without fear of judgment, and benefit from diverse perspectives. Collaborative learning helps to build confidence, as students realize they are not alone in their struggles and can collectively overcome challenges. The social interaction and shared responsibility for learning create a positive atmosphere that mitigates math anxiety.

Morgan (2019) defined anxiety as "a vague fear without knowing what the real problem is." Anxiety was defined by Freud as "something felt," an emotional state that included feelings of apprehension, tension, nervousness, and anxiety accompanied by physiological arousal (Spielberger, 1989). Although anxiety is expressed as a negative emotion in the definitions, it can also be expressed as an emotion that provides motivation for human survival and learning. Anxiety can also enable us to cope with negative situations as a source of motivation to take real action (Demirsu, 2018). Scovel (1978) defined two kinds of anxiety as positive and negative anxiety. Negative anxiety affects the students negatively and makes the learning process difficult. Positive anxiety enables people to be successful over their natural achievements.

5.2 CAUSES AND TRIGGERS OF MATH ANXIETY

Anxiety can occur in different areas in different individuals. One of the areas where anxiety is frequently encountered is; "Mathematics" is one of the fields that is available at all levels of education life, and is one of the fields that some people enjoy doing, while others do not like it because they cannot do it (Altun, 2000). Dowker, Sarkar and Looi (2016) also emphasized that individuals have more negative attitudes and more anxiety towards mathematics compared to other disciplines. When the literature on mathematics anxiety is examined, it is seen that the first studies started with the research of Gough (1954), who was a primary school teacher in the 1950s, and many definitions were made regarding mathematics anxiety. Gough (1954) investigated the negative emotional reactions of students and used the term "mathemaphobia" for these negative emotional reactions. The term "mathematics anxiety" was first used by Dreger and Aigen (1957) and defined as "the presence of a syndrome of emotional reactions to arithmetic and mathematics". Ma and Xu (2004) was defined mathematical anxiety as a discomfort state created when students are required to perform mathematical tasks. They expressed the main features of this condition as dislike, anxiety and fear with specific behavioral manifestations (such as tension, frustration, distress, helplessness, and mental disorganization). In short, math anxiety is a universal condition that is caused by negative emotional traces such as panic, fear, and helplessness that occur in life.

Many studies reveal that mathematics anxiety negatively affects mathematics learning processes, is at the root of failure in the field, causes less experience in the field, reduces fluency in mathematical thinking, negatively affects mental processes, triggers the feeling of not knowing anything in the student, and negatively affects metacognitive awareness (Baylan , 2020; Cates & Rhymer, 2003; Clute, 1984; Devine et al., 2012; Dowker et al., 2016; Ekin & Şanlı-Kula, 2022; Gündüz Çetin, 2020; Kaba &

Şengül, 2018; Ma, 1999; Mert & Baş, 2019; Miller & Bichsel, 2004; Radišić et al., 2015; Richardson & Suinn, 1972 as cited in Aydın Yenihayat, 2007; Sloan at al., 2002; Vinson, 2001).

It should be taken into consideration that mathematics anxiety, which is effective in a person's success in mathematics, the positive development of his feelings towards himself, and his ability to use problem-solving skills in his daily and professional life, may begin in later periods or at a very young age. In this case, revealing the causes of mathematics anxiety is important in terms of preventing the occurrence of mathematics anxiety and finding solutions. We can categorize the causes of mathematics anxiety as reasons arising from the person himself, the family, the teacher, the teaching process and the characteristics of the field of mathematics. From the research results (Ağdacı, 2021; Alkan, 2019; Baylan, 2020; Beilock et al., 2010; Bostancı, 2020; Dölek, 2022; Gündüz Çetin, 2020; Hlalele, 2012; Lazarus, 1974; Sade, 2020; Sarıgöl, 2019 ; Shields, 2006; Uusimaki & Nason, 2004), the causes of mathematics anxiety can be listed as follows:

a. Reasons Originating from the Work itself: Perception of self-worth, high expectation of success, fear/anxiety about making mistakes, dislike of mathematics course, emotional and psychological characteristics, prejudices, negative mathematics experiences in the classroom and in the past, fear of humiliation, lack of motivation, lack of learning. cognitive barriers to.
b. Reasons Originating from Family: Pressure from parents, high expectation of success, intolerant parental reactions in cases of unwanted success, parents' negative attitudes towards mathematics/high anxiety levels, seeing mathematics as very important.
c. Reasons Originating from the Teacher: Teachers' perception that 'doing mathematics requires a separate ability and skill', negative attitudes exhibited by teachers to show their expertise, teachers' concerns about mathematics and mathematics teaching, teachers' autocratic classroom management approach.
d. Teaching Process: Wrong teaching methods / teaching activities, focusing on only one correct solution to problems, ignoring individual differences and readiness levels, using teaching materials and teaching methods that are not suitable for learning styles, neglecting the principles of easy-to-difficult and concrete-to-abstract.

Giving tasks and assignments of the same difficulty to everyone, using homework as a means of punishment, monotonous teaching activities that are far from fun, crowds/noises that prevent the student from thinking deeply, etc. classroom environment, inadequate use of modern facilities/information technologies, peer bullying (behaviors such as mocking, laughing humiliatingly in case of mistakes and failures, etc.), measurement-evaluation processes that are not consistent with the teaching process.

e. Reasons Originating from the Field of Mathematics: Mathematics has a nature that includes abstract concepts, mathematical terms, formulas, symbols.

5.3 RECOGNIZING MATH ANXIETY IN STUDENTS

Although mathematics anxiety manifests itself in different ways in people, it can cause many cognitive, emotional and physical behaviors. If educators can be selective in detecting these behaviors in students, they can reveal the presence of mathematics anxiety. Individuals with high mathematics anxiety have negativities in the cognitive field such as low calculation skills, making many mistakes, and difficulty in discovering mathematical strategies; In the affective field, fear, timidity, shame, hopelessness, lack of self-confidence, decrease in personal value, decrease in pleasure; In the physiological field, they experience conditions such as irregular pulse, impaired concentration, tremors, and breathing difficulties (Ashcraft & Faust, 1994; Gündüz Çetin, 2020; Hendel, 1980 as cited in Aydın Yenihayat, 2007; Pena et al., 2013; Rubinsten & Tannock, 2010; Wu et al., 2012; Zakaria & Nordin, 2008). It is important for educators to have knowledge about these indicators in order to determine whether the child has mathematics anxiety and to find solutions. Because the fear caused by mathematics anxiety not only affects the individual's situations related to mathematics lessons, but also negatively affects his problem-solving skills in daily life. Mathematics anxiety also causes a lack of self-confidence, the formation of prejudices regarding learning mathematics, and increased exam stress (Bessant, 1995 as cited in Dede & Dursun, 2008).

A teacher who notices the symptoms of mathematics anxiety in his/her student can investigate whether the student has mathematics anxiety by working in coordination with psychological counselors and experts in the field of guidance, conducting interviews with the student, and using mathematics anxiety scales appropriate to the student's age group. Psychological counseling techniques and mathematical skill development techniques can be used for mathematics anxiety (Baloğlu, 2001 as cited in Gündüz Çetin, 2020). Just as teachers work in coordination with psychological and counselor guides, they should also work in coordination with parents in identifying and eliminating mathematics anxiety.

The most important duties to eliminate mathematics anxiety in the educational process fall on the teacher. Because among the causes of mathematics anxiety, reasons arising from the teacher and the teaching process have a large place. Creating learning environments that are free from fear and anxiety about making mistakes, based on teaching approaches based on learning by doing, using teaching methods suitable for understanding abstract concepts, following the developments of our age and using approaches such as web-supported blended education/flipped learning that use informatics and technology, The use of technology-supported materials in teaching and the integration of activities that develop algorithmic and computational thinking into the mathematics teaching process may be effective in the formation of mathematics anxiety or in eliminating existing mathematics anxiety.

5.4 HOW ROBOTICS CAN DECREASE MATH ANXIETY

The "Digital age," presented as the 21st year, is the age of information and innovation. In order to keep up with the speed of this age, "learn to learn" in education is to prioritize the transformations in basic computers. It is the STEM (Science, Technology, Engineering and Mathematics) approach, which is based on the characteristics and integration of systematic science, technology, engineering and mathematics disciplines from the 21st century, where learning rates are increased at all levels of education and where strong motivational details are broken down (Scaradozzi et al., 2015) . Broadly, it can be referred to as the sum of individual disciplines involved in STEM or an interdisciplinary approach to STEM education that emphasizes interdisciplinary relationships (Gao et al., 2020).

It is seen that STEM, which is considered as a treatment that encourages students to learn directly, enables them to achieve their dreams and transfer what they have learned to new and different problems (Yalçın and Akbulut, 2021), together with robotics and solvable education, which are the same as available, also come to the fore. As a matter of fact, robots are technological tools that attract great attention in primary education mainly due to their compatibility with STEM (Khanlari, 2019). Robotics teaching with Arduino, Mbot and Lego robots etc. While there are many teaching tools, there are also many programming tools such as Tinkercad, Mblock, Scratch for Arduino, which can guide robotic circuits using programs.

Figure 5.1. Using robotics in classes (https://museumsvictoria.com.au/learning/outreach-program/learning-kits/coding-and-robotics/, https://www.teacheracademy.eu/course/robotics-and-coding-easy/)

Robotic coding can be defined as a complex problem-solving skill that includes many cognitive processes such as problem solving, logical reasoning, creative thinking, algorithmic thinking, computational thinking skills (Anistyasari & Kurniawan, 2018; Grover & Pea, 2013; Monroy-Hern'andez & Resnick, 2008; Oluk & Korkmaz, 2016; Proctor & Blikstein, 2018; Rowe et al., 2017). Considering the thinking skills contained in robotic coding, it is seen that it is a part of logical reasoning and is one of the 21st century skills. It can be said that robotic coding is based on computational thinking, which has many things in common with mathematical thinking skills.

With robots, one of the most effective approaches to developing computational thinking in mathematics, children can offer alternative solutions to problems encountered in the field of mathematics; They can have opportunities such as organizing data, using simulations, and using algorithms in learning environments where digital teaching tools are used. Robotic coding supports the development of algorithmic thinking, one of the important components of mathematics, allowing students to build mathematical models, compare these models with what is known about the real world, and see whether this model is meaningful (Aminger et al., 2021).

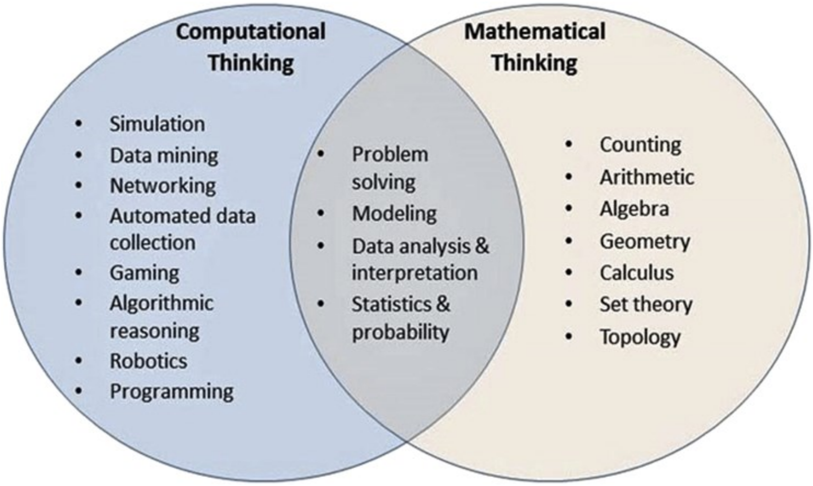

Figure 5.2. Similarities and differences between CT and mathematical thinking (Sneider et al., 2014)

One of the obstacles to being successful in mathematics is the idea that what is learned in mathematics has no application area. The use of robotics in mathematics teaching enables active learning of mathematics by doing and experiencing, and provides the opportunity to apply the learned knowledge and skills. The use of robots in mathematics teaching prevents the emergence of the idea that mathematics is completely abstract and far from application by providing students with some skills in terms of discovering, structuring and applying knowledge (Ching et al. 2019).

If we consider the use of robots in mathematics education in terms of their suitability for the child's interests and needs, one of the teaching principles; Children of all ages are very interested in moving objects, machines and toys. Considering this fascination with robots, it enables the creation of an ideal learning environment in terms of motivating the child while learning mathematics (Nugent et al., 2010).

The use of robotic coding in mathematics education supports cognitive and affective development, as well as the ability to build some physical objects, move robots, etc. Since it requires behaviors, it also contributes to the development of kinesthetic skills.

It is possible to list the advantages of robotic coding in terms of preventing mathematics anxiety and being successful in mathematics as follows:

- Experiential, that is, applied education with robotic coding, brings high motivation in learning by providing students with the opportunity to teach knowledge in the field of Mathematics, which has an abstract structure, by doing and experiencing real-world events.
- Robotic coding can be used within the framework of active learning principles in solving problems related to integers, ratio-proportion, measurement, geometry, and algebra equations (Stripling & Simmons, 2016 as cited in Çınar, 2020).
- Robotic activities offer students various opportunities to build some physical objects, make observations, interact with these objects and learn abstract concepts through experiential learning. In this way, it also contributes to the development of problem-solving skills (Petre & Price, 2004). In this case, it prevents the causes of mathematics anxiety, which originate from the field of mathematics (Mathematics has a nature that includes abstract concepts, mathematical terms, formulas, symbols).
- Children who are active with robotic coding have the opportunity to learn athematics with fun and can prevent the underlying affective causes of mathematics anxiety (negative attitude, dislike, boredom, fear, etc.).
- In mathematics education based on robotic coding, the student must complete the assigned tasks individually or in a team, based on collaborative approaches; It allows you to experience the feeling of success. Thus, giving the child a sense of achievement in the field of mathematics, especially in the primary school period, providing a team working environment, and going beyond the usual traditional techniques are effective in preventing the formation of mathematics anxiety.

5.5 BASIC PRINCIPLES IN THE APPLICATION OF ROBOTIC ACTIVITIES USED TO REDUCE MATHS ANXIETY

Today, interest in mathematics can be increased by using robotic applications with Z and alpha generation individuals, children of the age of information technologies, who are students of preschool, primary, secondary and higher education levels, the field of Mathematics, which is seen as abstract, can be concretized, active learning environments can be provided through experiential learning, children can learn by having fun, Learning mathematics by associating it with other fields within the framework of STEM can be supported, the development of many thinking skills such as problem solving / computational thinking / critical thinking / creative thinking can be achieved by using peer teaching based on collaborative learning, opportunities can be provided by taking into account individual differences so that they can experience the feeling of success in the field of mathematics, mathematics Negative attitudes and anxiety towards mathematics, which are obstacles to education, can be minimized. Based on all the benefits of robotic activities; Although it is not correct to say that using robotic applications alone improves mathematical learning, there are points to be taken into consideration when designing and implementing robotic applications that are effective in reducing mathematics anxiety. These can be listed as follows.

One of the most important issues in using robotic applications in mathematics education is to avoid learning environments where mathematical achievements remain in the background and robotic applications are the aim. In other words, precautions must be taken to ensure that the goal and the tool are not displaced, and educators' attention should be drawn to this issue.

Robotic coding, like many high-tech fields, is inherently "cool." Robotics can greatly increase the interest of students learning mathematics and can be a remarkable tool to start the course (Khanlari, 2019). The important point here is to maintain attention and motivation throughout the activity. One of the most effective ways to achieve this is to use scenario-based learning effectively in performing mathematical tasks. The fact that the scenarios to be used in robotic coding activities in mathematics education should attract the child's attention, be suitable for his/her real life, and have concrete outputs will be effective in sustaining the student's motivation until the end of the activity. Presenting activities with scenarios with these features can reduce mathematics anxiety by establishing the relationship between mathematics and real life.

Another important issue in robotic applications in mathematics education is; These are the difficulty levels of the tasks given to students. In the tasks given to students, care should be taken to give tasks that students can achieve, taking into account individual differences and cognitive characteristics. While some students have the ability to think mathematically, they may be challenged with algorithmic thinking and may have difficulty with tasks based on algorithmic thinking. If the student is faced with difficult tasks in both mathematical thinking and algorithmic thinking, he or she will experience failure, and successive failures may cause mathematics anxiety. This does not mean that 'easy tasks should be given to the student and the student should be able to do them in a very short time'. The important thing in tasks is that the student thinks that he can do and succeed if he makes an effort. Khanlari (2019) stated that it is also important to minimize the impact of technical issues related to robotics and to provide simple and functional tools that enable students to focus their attention in creating robotic activities.

One of the reasons why mathematics anxiety is higher than in other areas may be that children are directed to individual studies and that learning environments that will enable socialization and exchange of ideas with their peers are not adequately created. In line with how robotic applications can offer these opportunities to students; In the field of mathematics, it is important that it is designed and implemented in a way that enables students to learn through academic discussions and collaboration with their peers (Kopcha et al., 2017). Because students try to cope with some problems while learning with robotic technologies and need peer interaction in solving problems.

Overly competitive environments should be avoided in the implementation of robotic applications in mathematics education. These environments may cause some children to remain behind, cause losers to have negative attitudes towards mathematics, and as a result, trigger the emergence of mathematics anxiety.

5.6 SUCCESSFUL SAMPLE ACTIVITIES FOR PRIMARY SCHOOLS TO REDUCE MATHEMATICS ANXIETY

Teaching through activities based on robotic coding; It is one of the most effective ways to prevent mathematics anxiety by enabling primary school children to learn mathematics collaboratively by doing, experiencing and having fun, while developing various cognitive processes. In this section, some examples of teaching mathematics with scenario-based robotic coding, which have been developed and applied by experts and whose effects have been examined, will be presented. Application videos of these examples and more activity examples can be accessed free of charge at "https://blwithrobotics.eu/" and https://www.mindmaths.org/.

Example: 1

Scenario title/name of the game: Hardworking bees make the most beneficial honey

Children's age (primary school students): 7 years old

Time needed: 15 minutes

Content/Subject: Numbers (rhythmic counting)

Aim of the activity: Perform forward and reverse skip counting.

This activity aims to:

- develop the rhythmic counting skills by two, three, four or five forwards or backwards from a given number;
- increase children's interest in nature by providing them with information about how bees make honey;
- develop social-emotional aspects through their collaborative work as a team;
- develop algorithmic thinking skills giving by commands to robots.

The students' age-appropriate story of the event will take them forward or backward into a scenario using rhythmic counting skills by twos, threes, fours, fives!

Resources*:*

- colorized scotch to make the table on the floor;
- robot or arrows and a bee toy;
- chestnut, pine tree, sunflower, lavender and flower photos and pictures.

A detailed description of the scenario: There are many studies examining the contribution of honey to the development of children. Kaan, who is interested in this subject, examines the bees and how they make honey and learns that there are many types of honey and that each type of honey has different benefits. For example, chestnut honey stimulates appetite and is protective against cancer; pine honey is good for cough, hair loss and anemia; sunflower honey gives energy and has an antipyretic effect; lavender honey is good for the digestive system and helps us calm down; Flower honey is good for stomach cancer and acne. Kaan remains undecided as to which honey is the most beneficial in the face of the fact that all of these well-known honey types have different benefits. Which do you think is most useful? Or should we mix them to bring together the benefits of all of them and make the most beneficial honey, "our own mixed honey"? Say what? But to do this, bees need to collect dust from different places to make honey. Then how about helping them?

Steps:

1. The scenario is shared with the students by the teacher.
2. Students share their thoughts about the scenario and the information they already know. They ask the questions they want to ask.
3. The teacher places the chestnut, pine, sunflower, lavender and flower pictures in the appropriate places on the map. While placing these shapes, "Do you consume these types of honey? Which one are you consuming? Which do you think is better?" etc. It creates a conversational atmosphere by asking questions.
4. Students are asked to create a roadmap for the pictures they will collect to make their own mixed honey.
5. In order for the bee robots from the students to take this picture and make honey from this picture, the words under the picture "Count rhythmically from 2 to 14 by threes", "Rhythmic count backwards from 16 to 2 by two". etc. required to fulfill their duties.
6. Everyone programs their Bee Robot in turn (or put the arrows in the correct order) and press start!
7. Students take turns collecting their dust from their bees and make the most beneficial mixed honey.

Tips and tricks for the teacher

1. Give the rules and information of the event at the beginning.
2. Have children express their feelings and thoughts about the scenario aloud, and encourage them in this regard.
3. Prevent children from being afraid of making mistakes in coding robots, do not allow negative criticism of their friends. Encourage them when they make mistakes and make them feel that it is part of the game.
4. Insist on the student to fulfill the written task so that he can get the picture in a box on the map, encourage him in counting mistakes and give the correct answer by giving appropriate clues.
5. Do not allow other students to interfere with the student who will fulfill the task, be determined on this issue.

Scenario implementation and other resources: Maps, arrows, other materials especially created for this scenario.

Variants of the scenario/the game: If you prefer to have competition between teams in the event, you can perform the event with two bee robots on two different planes. However, please note that in this case an assistant teacher is also needed.

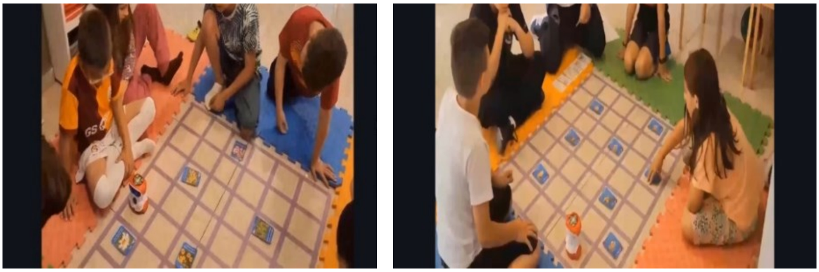

Figure 5.3. Hardworking bees make the most beneficial honey

Example: 2

Scenario title/name of the game: Junior architects design playhouse

Children's age (primary school students): 8 years old

Time needed: 15 minutes

Content/Subject: Geometry (triangle, square, rectangle, circle, pentagon, hexagon)

Aim of the activity: Describe and compare properties of two-dimensional shapes.

This activity aims to:

- develop social-emotional aspects of children in terms of providing empathy with other children who have been harmed in a natural disaster in a place and motivation to do something for them,
- understand comparing two different two-dimensional shapes and enabling them to choose and use appropriate
- develop their creative thinking skills as they will realize their own designs.

The age-appropriate story of the event will lead them to a scenario where they will use their knowledge of two-dimensional shapes in geometry to design a playhouse for earthquake-affected peers elsewhere!

Resources:

- Colorized scotch to make the table on the floor;
- Two Robots and direction arrows;

- Triangle, square, rectangle, circle, pentagon, hexagon (colors: yellow, blue, red, green, pink; textures: solid, striped, dotted, etc.) in different colors, sizes and textures.

A detailed description of the scenario: On February 06, 2023, a major earthquake occurred in Turkey that affected 10 provinces. As a result of this earthquake, buildings, schools, etc., where many people live and many places damaged. Many children your age have also been affected. One of these children, Hazal, lives in a tent with her family. Hazal sees a huge playhouse in her dream, she sees that she is playing in this playhouse with her friends living in the other tent. When he wakes up in the morning, he tells his mother about the playhouse he saw in his dream. Would you like to think and design the playhouse that Hazal saw in her dream? If you were in Hazal's place, what kind of playhouse would you design, what colors and shapes would it be? Would you like to be the architects of this design?

Steps:

1. Two different teams of 2-3 people are formed by the teacher, taking into account the number of children who will carry out the activity.
2. The scenario is shared with the students by the teacher.
3. Students share their feelings and thoughts about the scenario.
4. The teacher places the shapes in the appropriate places on the map. While placing the shapes, he asks the students to say the properties of the shape in his hand. A shape is not placed on the squares he chooses on the map, two different shapes are placed. Because the purpose is to choose one of these two shapes and to compare the two shapes while choosing.
5. The teams are asked to decide on the shapes for the playhouse they will design for Hazal and her friends, and the colors and textures of these shapes (shapes: triangle, square, rectangle, circle, pentagon, hexagon (colors: yellow, blue, red, green, pink; textures: plain, striped, dotted, etc.)
6. Students are asked to draw up a roadmap of the shapes they will collect for their playhouse design.
7. Each team programs their own Architect Robot (or put the arrows in the correct order) and hits start!
8. The teams collect the shapes of the playhouse you designed with your friends in order and build a playhouse for Hazal as little architects.

Tips and tricks for the teacher

1. Let's pay attention to the heterogeneity of teams to be formed of 2-3 people.
2. Ask each team to name their architect robot in a collaborative learning framework.
3. Give the rules and information of the event at the beginning.
4. Have children express their feelings and thoughts about the scenario aloud, and encourage them in this regard.
5. By changing the starting points of the two robots, you can avoid them overlapping at the same point.
6. Prevent children from being afraid of making mistakes in coding robots, do not allow negative criticism of their friends. Encourage them when they make mistakes and make them feel that it is part of the game.
7. Insist on the student choosing one of two different geometric shapes in a box on the map. Ask them to compare two shapes out loud in terms of their properties (number of sides, angles, etc.).
8. The playhouses designed by the students are "more beautiful, this is better, etc." Do not comment, do not allow it to be made. Because one of the important skills here is creative thinking.

Scenario implementation and other resources: Maps, arrows, other materials especially created for this scenario.

Variants of the scenario/the game: If the competition between the teams is too much in the activity, the activity can also be carried out as a single group, with the children choosing and collecting the shapes in turn.

Figure 5.4. Junior architects design playhouse

Resources for Educators and Parents

The following online resources can be recommended to families and teachers on the use of robotic applications to prevent anxiety in mathematics education.

1. https://scratch.mit.edu/
2. https://www.makeblock.com/steam-kits/mbot
3. https://education.lego.com/en-us/product-resources/wedo-2/downloads/programming-blockdescriptions
4. https://blwithrobotics.eu/ (there is a curriculum and many video application examples on the site)
5. https://www.mindmaths.org/ (There is a curriculum and many video application examples on the site)
6. https://www.youtube.com/watch?v=7snnRaC4t5c
7. https://www.youtube.com/watch?v=VTRriSQhs60
8. https://www.youtube.com/watch?v=U0Pq7xcqWnM
9. https://www.youtube.com/watch?v=KZNdBxdNGIE
10. https://www.youtube.com/watch?v=7WAmFQFH2sc
11. https://www.youtube.com/watch?v=Gz0Z_rojO1I
12. https://www.youtube.com/watch?v=ZH_h2LXpyO8

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CHAPTER 6.
MEASUREMENT AND EVALUATION IN ROBOTICS-MATH EDUCATION

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6.1 EDUCATIONAL EVALUATION

The word "assessment" comes from the Latin language word "assidere," which means "to sit next to" (De Villiers, Scott-Kennel, & Larke, 2016). Assessing students' performance is an important component of the educational process. Assessment is a core element of effective teaching/learning (Bransford, Brown, & Cocking, 2000).

Evaluation is the process of collecting, summarising, explaining and analysing information:

- to assess a student's literacy as skills, knowledge, attitudes;
- giving the student feedback on their learning by analysing their strengths and weaknesses;
- to check progress and assess the dynamics of a pupil's performance;
- to judge teacher effectiveness (Logins et.a., 2020).

There are two important points in the evaluation process for obtaining information. Firstly, no matter what methodology teachers use to collect data on learning. This process needs to present information about the students and the teacher. Secondly, gathering the information is a routine process and needs to be systematically planned and organized so that teachers receive a regular feedback as indicators of progress in the education. At the same time, teachers will be collection data about learning in unplanned, spontaneous situations when students do or say anything that indicates a level of progress of learning outcomes in the context of the lesson aim and objectives (Heritage, 2011).

Typically, the evaluation system has several objectives:

- to rank students according to their academic achievements;
- motivate students to study more and get a better education;
- provide feedback to students on their achievements and help improve academic performance (Kohn, 1994).

However, there are various risks in the assessment process, such as the fact that numerical grades or lettered levels are not a complete measure of learning achievement and often lead to a focus on grades rather than learning. Assessment can cause a situation of competitiveness and stress in the learning setting. This can have negative effects on students' motivation and engagement in learning (Kohn, 1994). Most importantly, assessments, suggestions, and grades do not provide enough descriptive and useful information that students need to achieve their goals (Kohn, 1994; Wiggins, 2012). To this end, alternative practices that provide more information about instructional performance and are forms of assessment focused on student growth should be used (Kohn, 1994).

Assessment enables both teacher and student to plan for improvement as an integral component of the education process, to monitor each pupil's progress and to provide support when and where it is needed. The basic principles of assessment, which are recommended, are set out in the teaching standards:

- the principle of systemicity – a system of regular, reasoned, sequenced activities for assessing learning outcomes;
- the principle of transparency and clarity - the pupil knows and understands the expected results and the criteria for assessing his/her learning performance;
- the principle of methodological diversity - using different methods to assess teaching performance methodological approaches to evaluation;
- inclusiveness – assessment of learning performance is tailored to the learning needs of each learner, for example, time allocation and duration, environment, how the learner demonstrates performance, access to assessment work;
- the growth principle – the assessment of learning performance, especially at the end of the learning phase, takes into account the dynamics of the student's learning performance (VISC, 2020).

Teachers need to create a collaborative and supportive classroom environment where questioning, constructive feedback and self-evaluation are not taken lightly (Heritage, 2011). To make assessment more effective, the eight-step model (Natriello, 1987) can be used. The model developed for the evaluation process is based on the following sequential steps:

1. Determining the evaluation objectives;
2. Assign tasks to students;

3. Identify student performance criteria;
4. Setting standards for student performance;
5. Collect information about student performance;
6. Evaluating student performance;
7. Provide feedback about student performance;
8. Monitoring student assessment results (Natriello, 1987).

Education uses several types of assessment, including

- diagnostic assessment;
- formative assessment – it is assesment for learning;
- summative assessment – it is assesment of learning (Assessment, evaluation and reporting handbook, 2013).

Each type of evaluation is characterised by certain features in its implementation, a specific evaluation objective (see Table 6.1) (Assessment, evaluation and reporting handbook, 2013).

Table 6.1. Types of evaluation, their characteristics

Diagnostic assessment	***Formative assessment***	***Summative evaluation***
• Takes place before learning starts • Obtaining and interpreting evidence • May include collecting data on the student's interests, preferences, background • Answers to the question "Where is the student in the learning process?"	• Happens often • According to the programme • Takes place during pupils' learning • Includes teacher modelling, student support and management • A guide to identifying the next stages of a pupil's learning • Helps the teacher to differentiate the learning of a particular student	• The assessment occurs at the conclusion of a learning period, such as a theme or specific lessons. • Can be used to inform the pupil about additional learning
Teacher's goal • identify what the learner already knows and can do in the curriculum • helps identify the next stages of learning • can help	*Teacher's goal* • monitor the progress of students towards their learning objectives • give clear feedback to students and identify the next	*Teacher's goal* • to get information about learning over a given period • evaluate the quality of a student's learning on the basis of defined criteria

	steps in the learning process for them	• to assess the student learning progress, obtain assessment data
	Student's goal • monitor your progress towards learning objectives (self-assessment) • giving feedback to other students (peer assessment)	

In terms of time, assessment can be divided into short-cycle assessment, long-cycle assessment and intermediate assessment (see Table 6.2) (Assessment for Learning, 2023).

Table 6.2. Breakdown of assessments by time of assessment (Assessment for Learning, 2023)

Short cycle evaluation	***Mid-cycle evaluation***	***Long-cycle evaluation***
Provides relevant information about the student's learning. Is a variable indicator of a pupil's progress, which helps to determine if and when the teacher needs to provide timely support. Assessments provide prompt and instant information, allowing the teacher to adjust their teaching and provide timely feedback. It is also known as: real-time assessments, diagnostic tests, rapid, informal assessments, continuous assessments.	Drives learning based on performance against a very specific set of academic objectives. Interim assessments measure performance over time. These assessments can guide learning if used formatively. It is also known as: diagnostic assessment, introductory assessment, ongoing assessment, quarterly or interval assessments.	Helps to determine the learning of content over time. It is commonly referred to as a learning assessment and, unlike other forms of assessment, Summative assessments are commonly known as 'high stakes' due to the extensive content they cover. It is also known as: end-of-semester/end-of-year assessments.

6.2 ESSENCE OF SUMMATIVE EVALUATION

The purpose of summative assessment is to measure students' proficiency at the end of a process by recording their achievements (Fulcher, 2010; Harlen, 2005). Summative assessment is typically conducted at the conclusion of a learning phase (e.g. a topic, multiple topics or a logical part of a topic, a school year, a stage of education or a grade level). It aims to ascertain a pupil's knowledge and skills, both quantitatively and qualitatively. It aims to assess the pupil's achievement. Summative assessment confirms the achievement of a certain level of requirements and indicates to the teacher and the pupil how the content of a particular subject has been mastered. The assessment is expressed in points (VISC, 2009).

As summative assessment aims to measure the whole of the content covered. Summative tests as assessments can also serve as interim or diagnostic assessments to monitor students' academic progress and their mastery of the content assessed in the final assessments. The purpose of summative assessment is not the provision of suggestions for the improvement of the learner's performance in the future. It only provides an overview of learners' achievements to date. Summative assessment is characterised by its purpose, timing, participants and assessment methods (see Table 6.3).

Table 6.3. Summative assessment features (Siarova, Sternadel, & Mašidlauskaitė, 2017)

Goal	Assess student learning outcomes Demonstrate student competences Can also support learning
Venue time	Cumulative At the end of the training
Participants	Teachers usually carry out assessments Students are not directly involved in the assessment process
Questions	Does the student demonstrate an understanding of the material? Is the student ready to move on to the next stage?
How do you rate?	Projects Performance assessments Portfolio Classroom tests School and national tests, etc.

Typically, summative assessment allows teaching methods to be aligned with performance levels. To this end, summative assessment methods can be categorised into multiple choice and constructed response (see Table 6.4) (Butler et al., 2005). In reproductive learning, students select answers from a list of possible answers. In productive learning, students construct the answers themselves. The constructed answers can be divided into two groups: the result of the pupil's work and the pupil's performance.

Table 6.4. Teaching methods for summative assessment (Butler et al., 2005)

Choice of answers	Constructing answers	
	Result	*Available at*
Multiple choice exercises Matching tasks Fill-in-the-blank exercises, etc.	Essays Magazines Drawings Portfolio Short summary of the text Notes Flow charts Thought maps Concept maps Scientific article	Practical work / laboratory work Presentation Demonstration Role plays Debates Panel discussion Theatre performance Musical performance Movement performance
Asking questions		
Formal and informal observation		
Teacher/student dialogue		

6.3 THE ESSENCE OF FORMATIVE ASSESSMENT

Typically, the use of the keyword "formative assessment" in the literature is not consistent (Siarova, Sternadel, & Mašidlauskaitė, 2017). Formative assessment is a type of assessment that helps students learn. The teacher uses evidence from the learning process to guide and support the student in achieving specific learning goals for the lesson or a longer period of time (Black & Wiliam, 2009). Formative assessment involves frequently assessing learners' progress and understanding through interactive assessments. This helps to identify their learning needs and make necessary adjustments (Wiliam, 2011). Formative assessment is designed to improve learning and achievement and takes place throughout the learning cycle. Formative assessment does not measure a learner's performance in terms of grades and 'turns' learning into a process. Formative assessment allows students to clarify their understanding before or during assessment without affecting their final grade. It is an opportunity for students to receive feedback and improve their knowledge (The Ten Principles of Assessment, 2018). The purpose of formative assessment is to collect evidence of student performance, interpret it objectively, and use it to make informed decisions about the next steps in the learning process. This ensures that the steps taken are more appropriate and valid (Black & Wiliam, 1998).

Despite the fact that both summative and formative assessment are based on assessment as a process, it is possible to identify differences between the two types of assessment (see Table 6.5). Summative evaluation can be described as a digital snapshot, whereas formative evaluation is like streaming video. One is an image that the learner knows is captured at one point in time, while the other is a moving image that demonstrates the learner's active thinking and reasoning (Van de Walle, Lovin, 2006).

Table 6. 5. Comparison of formative and summative assessment (Moss & Brookhart, 2019)

Formative assessment (assessment to improve learning)	**Summative assessment (assessment to measure achievement)**
Objective: to improve learning and achievement	*Objective:* to measure or audit achievements
It is carried out in the course of the learning process - every day, every lesson, during the process	Conducted periodically to raise awareness of past events
The process of learning and how it occurs is the focus of assesment	Focus on learning outcomes
Recognised as an integral component of the learning process	It is recognised as a separate activity to be carried out at the end of the learning process
Shared – Teachers and students understand their learning goals, and use assessment feedback to guide and adapt their learning. They know where they are headed and what they need to do to get there	Teacher-led – teachers indicate what students need to do and then assess how well they do.
Flowing – a continuous process, influenced by the needs of the	Constant – a constant measure of student achievement

students and the feedback of the teacher.	
Teachers and pupils take on a purposeful learning role	Teachers do the auditing and the students do the auditing
Teachers and students use this information to adjust their teaching and enhance learning performance	Teachers use the results to make final decisions on whether a set of learning activities has been passed or failed
Students don't need to be warned in advance because it's a learning activity	Students must be informed in advance of planned work

Formative assessment is considered formative assessment because it is a process of assessing how a pupil learns during the learning process. Assessing learning involves gathering evidence from various sources using different assessment tools. This evidence helps teachers and students identify key questions for formative assessment: where is the student in their learning; where should they be; how best to get there. Teachers can only effectively adapt teaching strategies, resources and environments to help all students learn. Teachers need to have information about their students' knowledge, abilities, and learning preferences at all times (Learning for all, 2013). Formative assessment is characterised by purpose, timing, participants and assessment methods (see Table 6.6).

Table 6.6. Features of formative assessment (Siarova, Sternadel, & Mašidlauskaitė, 2017)

Formative assessment	
Goal	Improve teaching and learning Diagnosing a pupil's learning difficulties Promote understanding of learning objectives and criteria
Venue time	Ongoing, before, during and after training
Participants	Teachers and students
Questions	What are the strengths of the subject? What are the weaknesses of the subject? What changes can be made to improve it?
How do you rate?	Observations Homework Feedback Peer learning Self-assessment Q&A sessions, etc.

For maximum transparency, students and teachers share or actively create a learning objective together at the start of the lesson. Teachers also communicate indicators of progress towards the learning target, either independently or collaborating with their colleagues in the classroom. These indicators can help teachers and students monitor progress during lessons. If the objective and indicators are clear, teachers can determine how to gather evidence of ongoing learning. There is no single method for obtaining evidence of formative assessment, as it is not a distinct form of assessment. For instance, teachers can gather information by interacting with students, observing their tasks and activities, or analysing their work (Heritage, 2011).

During the learning process formative assessment takes place. It provides learners with feedback on their progress. It also draws the teacher's attention to aspects of the learning process that may need to be adjusted (Wiliam, 2011). It is a continuous process in which teachers and learners engage by focusing on the learning objectives, reviewing their progress in relation to the objectives, and taking them into account in order to achieve them (Brookhart, 1997). Formative assessment refers to the process of observing student learning and assessing student performance. The resulting observations are used to modify the teaching and learning activities in which the teacher and students are engaged, with the aim of accelerating learning in general (Black & Wiliam, 1998). In addition, formative assessment is carried out by both the teacher and the pupils through ongoing observations. The primary advantage of formative assessment is the collaborative process between teachers and students, resulting in increased student achievement and motivation (Brookhart, 1997).

There are five effective formative assessment strategies to facilitate student growth:

- the advantage of students having prior knowledge of what they will be learning;
- monitoring students' learning;
- providing feedback;
- encouraging self-assessment;
- encouraging peer assessment (Williams, 2011).

Strategy 1 refers to the benefits of students knowing what they will learn. There should be a clear understanding of the purpose of the learning in the assessment activity. This will ensure that both students and teachers have a clear understanding of how learning is defined, and will facilitate opportunities to clarify and share learning intentions and criteria. Defining and sharing learning objectives is more than just writing them on the board. Teachers must be able to communicate them clearly and comprehensibly, with a thorough understanding of the features of high-quality work. Teachers need to take the time to help students see performance as quality work. Additional motivation is provided by discussion of benchmarks and exemplars in the classroom, which can increase pupils' understanding of targets and show higher levels of performance. A structured process that involves discussing and collaborating with peers can aid in the development of students' comprehension of the assessment criteria and process. This can lead to notable improvements in achievement and motivation (Williams, 2011).

Strategy 2 in formative assessment is to monitor students' learning. Effective class discussion involves asking questions and assigning learning tasks that allow the teacher to diagnose the current learning ability of their students. The primary objective is to determine what pupils already know, in order to establish their current level of understanding. One common method used in classroom instruction is questioning. However, questioning in the classroom is often designed in a shallow, narrow, or ineffective manner (Leahy, 2005). Questioning can be a valuable tool for eliciting information, exploring ideas and thoughts, applying different ytypes of knowledge, and promoting deeper levels of understanding. Therefore, it is essential that teachers aim to elicit questions that provide insights into students' thinking. These questions are crucial for improving the quality of students' learning (Williams, 2011).

Strategy 3 is feedback. The provision of feedback guides the student's learning and focuses on the teacher's response and on observing students' learning. Feedback is information that allows the student to validate, add to, rewrite, adjust or reorganise information in his or her mind (Butler & Winne, 1995). Feedback is an essential component in enhancing learner achievement (Hattie, 2009). Feedback is most effective when it is a specific and descriptive process that focuses on the student's work, rather than on the student themselves (Williams, 2011) If feedback is provided before students have had an opportunity to work on the problem, they will learn less as a result.

Strategy 4 is self-assessment. This strategy aims to develop the pupil's self-regulation skills, promoting self-regulated learning. Self-regulated learning is an effective academic form of learning that includes metacognition, intrinsic motivation, and strategic action. Learning is enhanced when teachers allow students to monitor their own progress and show them how to achieve their learning goals (Butler & Winne, 1995).

Strategy 5 is peer assessment. This strategy aims to involve students in the incorporation of learning resources. It focuses on peer learning. It can be challenging for students to comprehend the teacher's criteria for successful performance. Therefore, peers can assist each other in comprehending achievement and monitoring progress towards goals (Williams, 2011). Peer assessment should complement self-assessment and can be an effective precursor to it. This type of learning can lead to positive outcomes. To ensure success, consider context, objectives, curriculum area, participants, methods of assistance, length of contact, and required resources (Topping, 2009).

Formative assessment methods and techniques cover both individual and group work. Each pupil can be assessed individually, in pairs, in groups or as a whole class. Listening to pairs or small groups of pupils can help the teacher to quickly identify problems or misconceptions that can be corrected immediately. Observing group activity can also help to assess individual pupils to identify their needs more effectively. Often, the opportunity to work with others drives students towards mastery. The process of group assessment is part of learning, but the teacher can give some feedback to each pupil individually in the form of a brief comment or at least a 'plus' or 'minus' with a brief verbal explanation of what each symbol indicates (Dodge, 2009). Different teaching methods are used for formal and informal assessment (see Table 6.7).

Table 6.7. Teaching methods for formal and informal assessment (The Definitive K-12 Guide, 2016)

Formal formative assessment	***Informal formative assessment***
Is documented and is not usually marked: • Tests; • Written assignments; • Entrance ticket; • Presentations; • Concept mapping, • Written survey.	Not documented, performance assessment driven: • Quick comprehension tasks; • Asking questions; • Discussion; • Observation; • Confidence scores (thumbs up, thumbs down); • Interviews.

Typically, formative assessment can combine teaching methods with formal and/or informal assessment. Formal formative assessment is designed to provide evidence of student learning. Informal formative assessment, on the other hand, provides evidence of a learner's learning from everyday activities (see Table 6.8) (Ruiz-Primo, & Furtak, 2007).

Table 6.8. Teacher action in formal and informal formative learning (Ruiz-Primo, & Furtak, 2007)

FORMAL FORMATIVE ASSESSMENT: aims to show what a student has learned		
Collect	*Interpreted by*	*Taking action*
The teacher collects and summarises information about the pupil's learning. Izm anto tests and apps	The teacher analyses information about the pupil's learning. Reads pupils' work and provides written comments	The teacher plans actions to help pupils achieve the learning objectives. Modifies lesson plans based on students' level of proficiency
INFORMAL FORMATIVE ASSESSMENT: describes how a pupil's learning from everyday activities can be demonstrated through evidence		
Retrieved from	Acknowledged	Use
The teacher obtains information from the pupils' answers. Asks students to formulate explanations or provide evidence	The teacher acknowledges students' answers and compares them with scientific ideas. Repeats students' answers	During the lesson, the teacher makes use of the information provided by the pupils. Asks students to explain their answers, the learning objectives and the reasons for them

Teaching methods and techniques that can be used in formative assessment include:

- summarising and reflecting to help students reflect on, understand what they have heard or read, have personally meaningful learning experiences and/or improve their metacognitive skills. These techniques require students to use subject-specific language;

- lists, charts and graphic organisers. Students organise information, make connections and relationships using different graphic organisers;
- visual representation of information. Students use words and pictures to help them remember better, making it easier to retrieve information later. This 'dual coding' helps teachers to address the diversity of learners in the classroom, to choose teaching styles, and to present information in different ways;
- cooperation activities. Students can interact with their peers. They can develop and demonstrate their understanding of the concepts they are learning. Of these techniques, the use of self-assessment, checklists and performance level descriptions in formative assessment (Dodge, 2009) will be discussed in more detail.

Students are undoubtedly essential to the teaching and learning process. Formative assessment is a collaborative learning process that involves both teachers and students. Students are considered the key factor in driving the learning process forward. Pupils are the motivating force as they have the right to decide whether they want to learn and improve their thinking in a positive manner. For this reason, it is important to involve students in projects and classroom activities to enhance their academic performance (Stiggins, 2004).

6.4 THE ESSENCE OF FEEDBACK

Evaluation is based on effective feedback, which is possible if the doer has a goal, takes action to achieve it and is informed about his/her actions towards achieving the goal. If the learner does not have clear goals for the task, he/she cannot evaluate him/herself comprehensively and receive useful feedback. This is the key and primary step in achieving the goal – to know how far you are and whether you are on the right 'path'. The teacher, in turn, needs to pay attention to the correct "pathway" – to clearly state the child's results in relation to the goal. The best feedback is so clear that anyone with a goal can understand and learn from it (Wiggins, 2012). Feedback is information provided to students regarding their performance, which guides their future behaviour (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010). Feedback can support students in their learning by directing their attention to where there is room for growth and improvement in their performance, while pointing to opportunities for further learning (Moss & Brookhart, 2019).

Feedback has the following meanings:

- motivational (influences willingness to participate);
- reinforcing (supporting desired actions);
- informative (to change performance, how to demonstrate acquired knowledge in a new context) (Nelson, Schunn, 2009).

Feedback is information that the teacher can use to confirm, add, rewrite, adjust or restructure information in memory, such as knowledge, assumptions about self and tasks, or learning tactics and strategies. At the same time, feedback also has an evaluative component, whether or not it is provided by assessment. Effective feedback informs students "what they understand or do not understand, where their performance is going well or poorly, and how they should direct their future efforts" (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010).

Feedback is "extrinsic motivation" – motivation from outside the learner. Teacher feedback is information that students use to learn. Although teacher feedback can be helpful, it cannot guarantee student learning as it ultimately depends on the student's intrinsic motivation. (Moss & Brookhart, 2019). However, feedback can help students to reflect on their learning and develop strategies to improve it, and can provide opportunities for students to develop self-regulation and metacognitive skills (Hattie & Timperley, 2007).

Timeliness is also an important feature of feedback. Information is useful if it can be used. There is no point in giving advice if you cannot make a difference. To keep the "path" to the goal as straight as possible, it is necessary to guide the pupil continuously. It is very important to assess the pupil's results in good time, but there is not always time for that. Involving pupils in the feedback process is crucial. Remember that feedback doesn't have to come only from teachers or even from people in general. Before you say that this is impossible, keep in mind that feedback can come from a variety of sources. Computer-based learning offers unlimited opportunities for timely feedback, making it one of the most powerful tools in education technology. Peer assessment is another way to provide timely feedback. Teachers must teach students that feedback in small groups should be high quality, without being critical or praising unnecessarily (Wiggins, 2012).

Providing feedback is essential for improving learning, as it affects both a student's motivation to learn and their ability to do so. For high-quality feedback, learners must receive clear information on their strengths and areas for improvement. The quality of feedback is reflected in its strength (Nyquist, 2003). Feedback is purposeful if:

- helps you understand more clearly what a good achievement is (purpose and criteria);
- the learning tasks are designed to encourage students to take time and try;
- provides high-quality feedback to assist students in enhancing their own performance;
- experience in the use of feedback to bridge the gap between current and target performance;
- convinces you that assessment has a positive impact on learning;
- fosters collaboration and conversations about learning (student-teacher and student-to-student);
- encourages the development of self-assessment and reflection skills;
- gives the student a choice of topic, methods, criteria, time for assessment;
- involve students in decision-making about the assessment process;
- supports collaborative learning;
- fosters positive motivation, belief, self-confidence;
- the information provided can be used by teachers to improve their teaching (Nicol, 2008).

Feedback is crucial for learning and growth as it can assist students in identifying their strengths and weaknesses and provide them with specific guidance on how to bridge the difference between their current comprehension and the intended result (Black & Wiliam, 2009)

Three types of feedback can be distinguished:

- affirmative feedback is given immediately after observing the performance. For example, John, you did well with this experiment, and you followed all the safety rules for doing the demonstration!
- developmental feedback motivates the learner to do better. For example, Līga, you did very well with the thin cut of the page, but you should be more precise with the placement on the cover stick.
- effective feedback is about meeting the needs of the learner – this is evidenced by the teacher providing observational evidence (the teacher explains what has gone well, what has

gone badly, what needs to be improved and how). For example, when a piece of work is completed and handed in to the teacher, the pupil receives not only a mark but also a comment from the teacher (Jones, 2005).

So quality feedback:

- promotes the development of self-assessment or reflection in the learning process;
- fosters dialogue between teacher and peers about learning;
- helps to clarify what constitutes good performance by providing targets, benchmarks, and standards;
- an opportunity to bridge the gap between a student's current performance and the student's target performance;
- provide the student with information about his or her learning;
- encourage positive motivation and self-esteem;
- provides teachers with information that can help improve their teaching strategies (Juwah et al., 2004).

Feedback is crucial for motivating students and is most effective when used to provide participants with concrete information on how to improve their performance at different levels:

- at the level of the learning task;
- learning the content, understanding and completing the task;
- at learning process level;
- what is needed to understand and complete the task, the student's motivation, behaviour, attitudes;
- at the level of the pupil's personality, self-regulation;
- the learning strategies, methods, techniques, habits and self-esteem of the learner (Hattie & Timperley, 2007).

For feedback to be effective, it must provide actionable steps (Hattie & Timperley, 2007). The feedback model highlights that feedback aims to narrow the gap between a student's current understanding, performance, and purpose. It achieves this by providing information that helps the student to understand where they are in relation to their goals and what they need to do to improve. The purpose of the model is to provide answers to three main questions:

- The question "Where am I going?" asks about the goals associated with the learning task;
- The question "How am I doing?" is designed to indicate progress towards achieving the intended goal. Feedback

is usually effective when it contains information about students' progress and how to proceed;
- The question "What to do next?" is designed to identify the necessary actions for achieving better progress (Hattie & Timperley, 2007).

In addition, feedback related to the task, task processing and self-regulation should be the main focus. The optimal learning environment or experience is achieved when teachers and students strive to answer each of these questions (Hattie & Timperley, 2007).

Students engage in a complementary process of self-assessment and feedback, just as the teacher collects evidence in relation to the objective. Self-assessment involves metacognitive activities, which are a hallmark of effective learning (Heritage, 2011). Self-assessment, which aims to make the assessment process more student-centred, is a form of alternative assessment (Weisi & Karimi, 2013).

Self-assessment is a process in which students reflect on the quality of their work, evaluate the extent to which it meets clearly defined objectives or criteria, and revise their work accordingly. Self-assessment is considered a supplementary element of formative assessment (Black and Wiliam, 1998). Student self-assessment is one of the most commonly used techniques in formative assessment. In essence, self-assessment is a continuous process. It begins when the learner reflects on his/her learning, assesses his/her interests and metacognitive processes. Self-assessment involves self-evaluation, reflection, metacognition and the setting of goals. This means that if a pupil evaluates himself, he:

- assess the quality and knowledge of their work;
- discover your strengths and weaknesses;
- understands that they are responsible for their own learning;
- think about what he has learned and how he has learned it;
- understands what they need to improve (ideally, they should set their own learning goals and plan to achieve them) (The Capacity Building Series, 2007).

Self-assessment involves students in the evaluation of their own achievements and learning processes and in the participation in decisions about their further progress in learning (Sebba, Crick, Yu, Lawson, Harlen, & Durant, 2008).

Self-assessment is a valid and necessary technique for assessing student achievement. This is especially true in contexts where self-assessment is used for formative rather than summative purposes (Ross & Starling, 2008). However, to achieve the desired autonomous behaviours from students, the focus should be on developing self-assessment skills. Moreover, for explicit learning, it is necessary to encourage learners to first self-assess their learning and later to promote self-regulation. Accordingly, the training emphasises the use of certain meta-methods to refer to learning. Learners begin to experience the ability that autonomy implies as a certain very distinct behaviour that encompasses both the content of learning and the learning content as explained by (Little, 1999). Using self-assessment to observe learning performance has advantages and challenges (see Table 6.9).

Table 6.9. Advantages and challenges of using self-assessment (Guidance for Selecting and Developing Quality Assessments in the Elementary Classrooms)

Benefits	Potential problems
Provide students with the chance to reflect on their work Discover your pupil's strengths and weaknesses Can provide information on academic and non-academic competences, such as attitudes	It can be difficult for a pupil to interpret his or her own thoughts objectively, independently, without further discussion with the teacher Pupils may either overestimate or underestimate their abilities

Self-assessment, if properly organised, could significantly increase learning and achievement. Effective self-assessment is a critical part of managing your own learning. Of course, this requires that students have clear ideas about their learning objectives. An understanding of what might be considered good quality work that meets those goals, an idea of where they stand in relation to those goals, and the means to achieve them (Black & Jones, 2006; Hill, 1995). Self-assessment involves learners evaluating their own learning and achievements based on evidence from themselves and others. Learners are encouraged to take responsibility, particularly when developing benchmarks that are meaningful to them. Overall, self-assessment is a way for learners to take ownership of their own learning (Boud, 1995).

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CHAPTER 7.
GUIDANCE AND SUPPORT IN ROBOTICS-MATH EDUCATION

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7.1 THE LINK BETWEEN MATHEMATICS AND ROBOTICS

Mathematics is a discipline that is based on a series of rules for solving problems in various fields. Thus, mathematics lays the fundamental foundations of other sciences such as engineering, economics, science informatics, etc. The fields of applicability of mathematics keep pace with today's life, a modern and constantly moving life.

Mathematics has a lot of tools to rule the world, and to understand how it works and what its problems are (Hub, 2023).

One of the roles of the teacher is to convey to the students the importance of education and the information they receive to develop. Especially the place of mathematics in the real world, which, according to our studies, is the discipline that needs to be studied and has its roots in the primary classes.

Mathematics is an important component of the implementation of STEM in the teaching and learning process (Zhuang et al., 2022). There is more and more discussion about the integration of robotics education into the application of STEAM by developing interest in activities related to this reform (Gubenko et al., 2021).

The application of robots in primary education has proven to be a very important and beneficial strategy, namely robotics education involves the integration of the fundamental notions of computer science in various activities, which are contained in the programs of other subjects such as science, mathematics and social sciences (Zhuang et al., 2022).

Mathematics being the discipline with its abstract concepts can be explained in another interactive form, applying the new developments of robot science. A relationship is established between mathematics and education with robots that also need an intermediate point such as the student (Figure 7.1). The student and the robot are two important actors in effectively applying education with robots.

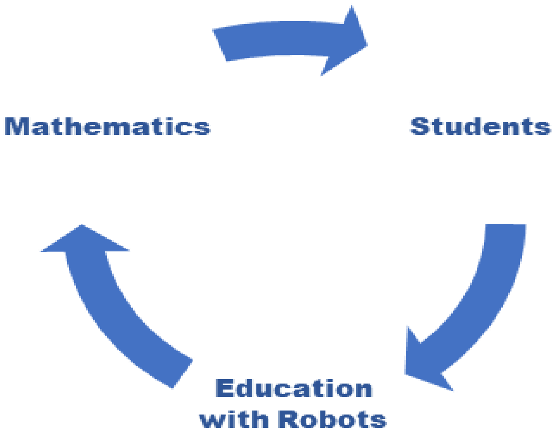

Figure 7.1. Mathematical Interaction - Education with Robots – Student

There are two main directions of application of robots in the educational environment such as the involvement of robots as a learning tool for certain subjects: mathematics, science, physics, etc. and another direction, studying robots using the robot as the main tool (Figure 7.2) (Jung & Won, 2018; Qu & Fok, 2022) .

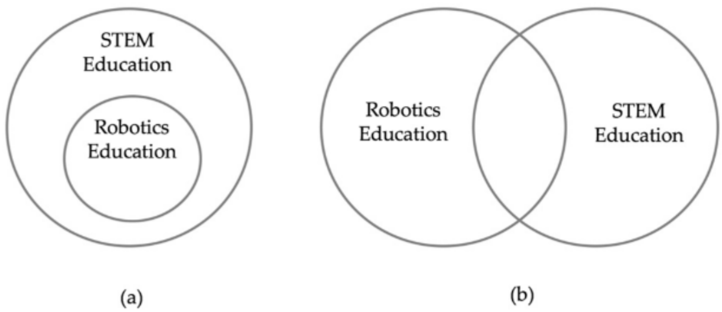

Figure 7.2. Robotics Education as part of STEM and Robotics Education as a subject
Source: (Jung & Won, 2018)

Some schools provide in school curricula the inclusion of robotics elements in training or the application of robots to study different theoretical and practical concepts for different disciplines (Zhuang et al., 2022; Hye Sun You, Vikram Kapila, 2017).

The advantages of applying education with robots to mathematics lessons from primary education can take two directions of development in the social and intellectual direction of the student. Education with robots provides activities in groups of children, which leads on the one hand to the development of collaboration, socialization, control, responsibility skills, on the other hand to the development of other intellectual capacities, computational thinking, problem solving, critical thinking, creativities. These features are in permanent correlation and overlap together when solving problems with the help of educational robots.

7.2 THE IMPORTANCE OF APPLYING EDUCATIONAL ROBOTS IN MATHEMATICS

According to the digital competencies framework of sec. 21st century, the knowledge and skills students need to succeed in work and life depend crucially on digital literacy, which is closely related to creativity and innovation, critical thinking, critical thinking and problem-solving, social responsibility and cultural competencies, global and environmental awareness, communication, digital literacy, collaboration and leadership, lifelong learning and self-direction and personal management (Ahmad Khanlari, 2013; P21_Framework_Brief.pdf, 2019).

On the basis of these important skills, teachers need to integrate into their teaching strategies elements that develop the necessary digital competences and allow continuous development in this direction (Figure 7.3.).

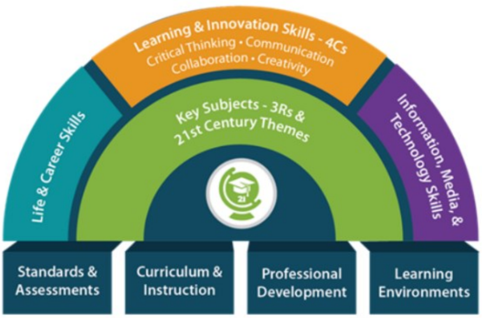

Figure 7.3. The Digital Competences Framework in sec. XXI
https://www.battelleforkids.org/networks/p21/frameworks-resources

In order to have a more correct and appropriate pathway to the basic requirements in terms of digital competences, teachers will take into account several aspects regarding the application of educational robots, namely the basic characteristics of their application and the basic elements that lead to the development of skills in the use of robots and the understanding of the basic concepts of mathematics (Figure 7.4.).

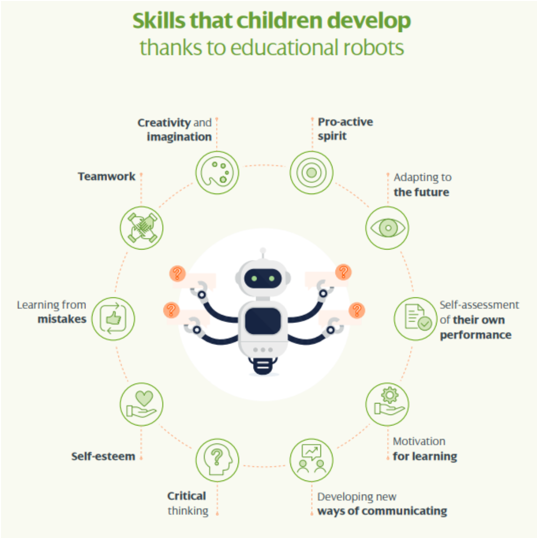

Figure 7.4. Skills developed with robots
https://www.iberdrola.com/innovation/educational-robots

The application of robots to teaching-learning-evaluation lessons in mathematics classes has several benefits. Various studies and statistics show that the most important benefits can be:

- development of computational thinking;
- development of cooperation skills;
- develops the creative part;
- critical thinking,
- solving problems;
- training for the workforce;
- preparation for practice;
- the activity are are more interactive and funny.

7.2.1 ALGORITHMIC AND COMPUTATIONAL THINKING

Algorithmic and computational thinking are two important concepts that are laid as a foundation by applying ER to mathematics. Computational thinking is divided between algorithmic thinking and logical thinking, applied to problem-solving (Kerimbayev et al., 2023). Algorithmic thinking is a thinking process based on certain rules and continuities, a way of organizing data so as to reach a finality respecting the proposed requirements (Doleck et al., 2017; *Creativity in mathematics – EDICT*, 2022).

In the process of developing computational thinking through education with robots, three phases are described (Qu & Fok, 2022):

- abstraction;
- automation;
- analyze.

The *first phase* is at the level of imagination, abstracting the stages and the entire process of applying robots to the proposed activity. It is a phase where students can apply the brainstorming method to transcribe the proposed problem into facts and actions. In the context of the educational robot application environment, abstraction occurs when students develop robots with constrained reactions to conditions that might occur in reality.

The second phase is the phase of tracking and observing the actions of the robot, it is the phase of visualizing the verbally formulated problem and putting it into practice.

The last phase is the conclusion and analysis phase, with forecasts and changes to the previous situation (Qu & Fok, 2022).

These phases can also be understood by preschool children, with more explanations from the teacher but with good results from the children. It was done with less explanation by older preschoolers, and with less explanation, only guidance from the teacher in the case of even older students (Jung & Won, 2018).

Several characteristics of computational thinking can be described (Wing, 2006), which are:

- conceptualization, without knowing programming concepts;
- development of fundamental skills, without knowing mechanics;
- people's thinking in various ways, not how a computer would think;
- combining mathematical and engineering thinking;
- development of different ideas, put into practice;
- accessibility for anyone.

It is important to develop strategies for the development of algorithmic and computational thinking in primary education, to prepare students for another level of information Applying educational robots to mathematics it is possible to execute a suite of operations in a certain order, approximately constant, by going through they arrive at a logical chain of contents.

Using the educational robots, skills of intellectual activities will be developed and elaborated based on logical analyses, which have made aware of each link of reasoning and the relationships between them, specific characteristics of computerized thinking.

7.2.2 SOCIAL COLLABORATION

Socialising is an important phenomenon for children both at school and in their free time. Combining school and a pleasant social environment is a goal that every teacher has. Through the use of robots in classroom learning a social collaboration takes place. Thus,is another important benefit for applying Robot Education to mathematics in the primary cycle, which develops cooperative skills, and organizational skills and involves a lot of patience on the part of each student in using robots.

As the complexity of a problem increases, so does the need to work collaboratively. Students move to another level of reasoning as part of computational thinking to solve a problem (Kerimbayev et al., 2023). Students like to work in teams and apply the acquired skills in more complex situations

This aspect is also important in the case of applying Educational Robots to mathematics. By involving a group of children with the same goal and through cooperation, optimal results can be brought to solving a problem. Cooperation implies the existence of a team that collaborates and organizes itself in such a way that having the same objectives with several ideas reach a solution. Teamwork also implies the existence of a person responsible for certain tasks imposed by the proposed problem situation, which leads to the division of tasks when going through the steps to solve a problem, which implies the existence of a team leader, so that the application of robots in team also leads to the development of managerial skills, and last but not least to the development of a responsibility (Ahmad Khanlari, 2013).

7.2.3 CREATIVITY

Mario Capecchi says “Creativity results from the abrasive juxtaposition of life experiences”. Within the framework of solving problems with the help of robots, another intellectual capacity such as creativity develops *Creativity in mathematics – EDICT*, 2022). Education with robots in mathematics involves two types of creativity: the first type leads students to discover new solutions, to develop new ideas, the second to apply new methods to already existing situations (Ahmad Khanlari, 2013).

Robotic education offers a special chance to observe how everyday creativity leads to interactions between students and their social, physical and cultural environments (Kerimbayev et al., 2023). In figure 7.5 we see what is needed to have a product as a result of applying creativity in correlation with other factors (Nemiro et al., 2017).

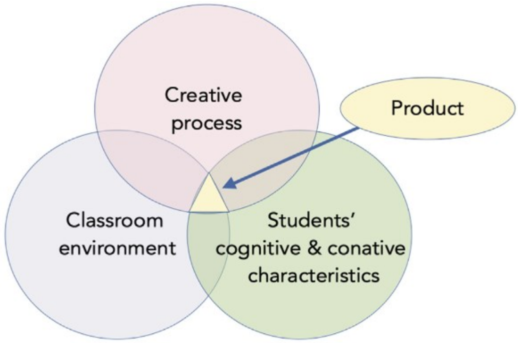

Figure 7.5. Confluence model for educational robotics. (Nemiro et al., 2017)

As creativity is another dimension of computational thinking and applying the principles of computational thinking in solving problems by applying robots to mathematics, it involves creative thinking in formulating new solutions or even bringing new artifices to solving problems (Doleck et al., 2017).

Modern machine learning algorithms allow robots to develop autonomous agents capable of learning by exploring their surroundings. Unlike computational creativity, robotics research using reinforcement learning is also situated in the sense that it uses methods applicable to embedded agents. In this sense, the robot.

The robot as a physical object can have a role as a perfect tool to study and model the emergence of creativity. Or created special models to stimulate creativity with robots (Gubenko et al., 2021).

To be able to have this process of simulating creativity in students through the application of robots, students must be prepared to develop the necessary skills for their most effective application.

Creativity is the process that describes the originality and value of an activity (Creativity in Mathematics - EDICT, 2022). In order to develop creativity and put students to work, they need key skills:

- Easily recalling thoughts, connections and expressions, making connections from previous experiences.
- To reactivate and reuse the acquired knowledge in various new situations. To apply their quantitative creativity with the fluency is another characteristic of creativity. Relationships, symbols and other notions to manage them at a fast pace and without difficulty.
- Flexibility is also an important characteristic. Rapid transition from a familiar situation to a new one, from one method to another. Students can move from one approach to another without difficulty.
- The characteristic of creativity that makes every problem situation more special, unique and incomparable is originality. Here one comes up with new ideas that do not fit the existing ones and are seen differently.
- And the last characteristic related to the sensitivity of a situation, pay attention to something unusual, unnoticed by others (Gubenko et al., 2021).

Edward de Bono Quotes (1933) says: ”Creative thinking - in the sense of creativity at the level of ideas - is not a mystical talent. It is a skill that can be practiced and cultivated.”

7.2.4 CRITICAL THINKING, DISCOVERY AND EXPLORATION

To engage in problem-solving, we need to think at a higher level and evaluate problems using or adapting existing knowledge and skills, while grounding in critical thinking (Doleck et al., 2017).

Defining the concept of critical thinking is quite complex due to the fact that it is a concept whose definition depends on the theoretical framework used (Merlo-Espino et al., 2018).

Critical thinking plays a role in acquiring new knowledge in mathematics, because through the application of critical thinking, creative thinking and interpretive reasoning, new knowledge is created and developed (Doleck et al., 2017).

Bloom’s taxonomy was searched for the level that would coincide with the development of critical thinking. It was found that the evaluation, would be that cognitive process that would be equivalent to critical thinking, the judgment of some effects, the justification of the actions, the argumentation of the result, supports the own ideas and opinions on the actions taken (Ebiendele E., P., 2012). When solving various problems in mathematics, critical thinking plays an important role and is an essential skill in mathematical thinking. Students are not initially prepared to be able to think critically, they are not born with this ability, but they can develop it from created situations, they need support and to prepare for critical thinking and then apply it to solving problems (Merlo-Espino et al., 2018).

In the process of applying robots to solving problems, the actions that the students have to do with the educational robot and the actual organization of the whole process, leads to an analysis, judgment and evaluation of the process, which means critical thinking based on the application of educational robots which links several different analytical skills.

For the integration of critical thinking in learning mathematics there are four difficulties (Ebiendele , 2012):

- lack of training, not all teachers have trained those critical thinking skills to be able to pass them on to students;
- lack of information, often there are not enough practical didactic materials to train the part of developing critical thinking;
- prejudices, prohibit critical thinking because they stop analytical skills such as correctness, openness and curiosity about a mathematical problem;
- time constraints, there is always little time for teachers to convey the content of the subject, there is a lot of information and the focus is more on the content than on the student.

7.2.5 PROBLEM SOLVING

The understanding of mathematical notions is not based only on theoretical content, it is necessary to apply it in practice, by solving exercises or solving problems. The applied part of mathematics is essential and makes the abstract, unclear, difficult to imagine notions to be understood. Practice at the problem-solving level teaches all relational understanding skills, based on the description of the three levels of practice: the exercise level, the application level, and the problem-solving level (Clements et al., 2023).

The basic activity in mathematics classes is problem solving – one of the surest ways that lead to the development of thinking, imagination, attention and the spirit of observation of students. This activity tests to the highest degree the intellectual capacities of students, requires all their mental availability, especially intelligence. But not only knowledge processes are mobilized in solving a problem, but the whole personality of the problem solver (Purcaru & Paraschiva, 2008) .

Using educational robots, the three practical levels of problem solving can be achieved:

- the level of practice, the application of several exercises on the same subject, with the modification of the content;
- the level of application, the various theoretical notions can be transcribed into applicable practical situations;
- the problem-solving level, which makes the translation of a textual content into stages of solving a problem.

A problem-situation represents a contradictory situation for the child from a cognitive point of view and created by the simultaneous existence of two realities: the previous experience and the element of novelty that the child faces. This conflict is important from a formative point of view as it encourages the child to search and discover, to identify new solutions through trial and error, to relationships between what is known and what is new (Marcut, 2015).

Based on the definition given by Polya (1981) who laid the foundation of research on problem solving, we have the definition of problem solving as finding a way out of a difficulty, a way around an obstacle, reaching a goal that was not immediately understandable. Finding a solution to a problem is finding a way out of a situation, so it leads us to a cognitive thinking process.

The use of educational robots orients the problem solving to the level of applying an algorithm, going through some stages and overcoming that obstacle by finding an effective solution (Doleck et al., 2017).

Solving problems requires more complex thinking than solving exercises. Solving exercises is based on a model and memories of previous solving sequences, while solving problems requires analysing the problem and building a mental model of the solution.

Solving mathematical problems calls on working memory resources in various ways, such as retrieving numerical information from long-term memory, performing numerical manipulations, retaining answers to partial problems and creating a representation of the problem, and following different steps in solving problems in multiple steps. Individual differences in memory capacity have been shown to be a significant predictor of math performance, with greater memory capacity associated with stronger math skills. It has been shown to be a significant predictor of mathematical performance, with greater memory capacity associated with stronger ability skills (Van der Ven et al., 2023).

7.2.6 PREPARE FOR THE FUTURE WORKFORCE

The future and the following jobs will be dependent on information technologies. The use of robots and knowledge of their functionality from an early age leads to the preparation of future generations for the application and administration of new technologies (Robotics for Kids: Unlocking a World of Innovation in 2023).

Along with learning to use educational robots, students will be prepared for the future child workforce with the following:

- robotics skills increase the chances of employment in various fields. More and more industries rely on automated robots that streamline the production process. Medical institutions are adopting robotic technologies for various branches of medicine. The logistics sector is another field that applies robots to warehouse automation, autonomous vehicles and systems based on artificial intelligence.
- robotics skills allow a faster adaptation to new technologies and their evolutions. With the advanced technologies and companies are constantly modernizing the robotics sector. Having the necessary skills, the new generations of children will be able to work with the latest technologies.
- adaptability in teamwork is another essential skill in the success of a well-organized company. Today many companies involve multidisciplinary teams involving robots in the design, construction and programming of robot systems.
- adapting to the fourth industrial revolution, industry 4.0 which tends to integrate advanced technologies such as robotics, artificial intelligence, the Internet of Things and big data analysis in manufacturing and other industries skills (Saijal, 2023).

The job market is evolving and there is a growing demand for professionals with robotics skills. The most well-known fields are: industries that increasingly involve automation and robotics technologies; organizations looking to apply robots to optimize processes, reduce manual work; emerging areas of application in medicine, agriculture, logistics and people capable of developing ideas in these areas.

The most important aspect of this direction is that robotics combines engineers, mathematics, informatics, physics and looks for specialists in all these directions who form professional teams with the same goals but with different visions.

7.2.7 HANDS ON LEARNING – PRACTICE

The game as a didactic method of teaching and as a learning activity is an important element in primary education. The game does not only play a role in intellectual development but also in the development of various skills and practical abilities. Educational robots can be applied in the form of a game activity, the activity will intervene on a specific training sequence, as a set of actions and operations that are organized in the specific form of the didactic game (Robotics for Kids: Unlocking a World of Innovation in 2023).

7.2.8 THE ACTIVITY ARE ARE MORE INTERACTIVE AND FUNNY

Making it enjoyable and fun building a conducive learning environment. The satisfaction and victory that children feel when finding a problem situation is a powerful and motivating emotion. The more complex the problem and requires a longer time to solve and train cognitive thinking, the happier the final moment.

The use of educational robots in mathematics will have a positive influence on the emotions they can experience when they carry out activities that connect with those who know and with learning activities. Achievement emotions are driven by cognitive appraisals, especially when they experience control over achievement activities and the results they achieve (Van der Ven et al., 2023). Applying robots to mathematics and harnessing the effort put into solving different problems or exercises will multiply positive emotions, emotions that will lead to motivation, pleasure and pride and self-esteem. Perfect conditions for learning and accepting new challenges, new requirements and easy assimilation of new information. Performances have been proven to depend on positive emotions and experiences (Van der Ven et al., 2023).

On the other negative side are emotions that lead to anxiety, disappointment and lack of courage, especially in mathematics. These emotions can be lessened, or even eliminated by applying new techniques to stimulate positive emotions with educational robots.

By building a pleasant and fun environment, a favourable learning environment by combining theory and practice in the form of a game guided, supervised and controlled by adults with a collaborative tool - educational robots, we can achieve good results and performance in mathematics.

The application of robots to mathematics as a didactic activity can be organized in the form of a game, it is seen as a didactic game by the students, the game has a purpose, rules, and objectives and reaches the goals foreseen and planned by the teacher.

Thus, using the game, the teaching staff achieves the following:

- to activate children from a cognitive, action and affective point of view, increasing;
- the degree of understanding and active participation of the child in the act of learning;
- to emphasize the mode of action in various situations;
- highlight the interaction of children within the group;
- to ensure the formation of effective self-control of conduct and acquisitions(Marcut, 2015).

Using the game as a method emphasizes the formative role of mathematical activities :

- practising thinking operations (analysis, synthesis, comparison, classification);
- developing the observational and imaginative-creative spirit;
- the development of the spirit of initiative, independence and teamwork;
- formation of correct and fast working skills;
- acquisition of mathematical knowledge in an accessible and pleasant form(Marcut, 2015).

7.3 TIPS FOR APPLYING ROBOTS IN ACTIVITIES

Any activity that a teacher prepares for the course requires planning. Good planning and well-chosen teaching strategies lead to good student results and high performance in any subject taught. As a teaching tool and teaching material, educational robots can be planned at any stage of the lesson and for any mathematical content given in school curricula.

In order to apply robots to the teaching-learning of mathematics, we must also pay attention to good planning of activities, to the choice of didactic strategies for the application of robots, taking into account the following factors:

- didactic concept: active methods are chosen, specific to learning and discovery;
- the nature of the content – one and the same content can be taught in different ways to different groups of students and at different ages;
- the children's learning experience – the age of the children and the level of instruction in mathematics influence the option regarding the way of organizing learning (Mărcut).

The core subjects and skills to which educational mathematics robots can be successfully applied are:

1. ***Geometry:*** recognize geometric figures (point, straight line, line segment, open/closed broken line, open/closed curved line, circle, polygon: triangle, square, rectangle), geometric bodies (sphere, cube, cuboid, cone, cylinder), their elements (top, side; tip, edge, face), in given models and in the environment.
2. ***Measurements:*** express and compare the results of some measurements, using suitable measurement units and their transformations: for length (mm, cm, dm, m, km); for mass (g, kg, t); for capacity (l); for time (second, minute, hour, day, week, month, year, decade, century); monetary.
3. ***Numbers:*** Counting in ascending and descending order. Understanding the properties of natural numbers; developing a fundamental understanding of number sense; developing a fundamental understanding of estimating quantities and operations – sets and associating numbers with sets of objects; removing and adding elements in sets; describe, build and compare numerical models; understanding and using even and odd numbers; performing addition/subtraction, multiplication/division, understanding basic fraction concepts and performing addition and subtraction with fractions (fractions with the same denominator only); solving routine and non-routine problems with fractions.

4. ***Four operations***: explain the method of calculation and the order of performing the operations in exercises with, at most, three operations, without and with parentheses; apply arithmetic operations and their properties to find unknown numbers in exercises, given strings.
5. ***Problem solving:*** solve problems with, at most, three operations: with a plan or with justifications, through exercise, formulate problems, with support in: incomplete statement; scheme; arithmetic operations; exercise; thematic; investigate everyday problem situations, which require the application of arithmetic operations, learned solving methods.
6. ***Data science:*** explore elementary ways of organizing and classifying data: schemes; tables.

By applying educational robots, we pursue several goals, including the one in which we make math activities easier to understand for children, and of course taking into account the goals we want to achieve. Because robots are perceived and understood as tools for games and activities become activities in the form of educational games.

With preventive planning and caution in some details when using educational robots in class, beautiful and very interesting activities for children can be achieved (Lydon, 2007). When applying educational robots, we will take into account several important suggestions:

- The learning objectives must be chosen well. Not to confuse the use of robots to develop skills in information technologies or the use of robots in the study of mathematics;
- Choose a meaningful learning context. This activity would tie in well-known characters to children, favorite animals, superheroes and others, so you can create an activity like a story, be attractive and friendly;
- Let children have time to explore and make mistakes. It is easy to help them to succeed, to be faster. They learn more and faster if they make mistakes sometimes, if they allow themselves to make mistakes they learn from their mistakes.
- To always be prepared another solution to replace the robots or to finish the active in another form, the battery of the robots runs out or other situations.

- To receive rewards, stickers or something else, They will show their parents and tell the activities done, with impressions and knowledge.
- Make the activities visible to other colleagues. It leads to exchanges of ideas and new visions of the application of robotots (Lydon, 2007).

7.4 CONCLUSION

The involvement of school students in robotics research, sharing technological information and basic engineering knowledge, and developing new scientific and technological ideas allows for the creation of necessary conditions for a high quality of education through the use of new pedagogical approaches in education and the application of new information and communication technology. Understanding technological legislation assists school-leavers in matching contemporary needs and finding their position in modern society (Kerimbayev et al., 2023)

Problem-solving and composing activity provides the most effective way in the field of mathematical activities to cultivate and educate creativity and inventiveness. This can be combined with tasks to solve or compose problems where as a motivational tool being an educational robot. The difference between learning to "solve a problem" and "being able" to solve a new problem is essentially creativity, but at different levels.

Solving a "studied" problem offers less ground for creativity than solving a new problem, which, in turn, consists in decomposing the problem into new ideas. This does not mean that solving problems is worked only on creative aspects, completely abandoning the reproductive ones. The opposition between algorithm and heuristic, between skill and reasoning ability, is only apparent. The creativity of thinking, its free movement, can only be produced on the basis of correctly formed, stabilized and effectively transferred skills (Petrovici & Neagu, 2006).

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CHAPTER 8.
FUTURE TRENDS AND EMERGING TECHNOLOGIES

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8.1 THE EMERGING TECHNOLOGIES

With the rapid development of technology, education is at the forefront of revolutionary change. It is becoming increasingly clear that children need to be prepared for a future driven by technology and one that will become increasingly complex as we navigate the complex web of the digital era. This chapter explores the area of "Future Trends and New Technologies", which is the starting point of an exploratory journey that looks at the development of robotics in education, the fusion of machine learning and artificial intelligence in mathematics education, and the incorporation of augmented and virtual reality into the classroom. (Crompton, H., Bernacki, M., & Greene, J. A. (2020).

Getting innovation moving in the right direction. The pace of technological development is both exciting and challenging. We aim to explore the frontiers of education, where the convergence of technology and pedagogy is creating the basis for a new age of education. We start by examining the evolution of robotics in education over time – from early experiments to an essential element of modern learning environments (Ratten, V., & Usmanij, P. (2021). We illuminate the revolutionary potential of these mechanical satellites in education through case studies and hints at the possible future of educational robotics.

"**Intelligence Unleashed delves into the nuances of artificial intelligence and machine learning, which are seamlessly integrated into maths teaching**" (Abad-Segura, E., González-Zamar, M. D., Infante-Moro, J. C., & Ruipérez García, G. (2020). The story highlights several apps that are revolutionizing math teaching. The advantages and challenges of artificial intelligence in understanding mathematics are explored, with practical examples demonstrating its effectiveness. This chapter serves as a compass to help teachers navigate the ever-changing landscape of teaching.

A journey into augmented and virtual realms beyond reality. As we learn more and more about the potential of augmented (AR) and virtual (VR) reality for education, these technologies are becoming increasingly prominent. We explore the nuances of these immersive technologies, assess how they fit into the classroom environment, and point to the enhanced learning opportunities they provide (Inomjonovna, R. I. (2023). In addition, we look into the crystal ball, speculating on possible future uses of AR and VR and the implications of their integration into the educational process as these innovations expand the definition of the traditional classroom.

Teaching tomorrow's thinkers: tactics for a technology-dominated future. Our journey ends with an in-depth examination of the fundamental duty to teach children for a technology-driven future. We discuss the value of technical literacy in today's world and offer tips on how to seamlessly integrate technology into the classroom. We explore the subtleties of fostering critical thinking and problem-solving skills at the intersection of education and technology, emphasizing that teamwork between teachers and technicians is essential to ensure student readiness (Jackson, D., Michelson, G., & Munir, R. 2023).

Speculation about the future road. This chapter starts with the firm conviction that the introduction and understanding of new technologies in education is not only a need but also a choice. With this research, we invite educators to chart a course toward a future where technology and education intersect to provide rich and empowering learning experiences, navigating these uncharted seas and responding to the changing tides (Grassini, S. 2023).

8.2 THE EVOLUTION OF ROBOTICS IN EDUCATION

The history of robotics in education is an intriguing one, full of inventions, trial and error, and game-changing developments. As we delve into the history of educational robotics, we will travel back to a time when the idea of robots in the classroom was more like science fiction. However, the story that changed the educational landscape was made possible by the early pioneers.

The idea of integrating robots into education originally came about in the mid-20th century with the rise of educational robotics. Seymour Papert's work with LOGO the Turtle in the 1960s marked the beginning of the use of robots in education. With the LOGO turtle, a programmable robot, students could learn geometry and coding concepts engagingly and practically (Poletti, G.).

Over the years, education has evolved to emphasize the use of technology to improve the educational process. In the 1960s and 1970s, personal computers were introduced, providing new opportunities for educational robotics. Simple robotics kits, such as the LEGO Mindstorms line, began to appear in classrooms, giving students hands-on experience in building and programming robots.

Today's educational robotics goes beyond the test lab. Today, robots are actively involved in education, stimulating students' interest and interaction. Robots such as Sphero and Dash contribute to mathematics education by bridging the gap between abstract mathematical ideas and their practical implementation. For example, by teaching a robot to navigate geometric shapes, students can reinforce mathematical concepts through hands-on experiments (Zhu, H., Wilson, S., & Feron, E. 2023).

Educational robots are starting to be used in fields other than mathematics. Students can use robots with sensors in science classes to carry out experiments, collect data, and analyze results. Interactive storytelling with robots fosters creativity and language development in language arts programs. The impact on learning is profound, as children become active creators and problem solvers, not just consumers of information.

8.3 CASE STUDIES: PIONEERS OF THE FUTURE

Case Study 1: Ozobot in Primary STEM Education

STEM teaching has changed since Ozobot robots were introduced in a Czech primary school. These small robots mimic the color codes drawn by pupils to introduce coding easily. Teachers have seen improvements in students' critical thinking and problem-solving skills, and the school has reported that children are more enthusiastic about attending STEM courses (Schwinghammer, M., Milisic, D., Schmidthaler, E., & Sabitzer, B. 2023, September).

Figure 8.1. https://www.robot-advance.com/EN/actualite-test-of-the-educational-robot-ozobot-evo-101.htm

Case study 2: NAO robot in language learning

RALL is assisted by NAO, a humanoid robot, to learn languages as part of an Erasmus+-funded project. NAO, which is programmed to speak several languages, offers personalized language learning tailored to the specific needs of each student. As a result, students' linguistic abilities have increased dramatically and they demonstrate better speaking and comprehension skills (Huang, G., & Moore, R. K. 2023).

Figure 8.2.
https://bradley.usd207.org/apps/pages/index.jsp?uREC_ID=300246&type=d&pREC_ID=693825

Case Study 3: LEGO Mindstorms in a high school robotics club

A robotics club has grown out of the introduction of LEGO Mindstorms kits in a secondary school in Paris. Students work together to design and program robots to perform various tasks, with an emphasis on collaboration and problem-solving. This club has not only stimulated interest in STEM professions but has also helped students to develop their technical skills and creativity (Freitas, E. J. D. R., Guimarães, M. P., Ramos, J. V., & Júnior, C. D. D. S. (2023, October).

Figure 8.3.
https://www.cmu.edu/roboticsacademy/roboticscurriculum/Lego%20Curriculum/

Our planning anticipates exciting and transformative developments and trends in educational robotics. The use of Artificial Intelligence (AI) in educational robots promises a more adaptable and personalized learning experience. Robots with AI can analyze individual learning habits, adjust information, and provide real-time feedback to meet the different needs of students.

In addition, the development of social robots for emotional connection with students opens up new possibilities for their use in education. Such robots can act as companions, providing emotional support and encouragement, which is particularly useful for children with different learning needs. The continuous miniaturization of robotic components enables the development of affordable and accessible educational robots that democratize the accessibility of technology-based learning experiences.

In summary, the development of robotics in education reflects a paradigm shift in our approach to learning. From the humble beginnings of LOGO turtles to the ingenious Ozobots, NAO robots, and LEGO Mindstorms robots, everything points to a future in which educational robotics will become a vital and transformative element in the learning process (Brechin, M. E. (2023). T).

8.4 ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN MATHEMATICS EDUCATION

The use of Artificial Intelligence (AI) and Machine Learning (ML) in education started a new era in pedagogy. AI – the ability of machines to mimic human intelligence – and ML – a sub-genre of AI that focuses on self-improvement through data analysis – offer unprecedented opportunities to improve mathematics teaching and learning. This introduction opens the door to the area where technology and mathematics meet, promising a new and personalized learning experience.

In education, AI and ML can be widely applied, including personalized learning methods and intelligent tutoring systems. The ability of these technologies to analyze large amounts of data, adapt to individual learning styles, and provide real-time feedback creates a dynamic and responsive learning environment.

In mathematics education, artificial intelligence and machine learning go beyond traditional teaching methods. Adaptive learning solutions such as DreamBox and Smart Sparrow use AI algorithms to tailor lessons to each student's unique strengths and weaknesses. These platforms continuously monitor student performance, change the difficulty of tasks, and provide targeted support to ensure optimal learning development (Pratama, M. P., Sampelolo, R., & Lura, H. (2023)).

Another worthy application is the use of AI-powered maths coaches. Virtual tutors such as Carnegie Learning's Mika interact with students in a conversational style, helping them to understand arithmetic concepts, identify difficulties, and provide individual explanations. This individual approach promotes student engagement and understanding, bridging gaps in understanding that may be overlooked in regular classrooms.

There are many benefits to be gained from using artificial intelligence in mathematics in education. One of the main benefits is personalization, which ensures that each student receives teaching tailored to his or her learning pace and interests. In addition, AI allows for rapid feedback, so students can correct mistakes and reinforce knowledge in real time.

But with awards come challenges. As AI systems collect and analyze huge amounts of data, there are ethical and privacy issues surrounding the use of student data. In addition, over-reliance on AI can undermine the role of teachers, so there is a need to ensure a balance between technology and human contact. These problems highlight the importance of the thoughtful implementation of AI and continuous assessment in mathematics education (Wang, X., Liu, C., Su, M., Li, F., & Dong, M. (2023)).

8.5 CASE STUDIES DEMOSTRETING EFECTIVE USE IN REAL CLASSROOMS

Case Study 1: DreamBox Learning in Primary Mathematics

"DreamBox Learning, an artificial intelligence-driven adaptive learning platform, has achieved great results in primary schools across Europe. Pupils participate in personalised maths lessons and the platform's algorithms continuously adjust the level of difficulty. Schools report that children's understanding of maths has improved dramatically, as have their standardized test scores (Foster, M. E. (2023)).

Case Study 2: Carnegie Learning in Mika High School Algebra

"Carnegie Learning's AI tutor Mika was involved in an algebra lesson in a Slovak high school." Mika provides real-time guidance, adapts to students' learning styles, and solves specific problems. The school has seen an increase in student confidence and a narrowing of the achievement gap, especially between students with different levels of maths ability (Shi, W., Nie, Z., & Shi, Y. (2023, October)).

*Tips & Tricks: How to make the most of artificial intelligence in maths education (*Wardat, Y., Tashtoush, M. A., AlAli, R., & Jarrah, A. M. (2023)).

1. **Professional development:** train teachers on how to successfully integrate AI tools into the curriculum. Professional development programs help teachers maximize the potential of AI to improve mathematics teaching.
2. **Regular monitoring:** assess the impact of AI programs on student learning outcomes. Use data analytics to refine and optimize AI algorithms, ensuring they meet educational goals and respond to changing student needs.
3. **Ethical:** Protect student data, address privacy issues, and communicate openly with students, parents, and teachers about the role and limitations of AI in maths education.

Research into artificial intelligence and machine learning in mathematics education is paving the way for more personalized, adaptive, and successful learning. The integration of these tools in the classroom shows that the future of mathematics education lies not only in textbooks but also in the dynamic interaction between human experience and artificial intelligence.

8.6 INTEGRATION OF AUGMENTED AND VIRTUAL REALITY

Exploring augmented and virtual reality in education can lead to areas where the real and digital worlds are inseparable. AR overlays digital information on top of the real world to enhance human perception, while VR immerses users in a virtual environment, removing them from the physical world. These technologies, which were previously reserved for games and entertainment, now have the potential to transform education.

With devices such as smartphones or AR glasses, AR information such as 3D models, and text or video overlays images of the real world. VR, on the other hand, immerses users in a completely virtual environment using a headset, providing a truly immersive experience. Understanding these technologies provides a framework for exploring their transformative potential in an educational context.

The use of augmented and virtual reality in educational contexts has become increasingly popular, as educators find that they can help create dynamic and engaging learning experiences. AR enhances traditional learning materials by adding interactive components. For example, AR apps can turn static textbooks into multimedia-rich experiences where students can explore 3D models, movies, and other information by simply pointing the device's camera at a page (Mendoza-Ramírez, C. E., Tudon-Martinez, J. C., Félix-Herrán, L. C., Lozoya-Santos, J. D. J., & Vargas-Martínez, A. (2023).

Virtual reality allows students to be transported to historical events, distant planets, and microscopic universes. Educational VR apps provide an immersive, hands-on approach to learning, allowing students to interact with subjects previously covered only in textbooks. Google Expeditions, for example, offers virtual field trips that take students to different parts of the world without leaving the classroom.

The use of AR and VR in education has led to more effective learning experiences that go beyond traditional methods. In anatomy lectures, students can use AR applications to dissect virtual creatures layer by layer to better understand biological structures. Virtual reality, which can simulate real-life situations, offers a unique opportunity for hands-on and experiential learning.

And these immersive technologies can be adapted to different learning styles. Visual learners benefit from the vivid and interactive aspects of AR, while kinaesthetic learners prefer VR environments where they can actively engage with the content. By turning abstract concepts into concrete experiences, these technologies encourage engagement, which improves memorization and comprehension (Trieu, A. (2023).

The future potential of AR and VR in education is enormous, opening up huge opportunities for innovation and pedagogical development. As technology advances, AR and VR applications are expected to become increasingly sophisticated and provide more realistic and immersive educational experiences. In the future, accessibility issues will need to be addressed to ensure that these technologies are accessible to all students, regardless of their socioeconomic status.

One possible approach is to incorporate AR and VR in collaborative learning environments. Virtual classrooms that transcend geographical boundaries and allow students to engage in a shared virtual space have the potential to change the perception of education. However, exploring these possibilities must prioritize ethical issues, with an emphasis on student privacy, content appropriateness, and the responsible use of immersive technologies.

The inclusion of augmented and virtual reality in education is not only a technological movement but also a fundamental change. As we travel across the immersive horizon, it becomes clear that these technologies have the potential to democratize access to rich learning experiences while transcending traditional boundaries. In an ever-changing educational landscape, AR and VR are powerful technologies that are transforming the way we perceive the world, interact with it, and ultimately learn about it.

8.7 PREPARING STUDENTS FOR A TECHNOLOGICALLY ADVANCED FUTURE

In the twenty-first century, technical literacy is more than a skill – it is an absolute necessity to cope with the complexities of the modern world. As technology advances at an unprecedented pace, the ability to understand, adapt, and apply technical advances becomes crucial. Digital literacy learners are better equipped to participate effectively in society, enter the labor market, and contribute to innovation. Technological literacy is not just a skill – it is the key to opening up opportunities in an increasingly digital world.

Integrating technology into the curriculum is a comprehensive approach that goes beyond the use of devices in the classroom. It means creating an atmosphere in which technology becomes an essential component of the learning process and is easily integrated into the education system. One effective approach is to link technology to educational objectives so that it enhances rather than detracts from learning outcomes.

Project-based learning combined with technology gives students real problem-solving skills. Platforms such as Scratch and TinkerCAD allow students to use programming and design principles practically and creatively. In addition, online collaboration tools improve communication and teamwork, preparing students for the collaborative environments they will encounter in the workplace.

Technological literacy is about developing critical thinking and problem-solving skills. In addition to acquiring technical knowledge, students need to be able to critically analyse information, evaluate the reliability of sources and solve complex problems. The inclusion of coding challenges, robotics projects, and simulation activities encourages experimental thinking and resilience to challenges(Suwono, H., Rofi'Ah, N. L., Saefi, M., & Fachrunnisa, R. (2023).

By encouraging students to solve real-world problems using technology, we encourage them to be purposeful and creative. Platforms such as Code.org's Hour of Code and educational robotics competitions allow students to apply their technological skills to real-world challenges, giving them a sense of achievement and confidence.

Collaboration between educators and technologists is essential for the successful integration of technology in education. Educators have pedagogical expertise and knowledge of students' learning needs, while technologists provide technical insights and knowledge of new trends. By fostering open communication and collaboration, a symbiotic relationship is formed to ensure that technology effectively supports educational goals.

Professional development programs that promote collaboration between educators and technologists are essential. Seminars, webinars, and joint projects allow educators to improve their technological skills and technologists to learn about the educational environment. This collaborative approach not only bridges the gap between theory and practice but also ensures that technology implementation is in line with educational objectives.

At the crossroads of education and technology, preparing students for a technologically advanced future is crucial. Technological literacy is both a tool and a transformative force, enabling students to become creators, innovators, and critical thinkers. Educators are preparing for a future in which children are not.

Like all technologies, teaching methods, and techniques, these educational technologies have their advantages and disadvantages (Chan, C. K. Y. (2023).

Table 8.1. AR, VR, and AI comparison. Advantages and disadvantages (Chan, C. K. Y. (2023)).

Aspect	Augmented reality (AR)	Virtual Reality (VR)	Artificial Intelligence (AI)
Benefits			
Enhanced learning	An interactive and engaging experience.	Realistic simulations are created for hands-on learning.	tailor learning experiences based on data.

Visualization	Digital information is transferred to the real world.	puts users in a virtual environment.	Visualizes complex concepts through data analysis.
Engagement	Captures students' attention through interactivity.	Increases engagement in immersive experiences.	Promotes engagement through adaptive learning.
Experiential learning	Facilitates real-world exploration and experience.	simulate real-world scenarios to learn from experience.	Offers practical applications through simulation.
Personalization	"Tailor information is based on the context of the user.	adapts content to individual learning styles.	tailored learning pathways for each pupil.
Global cooperation	connects students across geographical borders.	Facilitates virtual collaboration in a collaborative environment.	Enabling collaborative projects with the help of artificial intelligence.
Disadvantages			
Availability	Optimal use requires compatible devices.	Widespread application may be too costly.	Availability depends on the internet and device access.
Technical requirements	Based on devices with cameras and sensors.	VR headsets and powerful computing resources are required.	A reliable technical infrastructure is needed.
Learning curve	Teachers and pupils may need time to adjust.	To be used effectively in education, training is needed.	Initial challenges to understanding and implementation.
Insulation	This can lead to feelings of isolation in the real world.	Limits physical interaction with the real environment.	This can reduce the direct interaction between teacher and student.

Content creation	Creating AR content can be time-consuming.	Special skills are needed to create VR content.	Developing content based on artificial intelligence can require advanced skills.
Ethical issues	Privacy issues related to real-world augmentation.	Possible psychological effects, especially for young users.	Ethical aspects of data privacy and bias.

It is up to the teacher to decide which of the technologies can be used in his/her classroom, and how much resources and knowledge he/she needs to use and teach students to avoid causing more harm.

8.8 CONCLUSIONS

In the previous chapters, we began to explore the ever-changing field of learning technologies. From the evolution of robotics to the incorporation of artificial intelligence and machine learning into mathematics education, from the immersive possibilities offered by augmented and virtual reality to the need to prepare students for a technologically advanced future, each chapter has highlighted a different aspect of the transformative potential of technology in education.

We have witnessed educational robotics evolve from humble beginnings to interactive companions that influence students' learning experiences. Artificial intelligence and machine learning have become useful methods to tailor maths teaching to individual needs. Augmented and virtual reality have become gateways to immersive learning, bridging the physical and digital worlds. The call to prepare students for a technologically sophisticated future has highlighted the need for technological literacy, critical thinking, and teamwork as essential skills for future leaders (Atman Uslu, N., Yavuz, G. Ö., & Kocak Usluel, Y. (2023)).

In concluding this study, it is important to underline the importance of keeping pace with technological progress. The high pace of invention requires constant learning and adaptability. Technology is not a static object, but rather a dynamic force that changes our environment. Educators who keep abreast of technological change are better able to guide their students in an ever-changing world and educate them not only about today's problems but also about tomorrow's uncertainty.

The way forward requires teachers to embrace and adapt to new technologies. The combination of pedagogy and technology creates a synergy that encourages creativity, critical thinking, and collaboration. Teachers are not only transmitters of knowledge but also the architects of the future, shaping the brains of the next generation. The road to educational technology is not without obstacles, but the benefits are endless: a generation of students ready to face the complex demands of a technologically advanced world.

Finally, I would like to call for action. Embrace the revolutionary potential of technology in education. Embrace the challenges, the chances, and the opportunities that will help build a future where innovation, collaboration, and lifelong learning are at the heart of education. The journey doesn't end here, it continues as we chart a path to a future where education and technology merge to inspire, empower, and reinvent learning.

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CHAPTER 9. PROFESSIONAL DEVELOPMENT FOR EDUCATORS

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9.1 THE CONCEPT OF PROFESSIONAL DEVELOPMENT

Teacher professional development is an essential part of continued growth and flexibility in the fast-changing world of education. This section provides a brief overview of the key role that continuous learning plays in improving teaching effectiveness.

Professional development is not just a series of seminars or courses; it is a dynamic and continuous process that allows teachers to develop their skills, and keep up with new pedagogical developments, (Fairman et al., 2023). and meet the diverse demands of today's learners. In a rapidly changing educational environment, teachers need to have the knowledge and tools to tackle new challenges, apply creative teaching methods, and have a positive impact on student achievement.

Education is not a static field; it adapts to changes in society, technological advances, and new developments in education. Continuous professional development ensures that teachers keep up with these changes and can adapt their teaching practices to meet the changing demands of students. It is a proactive approach that allows teachers to embrace change and incorporate the latest research and best practices into their teaching methods (Iroda, 2023).

Professional development is all about the ability to improve teaching effectiveness. Continuous learning provides educators with useful insights into effective teaching methods, student engagement initiatives, and personalized learning approaches. This, in turn, helps to create dynamic, adaptable classrooms that promote student achievement.

In today's schools, pupils come from different backgrounds and have different learning styles. Continuous professional development gives educators the tools they need to respond to this diversity. By understanding the individual needs of each pupil, teachers can adapt their approach and create an inclusive learning environment that maximizes the potential of each pupil (Idrizi et al., 2023).

Finally, this chapter provides a basis for further research on teacher professional development. It highlights the importance of continuous learning in the context of the dynamics of education and sees professional development as an essential component of improving teaching effectiveness. As we delve deeper into the following chapters, we will discover the many facets of education, collaboration, and technology integration that contribute to the holistic development of twenty-first-century educators (Kilag et al., 2023).

9.2 TRADITIONAL TRAINING PROGRAMMES

Traditional professional development programs for a wide range of professions, including education, often take a variety of forms to suit different learning styles and practical constraints (Smith, 2023). Here is a brief overview of some of the traditional training approaches:

1. **Personal seminars and workshops** (Sharofutdinov, 2023)**:**
   - *Description: This is face-to-face training that takes place in a physical environment, such as conference rooms, training centers or other dedicated venues.*
   - *Benefits: direct interaction between trainers and participants, immediate feedback, networking opportunities, and hands-on activities.*
   - *Challenges: timing, location, likely travel, and venue charges.*
2. **University professional development courses** (Avidov-Ungar, 2023)
   - *Description: Universities often offer courses and seminars as part of their professional development programs. They can be part of a degree program or stand-alone courses.*
   - *Advantages: access to academic material, competent teachers, and an organized program. Participants can earn academic credits or certificates.*
   - *Challenges: this may involve prior requirements or admission restrictions, and the timetable can be difficult for working professionals.*
3. **Integrating curricula into teacher training programs** (Graziano et al., 2023):
   - *Description: Teacher training programs can include professional development modules or courses to support lifelong learning and skills development.*

- *Advantages: seamless integration into the larger school system, relevance to educational standards, and emphasis on practical classroom application.*
- *The challenges are to ensure that the integrated information is relevant and up-to-date and to manage possible time constraints within the existing curriculum.*

4. **Online and distance learning opportunities** (Sofi-Karim et al., 2023):
   - *Description: Webinars, virtual classrooms, self-paced courses, and other digital resources are just a few examples of the online platforms used to deliver learning programs.*
   - *Advantages: cost-effectiveness, access to a wide range of resources, flexibility in time and location, and asynchronous learning.*
   - *Opportunities and challenges include dependence on technology, less engagement than in person, and the self-discipline required in self-study courses.*

It is important to bear in mind that the environment, the type of content, and the preferences of the participants can influence the effectiveness of a particular approach. Many modern professional development programs incorporate aspects of these traditional approaches to create a more comprehensive and adaptable development process (Dahri et al., 2023).

Professional development opportunities can be found on many websites in many categories. Below are recommendations for each category of conventional learning:

1. **Face-to-face seminars and workshops** (**online alternatives**) (Garcia Sierra et al., 2023):
   - **LinkedIn Learning:** offers a range of courses in technology, business, and creative skills. Courses include webinars and workshops.
   - **Udemy:** This platform offers interactive learning by offering live online courses in addition to video-on-demand courses.
2. **University professional development courses** (**online**) (Lin et al., 2023):
   - **edX:** provides online courses from global universities on a wide range of topics, including professional development in technology, business, and education.
   - **Coursera:** Coursera offers online courses, specializations, and degrees in a wide range of fields,

including professional development, in partnership with universities and organizations.

3. **Integrating curricula into teacher training programs (online)** (Salmi et a., 2023):
   - **National Centre for Teacher Education (NCTE):** offers online resources for educators wishing to develop their skills in areas such as classroom management, curriculum development, and assessment methods.
   - **Teach Away:** provides online teacher development courses focusing on teaching English as a second language and international education.
4. **Online and distance learning opportunities** (Baxter et al., 2023):
   - **Skillshare:** offers online lessons, workshops, and projects as a tool for teaching creative and business skills.
   - **Khan Academy: the** Khan Academy provides free online lessons and courses on a variety of topics.

Table 9.1. Proposed online training platforms in several categories of traditional training (Cao et al., 2023)

Training category	Online platforms	Main functions
In-person seminars and workshops (online alternatives)	"LinkedIn Learning; Udemy	Online courses and seminars; interactive learning opportunities; a wide range of subjects and skills
University professional development courses (online)	"edX"; "Coursera	Courses offered by international universities; degrees and specializations offered; various subjects
Integration into teacher training programs (online)	National Centre for Teacher Education (NCTE; Teach Away)	Online tools for teachers; emphasis on classroom management, curriculum, and assessment.
Online and distance learning opportunities	"Skillshare"; "Khan Academy	Skills related to creativity and entrepreneurship; free courses offered; K-12 school and wider subjects

Although this table provides a summary, it is very important to examine each platform individually to make sure that it meets your unique requirements and preferences. Consider user feedback, learning format, training materials, and any associated fees when making your choice (Chen et al., 2023).

Before joining this platform, it is essential to read the reviews, review the course materials, and think about your unique learning goals, as the effectiveness of these platforms varies. If you have professional development needs, it is a good idea to contact universities and other educational institutions directly as many of them offer their online learning platforms.

9.3 WEBINARS AND VIRTUAL CONFERENCES

Technology integration has become an important catalyst for teachers' professional development in a rapidly changing educational environment. This chapter explores the digital world, focusing on key components such as webinars, virtual conferences, online courses, certification, and access to educational resources (Kingston, 2023). Understanding the benefits and challenges of these technological tools is essential for educators embarking on a continuous learning journey to make full use of them and to create creative and productive learning environments.

Webinars: webinars, which are the mainstay of professional development, provide educators with a dynamic and participative virtual learning environment (Khosla et al., 2023). Teachers can participate at their convenience thanks to flexible scheduling. Few opportunities for networking and face-to-face interaction. Workshops led by experts cover a wide range of topics, providing a variety of learning opportunities. Technical problems such as platform compatibility issues or connectivity problems may occur. Cost-effectiveness: Unlike traditional workshops, there is no need to consider travel costs. Self-monitoring is required as individuals need to continue to participate even in the absence of their collaborators.

For example, Maria, a secondary school English teacher, often participates in webinars run by well-known literacy experts. She appreciates the fact that she can connect with educators from all over the world and interact with the subject at her own pace. Recommended webinar solutions include Zoom, Microsoft Teams, or Google Meet. Websites such as EdWeb offer a wide range of webinars for educators on a variety of educational topics (Anggraeni et al., 2023).

Virtual conferences. The webinar experience is enhanced by virtual conferences, which provide a comprehensive platform for communication and collaboration. Advantages Challenges Global reach, allows educators to connect with colleagues and professionals from anywhere in the world. Possible feelings of loneliness are caused by physical proximity and lack of casual dialogue. Technical difficulties, such as the requirement for a reliable internet connection and experience with conferencing software (Lampadan et al., 2023). Savings due to reduced travel costs. Difficulties in imitating the enthusiasm and participation of face-to-face conferences.

For example, James, a science teacher, took part in a panel session at a recent virtual conference on integrating virtual reality into science education. This meeting expanded his professional network and introduced him to innovative teaching methods. Tools to consider: Hopin, Airmeet, or Virtual U are recommended for virtual conferences. Among the conference sites that often organize virtual events are ASCD and ISTE (Torres, 2023).

Online classes. Teachers can improve their knowledge and skills by taking online courses. Advantages Difficulties A Flexible timetable allows teachers to combine professional development with teaching duties. Self-monitoring requirement and a natural inclination to complete the course independently. A wide choice of courses covering a variety of topics and pedagogies. The ability to learn from anywhere, removing geographical barriers to learning for teachers. Lack of real-time communication with lecturers and fellow students.

For example, Sarah, a maths teacher, signed up for an online course on creative teaching methods. The course provided her with useful tools and resources that she could use immediately in her classroom. Recommended tools: Coursera, edX, or Khan Academy, which can be used for a variety of online courses, are recommended (Lan et al., 2024). Platforms for educators who want to design and develop their courses, such as Moodle or Teachable.

Certificates. It gives teachers concrete recognition and confirms their competence and commitment to continuous professional development. Benefits Barriers demonstrate commitment to lifelong learning and professional development.

Possible financial costs associated with certification courses. Increases competitiveness and reputation in the labor market. Ensures relevance and recognition of certification by educational institutions or employers (Martín Gómez et al., 2023). Offers a methodical approach to learning and skills development. Ensures a balance between training commitments and the time required for certification.

For example, Michael, a primary school teacher, was working towards a qualification in inclusive education. The qualification allowed him to expand his knowledge and take the lead in creating inclusive learning environments. The National Board for Professional Teaching Standards (NBPTS) is the recommended source for nationally recognized certificates (Goodwyn, 2024). Platforms where vendor-specific certifications can be obtained, such as Microsoft Educator Center or Google for Education.

Table 9.2. Benefits and challenges of distance learning for professionals: a comparative chart (Sofi-Karim et al., 2023)

Aspects	Webinars/virtual conferences	Online courses/certificates
Benefits		
Planning flexibility	• Flexible timing.	• Teachers can learn at their own pace.
Various learning opportunities	• Offers expert-led sessions on a range of topics.	• A wide range of topics and methodologies are covered.
Cost-effectiveness	• Travel costs are waived.	• Reduces the need for physical exercise.
Global reach	• Connecting educators around the world.	• Access from anywhere in the world.
Networking opportunities	• Facilitates communication with colleagues and experts.	• Allows you to collaborate with the online community.
Challenges		
Limited face-to-face communication	• Informal personal discussions may be lacking.	• Lack of real-time interaction with peers.
Technical issues	• Possible connectivity problems.	• Concerns about the quality of content in online courses.

The need for self-discipline	• Requires participants to continue activities independently.	• requires intrinsic motivation to complete the course.
The possible feeling of isolation	• Participants may feel isolated.	• Lack of social interaction with teachers and peers.
Platform compatibility	• Compatibility issues may arise.	• Ensuring that certificates are up-to-date and recognised.

A well-stocked resource library is essential for effective teaching. This section will highlight the importance of digital platforms for sharing and accessing educational resources. It will look at different online repositories and how educators can use them to improve the quality of their lesson plans. To ensure that teachers can easily incorporate technology into their teaching practice, it will suggest useful ways of collecting, evaluating, and integrating these digital materials into their daily lesson planning (Chan, 2023).

Teachers need to take advantage of the digital professional development resources available to them as technology continues to transform the educational landscape. Webinars, virtual conferences, online courses, certification, and access to educational resources are an essential part of this digital shift. Teachers can make better use of technology to improve their teaching when they are aware of the advantages and disadvantages of these resources (Zahra et al., 2023). The integration of traditional and technical approaches will enable educators to successfully educate students in an ever-changing world as we move into the digital frontier of education.

9.4 THE IMPORTANCE OF A WELL-EQUIPPED RESOURCE LIBRARY

Effective teaching requires access to a well-stocked library and its materials. In the digital age, the value of carefully selected teaching resources and online learning environments cannot be overemphasized. This chapter explores the importance of a well-stocked library of resources, discusses online platforms that facilitate sharing and access to educational content, and suggests feasible tactics for incorporating these resources into regular lesson planning (Aithal et al., 2023). By understanding the mutually beneficial relationship between teachers and the tools at their disposal, we can unlock the potential for a more vibrant and stimulating educational environment.

Collecting a live range. A well-stocked resource library is a dynamic collection that evolves to reflect the ever-changing educational environment, not just a warehouse of books and materials (Ryan, 2023). This section will discuss the importance of collecting a wide range of resources – digital materials, manipulatives, multimedia tools, and textbooks – to meet the different requirements and learning preferences of students. Case studies will reveal situations where well-chosen resource libraries have improved teaching and student engagement.

Supporting differentiated teaching. Differentiated instruction is made possible through a resource library that allows teachers to modify lesson plans to meet the unique needs of their students. This section of the chapter will explore how a well-resourced resource library supports teachers in using a variety of instructional tactics and adapting lessons to meet the needs of students with different learning styles, abilities, and paces (Anggraeny et al., 2023).

Encouraging development in the workplace. As well as helping children to learn, the Resource Library has a significant impact on teachers' professional development (Waaland, 2023). This section will explore how teachers can keep abreast of cutting-edge teaching methods, evolving technologies, and new pedagogical approaches by having access to an extensive library of teaching materials. Examples will be given of how resource libraries have helped educators to develop professionally.

9.5 ONLINE PLATFORMS FOR SHARING AND ACCESSING TRAINING MATERIALS

Collaboration platforms. The digital age has given rise to several collaborative platforms that allow educators to share and use teaching content (Dehbi et al., 2023). This section will discuss the benefits of collaborative platforms, focusing on how they help trainers feel more connected to each other. Scenarios, where teachers have effectively collaborated using online platforms to improve their teaching resources, will be highlighted through real-life examples.

Open Educational Resources (**OER**). Open Educational Resources (OER) have given educators access to a wide range of freely available resources and democratized access to educational content. This section of the chapter will discuss the benefits of Open Educational Resources (OER), as well as features such as scalability and cost-effectiveness for quality assurance. Using examples, we will show how teachers can incorporate OER into their resource libraries to provide access to a wider range of high-quality materials.

Professional Learning Networks (**PLN**). Online platforms are essential for the development of professional learning networks where teachers can collaborate and exchange materials. This section will discuss the advantages of joining Professional Learning Networks (PLNs), including the ability to connect with educators around the world and share creative teaching ideas. Case studies and testimonials will show how lecturers have improved their teaching materials through the use of PLN.

Table 9.3: Examples of real platforms for sharing and accessing training material (Kaddoura et al., 2023)

Platform type	Example of a platform	Description
Collaboration platforms	"Google Drive	With Google Drive, teachers can create, share, and collaborate on documents, spreadsheets, and presentations. Sharing resources encourages teachers to collaborate in real-time.
Collaboration platforms	"Microsoft Teams	Teachers can work together to create lesson plans, hold virtual meetings, and share files in a common workspace created in Microsoft Teams. It's easy to integrate with Microsoft Office applications.
Open Educational Resources (**OER**)	Khan Academy	"Khan Academy offers a wide range of excellent free educational resources covering a variety of areas. Teachers can use teaching materials, films, and practical sessions to enhance their courses.
Open Educational Resources (**OER**)	OER Commons	The digital library of freely licensed educational material is called OER Commons. On this platform, teachers can find, share, and work together on a wide range of resources.

Professional Learning Networks (PLN)	"Twitter"	Educators can use hashtags such as #EdChat to connect on Twitter. Educators exchange materials, discuss, and engage in dialogues to improve their pedagogical approaches.
Professional Learning Networks (PLN)	Edmodo	The Edmodo social learning platform makes it easier for teachers to communicate and share resources. It allows teachers to work together and exchange lesson plans with other teachers in the neighborhood.
Learning Management Systems (LMS)	Canvas	The course material is created and managed by the LMS Canvas. Lecturers can facilitate an organized and productive learning environment by sharing materials, assignments, and assessments with students.
Learning Management Systems (LMS)	"Moodle"	Teachers can create online courses using Moodle, an open-source learning management system. It includes discussion forums, resource sharing, and teamwork tools that increase the effectiveness of online learning.
Content curation platforms	Wakelet	"Wakelet is an information curation platform that allows educators to collect and distribute resources. It is a flexible resource-sharing platform that allows the creation of collections containing text, links, images, and videos.
Content curation platforms	Coaster	Teachers can collect and share any content on the Padlet virtual bulletin board. It encourages participation and collaboration by allowing teachers and students to add to the board.

These are just some of the different platforms that trainers can experiment with according to their requirements and interests.

9.6 STRATEGIES FOR INTEGRATING RESOURCES INTO DAILY LESSON PLANNING

To create an engaging and successful learning experience in a dynamic educational environment, a variety of materials need to be seamlessly integrated into daily lesson planning. This chapter discusses tactical approaches that enable teachers to incorporate a well-stocked resource library into their lesson preparation. These tactical approaches, which range from the use of technology to integrate resources to the use of multimodal materials, aim to provide educators with the knowledge and resources they need to improve their teaching. By exploring the art of resource integration, we can create dynamic and enriching lessons that meet the diverse demands of 21st-century learners.

Needs assessment and coordination. Alignment with curriculum objectives and needs assessment are the first steps in effective resource mobilization. This section of the chapter will provide teachers with useful tactics for identifying students' needs and aligning available resources with learning objectives. Examples will be given of where strategic alignment of resources has led to improved learning outcomes.

Using technology to integrate resources. Technology provides tools that facilitate the integration of resources into lesson plans (Aldila et al., 2023). This section will discuss digital tools and platforms that facilitate the organization, sharing, and integration of resources. It will provide useful tips and recommendations on how to use resources such as content curation platforms, learning management systems, and shared documents.

Embedding multimodal resources. A variety of educational resources to help promote engagement and understanding. This section of the chapter will look at ways of integrating text, pictures, videos, and interactive elements – all multimodal resources – into lesson plans. Case studies will show how educators effectively integrate multimodal resources to make lessons dynamic and engaging.

Continuous reflection and improvement. The process of lesson planning is iterative and continuous reflection is essential for improvement. This section will highlight the importance of reflection in improving and optimizing the use of resources. We will look at ways to get input from students and modify the use of resources according to the objectives of the activity.

The value of a well-stocked resource library and an online learning environment for effective teaching cannot be overstated. This chapter explores the various functions of resource libraries, from promoting professional development to supporting differentiated learning. It also explores the potential of online platforms for sharing and accessing learning materials, showing how PLNs, OERs, and collaborative platforms contribute to a thriving educational ecosystem. In addition to practical insights to help educators create rich and dynamic learning experiences, strategies for seamlessly integrating these resources into everyday lesson planning are provided. As we move into the digital world, the interaction between educators and resource libraries is becoming increasingly important to foster an atmosphere conducive to both teaching and learning.

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CHAPTER 10.
CONCLUSION AND FUTURE DIRECTIONS

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10.1 REFLECTING ON THE IMPACT OF ROBOTICS IN MATH EDUCATION

The deep integration of robotics into mathematics education has the potential to leave a lasting mark on pedagogy, ushering in a new era in schooling, characterized by dynamic and engaging learning experiences (Kivunja, 2014; Holbrook, 2019). It is critical to fully understand how robotics not only complements, but fundamentally redefines the educational paradigm. Traditional barriers associated with abstract mathematical concepts are disappearing, thus instilling a true passion for learning among students (Alamri et al., 2021; Michaelsen, 2020).

10.1.1 TANGIBLE LEARNING EXPERIENCES

Robotics' key contribution to mathematics education lies in its ability to provide hands-on learning experiences, effectively bridging the gap between theoretical concepts and practical applications (Benitti, 2012; Ke, 2014). Through interactive engagement, students change from passive observers to active participants, manipulating robots to apply mathematical principles to real-world scenarios. This paradigm shift not only deepens understanding, but also stimulates curiosity and provokes the exploration of new horizons (Bernard & Mazur, 2009). Tangible experiences transform abstract ideas into concrete reality, creating a stronger connection between students and the object being studied (Clark, 2018).

Moreover, the tangible nature of these experiences reinforces the deep bond between students and the field of mathematics, making the laws and formulas learned more memorable and easier to apply (Jonassen et al., 1999). Students develop a deep sense of confidence and pride as they control robots to solve complex math problems. In this way, they cultivate a positive and empowering approach to mathematics (Krajcik & Blumenfeld, 2006).

10.1.2 ENGAGEMENT

Robotics is proving to be a powerful tool for promoting inclusion and engagement, taking into account a variety of learning styles and skills (Bonk & Graham, 2005). The interactive and visual nature of robotics is of interest to students who may have felt disconnected from the traditional way of teaching mathematics, which effectively democratizes education (National Research Council, 2007). Robotics goes beyond adapting learning styles. It takes into account diverse cultural and socioeconomic backgrounds, creating an educational tool that is accessible and equitable at the same time (Clark, 2018).

Collaborating on robotics projects not only fosters teamwork and communication, but also the necessary mathematical skills. As a result, it extends to various aspects of life (Benitti, 2012). The inclusion and engagement that robotics provides contributes not only to academic success but also to the sustainable development of successful individuals in various fields of professional activity (Ke, 2014).

10.1.3 FOSTERING 21ST CENTURY SKILLS

Outside of mathematics, operating robots equips students with skills necessary for the 21st century, such as problem-solving, critical thinking, and collaboration (S. Michaelsen, 2020). As students overcome the difficulties of robotics activities, they not only master mathematical concepts, but also hone the skills with which they will be able to face future challenges (Bonk & Graham, 2005). The design and use of robots is becoming an activity in which students are shaping themselves into flexible and versatile individuals, ready to face the challenges of the future (World Economic Forum, 2020).

Developing 21st-century skills with robotics goes beyond traditional educational boundaries. Students involved in robotics projects learn to think critically and analytically, approaching problems in a creative and innovative way (Duckworth, 2007). The collaborative nature of robotics projects reflects teamwork and interdisciplinary collaboration, effectively preparing students for careers that require a high degree of adaptability (Seligman, 2011).

10.2 THE ROAD AHEAD: CONTINUOUS IMPROVEMENT AND INNOVATION

Given the progress that is being made with the incorporation of robotics into mathematics education, it becomes evident that the journey ahead is not final, but rather it is a never-ending path of continuous improvement and innovation (Kivunja, 2014; Holbrook, 2019). To ensure that robotics remains a dynamic force for positive change, educators must wholeheartedly commit to adapting and evolving to the ever-changing educational reality.

10.2.1 CONTINUOUS IMPROVEMENT IN TEACHING PRACTICES

The pursuit of continuous improvement begins with a thorough examination of teaching practices, recognizing that effective education is a continuous journey marked by continuous improvement (Bonk & Graham, 2005). Teachers should actively support this improvement by seeking feedback on the quality of their classes not only from students but also from their peers (Kivunja, 2014). Professional development opportunities play a key role in this improvement process, enabling teachers to be exposed to the latest pedagogical trends and innovative teaching methodologies (Alamri et al., 2021).

10.2.2 HARNESSING EMERGING TECHNOLOGIES

Innovation underpins effective education, and the incorporation of robotics into mathematics education provides a strategic opportunity to harness new technologies (Alamri et al., 2021). Artificial intelligence, machine learning, augmented reality, and virtual reality are proving to be powerful tools with great potential to change the future of robotics in mathematics education (Michaelsen, 2020). These state-of-the-art technologies offer personalized learning experiences tailored to individual needs and learning styles, thus revolutionizing the image of modern education (Michaelsen, 2020).

10.2.3 COLLABORATIVE PLATFORMS AND NETWORKING

Effective use of available tools requires collaboration and knowledge sharing (Duckworth, 2007). Learning communities prove to be valuable platforms for exchanging ideas, sharing best practices, and tackling challenges together (Kivunja, 2014). Networking with professionals in technology, robotics, and education is becoming an integral part of fostering a collaborative culture, thereby driving the pace of innovation (Michaelsen, 2020).

As the idea of using robots in education evolves, the spirit of collaboration is taking over as a guiding force. Educators, technologists, and innovators are collectively creating a future in which the seamless integration of robotics and mathematics education becomes the norm, surpassing individual efforts to shape a collective vision of transformative learning experiences (Duckworth, 2007).

10.3 ENCOURAGING LIFELONG LEARNING IN STUDENTS

The true success of robotics in mathematics education can be measured by its ability to instill in students a love of learning, which will have a lasting impact on their educational path (Holbrook, 2019).

10.3.1 NURTURING CURIOSITY AND EXPLORATION

Educators will design a learning journey that transcends conventional boundaries, actively sparking curiosity through challenges that require innovative and creative solutions (Bonk & Graham, 2005). Robotics is emerging as a transformative force that will transform education from a mere transmission of information to an exciting exploration of limitless possibilities (Kivunja, 2014). By encouraging students to delve into the unknown, teachers will ignite a sense of fascination that will extend far beyond textbooks and standard curricula, shaping students into enthusiastic learners who are lifelong learners (Duckworth, 2007).

10.3.2 BUILDING RESILIENCE AND ADAPTABILITY

The challenges posed by robotic classes will significantly contribute to the development of adaptability among students (Seligman, 2011). By engaging in robotics, students will learn that failure is not an obstacle, but a stepping stone to ultimate success. They will also gain valuable life skills (Duckworth, 2007). These coping lessons will go far beyond the immediate context of the classroom, preparing students to grapple with the uncertainty of their future endeavors. They will learn self-confidence, determination, and a positive attitude to solving real-world problems (Seligman, 2011).

10.3.3 CULTIVATING A COMMUNITY OF LEARNERS

Encouraging lifelong learning goes beyond individual efforts to cultivate a thriving community of learners (Kivunja, 2014). In this collaborative environment, students will seamlessly become integral members of a community where knowledge is a dynamic force, constantly evolving through collective efforts (Bonk & Graham, 2005). Peer-to-peer learning initiatives and mentoring programs will further strengthen a culture of continuous learning, where experiences are shared and collaborative problem-solving becomes the norm (Seligman, 2011).

By initiating the building of a community of learners, educators will not only develop intellectual curiosity but also create an environment where shared experiences fuel the joy of learning and exploration, setting the stage for a lifelong commitment to knowledge and development (Kivunja, 2014).

As a result, it is important to note that it is becoming evident that the inclusion of robotics in mathematics education means more than just technological improvement. This marks a profound paradigm shift that will shape the future of education. Robotics is emerging not only as a tool, but also as a transformative force, arming future generations with the necessary skills needed to adapt and thrive in a knowledge-driven society (Michaelsen, 2020).

As we continue this journey into the field of robotics in mathematics education, it becomes necessary to fully embrace the numerous challenges and opportunities that appear on the horizon of education. The Way Forward sets out the principles of continuous improvement, continuous innovation, and an unwavering commitment to nurturing individuals as lifelong learners (Bonk & Graham, 2005). It is a journey in which teachers, students and stakeholders will walk hand in hand, united by a collective vision of a future in which education crosses borders of the classroom to become a journey marked by continuous discovery, growth and intellectual fulfilment.

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