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Pregledni članak
Review article

Teaching robotics in primary school as a means of promoting diversity and maintaining children's mental health

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Abstract

The article discusses the importance of learning and teaching automation and robotics for the development of children and adolescents and criticises the generalised understanding of the importance of this field only in the context of teaching programming, the needs of society or in the context of talent selection. The multidisciplinary nature of this field is emphasised as a basis for promoting student diversity. In this sense, the developmental limits and possibilities of primary school students are presented, as well as possible learning and teaching approaches and motivating and demotivating elements of such approaches. Integrated teaching is highlighted as a solution that offers different "brains" the opportunity to discover their own preferences and realise themselves. In this way, the "clash of differences" encourages collaboration, develops communication skills and leads to acceptance of diversity. The paper concludes that inclusive robotics education is more than the acquisition of skills in programming, maths or engineering, it is an opportunity for a more successful development of 21st century skills. It is also an opportunity to learn "unattractive" content in an attractive way and to contribute to students' mental health by demystifying technology and moving away from the usual (consumer) use of technology. At the same time, the activities on the challenges students face develop their mental mechanisms by stimulating their curiosity, provoking discoveries and developing critical thinking - a departure from the conformist attitude of today's young generations.

Key words: *integrated teaching; mental health; educational robotics; robotics; self-realisation.*

1 Introduction

Robotics has been gradually finding its way into the education of younger generations since the 1980s. Even then, educational theorist Saymour Papert (1993) believed that robotics activities had the potential to improve teaching and that the social and affective involvement of students in IT content could make programming, an interdisciplinary tool for learning other disciplines (Papert, 1980; Kálózi-Szabó, 2022). All this was of course fuelled by the rapid technological changes in business and society, but also by numerous popular contents that popularised this field among the public. Since then, great progress has been made in the use of robots in the educational process, whose use of which is now considered under its own term, Educational Robotics (ER). In addition, numerous robotic platforms for educational purposes have been developed over the last three decades, with different capabilities, intended for different age groups of students and with different price ranges (Rubenstein et al., 2015). In this sense, the educational robot is considered a transformative learning tool that promotes the learning of computational thinking, coding, and engineering as critical components of STEM learning to prepare students for a technology-driven future (Eguchi, 2015). Although educational robots are still most commonly used for the purposes implied by this definition, namely to support subjects closely related to the field of robotics, such as robot programming, robot building or mechatronics (Barreto and Benitti, 2012), experts believe that the way robotics is introduced in educational settings is unnecessarily narrow (Rusk et al., 2008; Barreto and Benitti, 2012; Alimisis et al., 2019). In other words, different students are attracted to different types of robotics activities (Resnick, 1991), and activities in areas they are more inclined to may better motivate them to engage in such activities. While younger children are more suited to working with robotics sets and a 'black box' approach, slightly older students can handle more mechatronics and a deeper consideration of details through the so-called 'white box' approach (Lammer et al., 2017). Therefore, it is important to provide students with multiple pathways when learning and teaching robotics to ensure a starting point for engagement of young people with different interests and learning styles and a balance between the 'black box' and 'white box' approach (Rusk et al., 2008, Kynigos, 2008). Therefore, educational robotics today should be a broader platform for developing different skills in students that are not only closely related to technology and engineering.

This paper therefore provides an overview of the current theoretical underpinnings of educational robotics and an analysis of recent research on the impact of such teaching on outcomes. The aim is to identify the real reasons for introducing robotics in the classroom, whether the content of robotics is attractive to all students, whether all children can master certain highly abstract content of such teaching, and whether teachers have sufficient technical and pedagogical skills and competences to deliver such teaching. By synthesising the findings from reviewing and analysis of the research, the main aim is to determine whether educational robotics as a multidisciplinary field can be more than a learning technology and/or programming, or whether it can promote diversity and help today's children to maintain their mental health. Finally, based on the problem analysis, the concept of educational robotics as a means of promoting diversity and maintaining the mental health of primary school children will be presented.

2 Theoretical starting points of educational robotics

The background of learning and teaching in the field of educational robotics is essentially constructivism and constructionism (Anwar et al., 2019; Reyes Mury, 2022). Constructivism as a theory of learning or as a theory of knowledge creation and educational approach emphasises the ways and mechanisms by which humans create an image of the world and find meaning through a series of individual constructions (Purković, 2013, 2015). Although the roots of constructivism in education can be found in early philosophy and psychology, John Dewey (Dewey, 1952) is certainly one of the founders of this approach through the philosophy of constructing knowledge based on one's own experience. It is a concept that states that reality, as long as it can exist separately from experience, can only be recognised through experience, resulting in a personal, unique reality (Doolitle and Camp, 1999; Purković, 2013). In this sense, knowledge is seen as an experience that is actively constructed through interaction with the environment (Piaget and Duckworth, 1970). In this context, students usually work in small groups or teams on authentic problems, with their previous experiences and prior knowledge forming the basis for the construction of further knowledge (Lapov-Padovan et al., 2017; Anwar et al., 2019). It is essentially experiential learning (Kolb, 1984) that takes place in a meaningful learning and teaching context (Purković, 2016). Students' work on authentic problems encourages the development of solutions using a technological framework with the aim of engaging and motivating students (Papert, 1993). Constructionism shares ideas with constructivist learning and teaching theory, but extends them to include a real-world context that leads to the generation of new knowledge (Papert, 1980, 1993; Anwar et al., 2019). The focus is on learning through the discovery of tangible objects and making connections between prior knowledge and new information in the real world (Alimisis and Kynigos, 2009, Anwar et al., 2019). In the background, learning through working, creating and manipulating physical objects is therefore crucial to the learning process (Purković, 2013, 2016; Anwar et al., 2019; Reyes Mury, 2022). This requires students to use their knowledge to develop and plan solutions to problems and then manipulate objects to test the effectiveness of the solution (Reyes Mury, 2022). In this sense, the importance of manipulation and the role of the body in learning is emphasised, as it not only performs a sensory and executive mediation function between the brain and the outside world, but also represents the main instrument through which we develop learning and produce knowledge by realising experiences (Damiani, 2015, after: Negrini and Bernaschina, 2018). In addition, the manipulation of objects makes learning visible and encourages the verbalisation of one's reflections and the sharing of discoveries (Reyes Mury, 2022), while physical embodiment allows for greater student engagement and has a greater advantage over other commonly used teaching methods (Papadakis et al., 2021). Involving students in process-oriented tasks makes thinking and learning visible (Anwar et al, 2019). This should not ignore the social role of learning, which enables the development of transversal competences through interaction with others (Reyes Mury, 2022), thus develops critical thinking, communication and cooperation skills, problem-solving skills and creativity (Rapti and Sopounidis, 2024) ; Mangina et al., 2024). Anwar et al. (2019) state that the main difference between constructivism and constructionism is that constructivism refers primarily to students mental processes of students and constructionism to the physical processes, although they have the same theoretical starting point. For although mental processes are at the background of all learning and teaching, learning in the broad field of engineering and technology, but also in other areas of application, is best achieved through experience and meaningful interaction with physical objects. In the author's many years of pedagogical experience, the emphasis on the differences between these two approaches may be the result of a lack of understanding of the background processes that take place in the student during their experience with objects, but also a persistent denial of the importance of interaction with the physical world for the holistic development of the student. In fact, many experts and teachers believe that verbal and exclusively virtual interaction is sufficient for the acquisition of an adequate level of knowledge and the development of students, possibly due to the same misunderstanding, but also due to insufficient knowledge and experience from their own teaching practise. Moreover, only teachers who have dared to use concrete (meaningful, complex and practical) activities in their own lessons can understand how organisationally and pedagogically demanding it is to conduct such a lesson, how committed they need to be, what level of knowledge and competence they need to have for such a lesson and what effect such a lesson has on the students. Of course, it is much easier to conduct the lesson “ex cathedra” or exclusively virtually, especially since virtual simulators are well advanced (Camargo et al, 2021), so that such a lesson can be cheaper and “easier" for everyone involved. However, it is then not We should be surprised at the lack of comprehensive student development. While virtual learning and teaching of robotics is important, it is even more important from the perspective of higher education (Gabriele et al., 2012), where students are a more mature, cognitively capable and skilled population. Therefore, educational robotics in primary and even secondary education cannot be realised without physical interaction with robots. Only in this way does it have the potential to change inappropriate perceptions of education in this area.

3 Research on the effects of educational robotics

Research on the impact of educational robotics in the classroom on student achievement in many domains can answer the question of the real reasons for introducing robotics in the classroom, but also whether the content of robotics instruction is engaging for all students. Although most research emphasises the interdisciplinary and multidisciplinary nature of educational robotics, numerous studies show that teaching and learning is often conducted with a one-sided emphasis on only one component or dimension of student achievement. In earlier studies, the use of robots in education focused mainly on teaching computer programming or various concepts of so-called STEM education (Mason and Cooper, 2013; Anwar et al., 2019). More recent research focuses more often on the development of students' IT skills, i.e. computational thinking (Bers et al., 2014; Bakala et al., 2021), the application of computational thinking skills in a different context (Kálózi-Szabó, 2022), or the overall contribution to children's development (Negrini and Bernaschina, 2018; Mangina et al., 2024; Rapti and Sapounidis, 2024). Perhaps the best systematic review and classification of research on the impact of educational robotics on students comes from Anwar et al. (2019), who categorised the relevant research into five groups: a) general benefits, b) learning and skills transfer, c) creativity and motivation, d) respect for diversity and inclusion, and e) teacher professional development (Anwar et al., 2019). A very similar categorisation of educational robotics research was previously presented by (Bascou and Menekse, 2016).

In terms of the overall contribution to student development, research suggests that robotics education promotes an active learning pedagogy and contributes to enhancing the learning experience (Anwar et al., 2019). For example, some studies in which engineering design was integrated into lessons have shown that students collaborate better with each other, solve problems more successfully and take better control of their own learning after such lessons

(Sahin et al., 2014; Mosley et al., 2016). It has also been observed that the use of robotics in the classroom promotes the development of students' critical thinking (Sahin et al., 2014) and that it has a positive impact on their engagement in class (Mac Iver and Mac Iver, 2014; Purković and Prihoda Perišić, 2018). At the same time, research has shown that teaching robotics also contributes to the development of transversal skills (Amo et al., 2021), which can be at the centre of these lessons, while robotics serves as a means of catalysing these skills.

In terms of learning and knowledge transfer, some research suggests that teaching robotics can help students learn and construct new knowledge by investigating, exploring and making cognitive connections to previous experiences (Anwar et al., 2019). For example, some research suggests that the hands-on experience of learning with robots enables students to better understand abstract terms and concepts regardless of age and gender (Krishnamoorthy and Kapila, 2016), provided that the activities are matched to the developmental age of the students and are implemented in an appropriate manner. Research also suggests that the use of engineering design in robotics lessons has a positive impact on students' understanding of scientific concepts and coding skills, as well as on teachers' and students' confidence in their own performance (McKay et al., 2015), although this is not always reflected in their grades. It has also been observed that robotics education can be a good tool to better understand mathematical concepts and spatial intelligence and to increase interest and motivation for learning maths (Williams et al., 2012; Julià and Antolí, 2016), but on the condition that students carry out team activities where they apply mathematical concepts in the 'real world'. Research also suggests that educational robotics facilitates student learning, regardless of what is actually learnt (Wang et al., 2023) and that students gain experiences and skills while learning and teaching that help them apply the acquired knowledge in new situations or in a different context (Okita, 2015; Kálózi-Szabó et al., 2022).

Regarding students' interest and motivation for learning robotics, some research shows that this area of learning and teaching is one of the most popular among primary school students (Purković et al., 2022). Research also shows that robotics can be a tool to encourage and strengthen students' interest and motivation for learning technology and STEM concepts (Cuellar et al., 2014; Rubenstein et al., 2015; Wu et al., 2018). Educational robotics has also been found to have the potential to enhance student creativity (Rubenstein et al., 2015; Nemiro et al., 2017; Tzagkaraki et al., 2021). Research generally suggests that the inclusion of creative (design) activities in the early stages of this education acts as a catalyst that nevertheless lowers the learning curve and increases student interest. However, students' interest and creativity decrease as learning progresses (Anwar et al., 2019). Therefore, robotics education could help teachers to design socially and culturally relevant learning activities that can increase students' creativity and motivation (Anwar et al., 2019). In other words, learning and teaching robotics solely as a technical discipline or solely to develop IT skills is likely to reduce students' interest in this area as they grow older, which could be the reason for the observed decline in interest among primary school students as they grow older (Purković et al., 2022).

Studies that have examined the impact of robotics workshops on teachers' professional development have shown that such workshops can be used effectively to introduce teachers to the field, contribute to the acquisition of knowledge and self-efficacy in their own teaching, and improve and develop their own curricula (Anwar et al., 2019). However, to achieve greater success, ways must be found to train teachers in effective methods to promote student learning across physical and virtual platforms, whether such training is delivered face-to-face or online (Bascou and Menekse, 2016). Indeed, research repeatedly shows that difficulties arise at the technical level because teachers lack sufficient knowledge or have not made adequate provision for the effective integration of educational robotics into the primary school curriculum (Tzagkaraki et al., 2021).

4 Educational robotics and the promotion of student diversity

Research on the impact of robotics education on the promotion of diversity among students and retention in STEM subjects has mainly been conducted on programmes that were specifically integrated into the curriculum or served as an intervention tool for the integration of disadvantaged or underrepresented groups or as part of a platform for informal learning. Research suggests that appropriate teaching of robotics can positively influence female children's attitudes towards computer science and engineering and increase their confidence in their own abilities (Mason et al., 2011; Master et al., 2017). Educational programmes that incorporate robotics have also been observed to be more successful in promoting student diversity and stimulating interest and retention in STEM subjects than other forms of creativity-based activities (Searle et al., 2014; Anwar et al., 2019). Some studies on the use of robotics programmes for minorities and other underrepresented groups also show a positive impact on attitudes and interest in robotics and the STEM field (Bascou and Menekse, 2016; Anwar et al., 2019), although it is desirable to include cultural, social and aesthetic elements specific to that community, including a teacher who is a member of such a community.

5 Technology and mental health of students

Rare research findings emphasise the importance of educational robotics for student mental health, the preservation of which should be a priority in education today. Indeed, inappropriate use of technology in terms of content, duration, frequency and physical posture that students adopt when using technology poses a number of health risks, including developmental problems, musculoskeletal problems, physical inactivity, obesity, sleep disorders (Mustafaoğlu et al., 2018), but also numerous mental health problems. For example, cognitive and psycho-emotional difficulties are very pronounced in today's children and adolescents. In this sense, around 2% of children and adolescents suffer from depression and around 5% from anxiety" (UNESCO, 2021). The number of students with special educational needs is also increasing, with large differences identified in relation to the national context, but also in relation to the understanding of this term (Sannicandro, 2022). Furthermore, research has found a significant correlation between the higher frequency of modern digital media use and later symptoms of ADHD (Ra et al., 2018), as attention deficit hyperactivity disorder in students. Attention deficit disorder in students is also cited by Technical Culture teachers in Croatia as one of the main distracting manoeuvres in the classroom in recent years. However, although modern technology is causing communication difficulties in the younger generation (Petrina, 2007), a rapid loss of interest in complex areas such as robotics (Purković et al., 2023) and a pervasive lack of concentration in students on activities that require attention and patience, children cannot be isolated from technology. Therefore, experts believe that the connection between pedagogy (didactics and methodology) and digital technologies could facilitate the construction of meaningful learning, as tools and resources that promote the autonomy of children and adolescents and improve processes related to the principles of inclusion and personalisation (Sannicandro et al., 2022). Given the multidisciplinary and transdisciplinary nature of educational robotics, appropriate implementation in the teaching process can create a learning environment in which children can interact with their environment and work on real-world problems (Alimisis, 2013). In other words, educational robotics encompasses numerous disciplines but is also applicable to different areas of human activities, which represents a pedagogical potential for the development of students according to their developmental abilities and educational needs.

6 Discussion

It is clear from the research presented here, as well as from numerous other studies, that the learning and teaching of robotics in primary school takes place for several reasons. The first reason is to develop students' computational thinking, i.e. their computer programming skills. Although this is an important and legitimate reason, it should be emphasised that this is also often the reason why some students give up on such activities. The second reason for learning and teaching robotics aims to develop the ability to use information technology or the academic performance and skills of students in the so-called STEM field. This often refers to achievement in science (physics and maths) as well as electrical and electronic engineering. The third reason aims to stimulate interest in technology and STEM and to retain students in this field. The fourth reason is to foster students' critical thinking, communication, collaboration and creativity, the so-called 4C skills for the 21st century (Kivunja, 2015). While educational robotics can enhance the development of students' cognitive skills and creativity, it cannot facilitate their interaction in terms of emotional expression (Rapti and Sapounidis, 2024). This means that the development of communication skills and co-operation between students is still very much in question. From all this, it can be clearly concluded that the primary reasons and goals of educational robotics in primary education today are still centred on the development of those students whose dispositional skills allow them to succeed in a very narrow domain of programming, computational thinking and mathematical logic. In other words, robotics is learnt and taught in primary school primarily for those who can do it. This suggests that the focus of this type of teaching is on talent discovery. However, students who are not naturally inclined towards the areas of maths, computational thinking and programming, but could well show that they are good at some other areas of robotics, are largely neglected in this type of learning and teaching. This is also the first observed problem of this education in primary school.

Another issue that arises in research is the treatment of diversity and inclusion. The differences between students, especially in primary school, are not only those of age, gender, nationality, ethnicity or differences related to other sensitive and vulnerable groups in society. The differences are primarily related to the functioning of the human brain, which manifests itself in interests, preferences, the way one best acquires knowledge and skills and succeeds, as well as the dispositional abilities and level of cognitive development one can achieve. The stages of human cognitive development presented by Jean Piaget (1973) in his theory are based on four developmental phases: Sensorimotor stage (up to the age of 2 years), Preoperational stage (from 2 to 7 years), Concrete operations stage (from 7 to 11 years) and Formal operations stage (from 12 years onwards) (Piaget, 1973). The last phase of Piaget's theory involves an increase in logic, the ability to think deductively and the understanding of abstract ideas (McLeod, 2009; Scott & Cogburn, 2024). The ability to think about abstract ideas and situations is a key feature of the formal-operational stage of cognitive development, as is the ability to systematically plan for the future and think about hypothetical situations (McLeod, 2009). However, research shows that reaching the formal operational stage is not guaranteed, is not always related to the age of the student and is probably not achievable for every individual. This is supported by research showing that 40-60% of students fail formal operational tasks (Keating, 1979) and that only one third of adults ever reach the formal operational stage (Dasen, 1994). Since learning and teaching robotics requires cognitive skills equivalent to the developed formal operational stage, it is clear that some, perhaps even most, students will not successfully master the demands of such a teaching and learning process. This can only be an additional source of frustration for students, a reason to give up, but also a reason for the emergence of negative feelings and attitudes towards those who succeed easily. This also leads to a certain polarisation among the children into those who can and those who cannot, which only deepens the misunderstanding of the qualities of others and thus undermines the possibility of complementarity in activities, cooperation and respect for differences. In addition to differences in cognitive development, there are also differences in dispositional abilities between students that are related to the type of intelligence each of us was born with. The theory of multiple intelligences (Gardner and Hatch, 1989; Gardner, 1993) distinguishes at least seven different types of intelligence as possible natural dispositions of a person that determine their behavioural, working and learning styles. A distinction is made between linguistic, musical, mathematical-logical, physical-kinesthetic, spatial-visual, interpersonal and intrapersonal intelligence types (Gardner and Hatch, 1989). It is important to emphasise that a person learns more successfully when the learning method is adapted to his or her intelligence type. If, on the other hand, he or she is forced to act and think in an unnatural way, this has a very negative effect on the effectiveness of learning, but also creates negative feelings towards learning. In other words, someone will understand something better if it is drawn to him, someone if it is described to him, someone will understand it from a diagram or arithmetic operation, and there are also those who understand it because of someone or for someone, and so on. Given the complexity of robotics and its broad application, which relies on students being exposed to different (multiple) manifestations and interpretations (Black and McClintock, 1995), the teacher should first identify the intelligence type of the student or group of students. Then, he or she should support a learning method that fits the intelligence types of his or her students, but also apply what the students do to areas that fit those intelligence types. In this way, he or she would support the different ways in which students build knowledge about a reality and allow the "different brains" to come to similar realisations. It is very important to understand that learning and thinking cannot exist without content and that general thinking skills cannot be developed without context (Slangen, 2016). Therefore, the diversity in the use of different categories of thinking behaviours and processes is due to the nature of the content. In educational robotics, it is therefore important to carry out many more research tasks for problem solving, but also complex project-based activities (Purković and Salopek, 2015), where different tools and simulations can be used. The teacher should therefore recognise that students' skills cannot be developed in isolation, but that learning and human thinking are more than the sum of individual skills (Slangen, 2016).

The third problem observed is the types of teaching activities carried out in educational robotics and the forms (ways) of integrating robotics into primary school education. In most of the studies presented, the students' activities, although appropriate to their developmental age, were carried out in experimental contexts of such teaching. They explicitly examined only the effects on specific skills and performance, but not on the overall development of the students. In classroom practise, these lessons are mainly conducted with commercially available educational robotics platforms, where students assemble a robot based on a task and implement a software solution for its functionality with the help of a teacher. Students are often given a ready-made software solution rather than finding the solution themselves. Although such activities are useful as an introduction to learning, they are not sufficient for students' cognitive development. Therefore, robotics activities in the classroom should focus on solution finding (design, construction and functionality of the robot) through student research and experimentation, problem solving and the application of complex project activities (Purković and Salopek, 2015). Furthermore, the above-mentioned research is mostly based on interventions or extracurricular activities and is very rarely part of formal compulsory education. This makes it difficult to generalise the effects of such teaching on students, as it is usually not a broader population of students. At the same time, there is no standardised approach to integrating educational robotics into compulsory primary education. Whilst the approach is not necessarily the same for every traditional and cultural educational context, such an approach should still be developed.

The fourth problem identified in the research analysis is the problem of teachers' skills and competences. It is often observed that teachers are generally unprepared to teach robotics in schools so that students can develop a conceptual understanding of robotics. At the same time, teachers struggle to deal with the fears and skills associated with robot programming (Slangen, 2016). They often do not understand that a design and enquiry-based approach is more important for students, where the process itself and the resulting conceptual development have greater value than correct solutions to the problem. In other words, a teacher does not need to "pull ready-made solutions to problems out of a hat", but it is much more useful to admit that they know nothing and let the students explore and find a solution. On the other hand, teachers who are "strong" in programming often do not have sufficient conceptual or procedural knowledge and skills in mechanical construction and design, electrical and electronic engineering, robotics concepts or do not have sufficient knowledge of the application of robotics in the "real world". At the same time, they often do not have sufficient knowledge of the content of the subject itself (Subject Matter Knowledge - SMK), often not even pedagogical knowledge (PK) and especially pedagogical content knowledge (PCK) and technological pedagogical knowledge (TPK). In this sense, it is important to develop teachers' pedagogical content knowledge and technological pedagogical knowledge during their professional training. Pedagogical content knowledge (PCK) refers to the understanding of how certain topics, problems or questions can be organised, presented and adapted to meet the diverse interests and abilities of students (Huang et al., 2022; Purković and Kovačević, 2024). Technological pedagogical knowledge (TPK) is the knowledge of the interaction between technological tools and specific pedagogical practises (Mishra and Koehler, 2006; Purković, 2024). A teacher should acquire pedagogical knowledge during their formal education and this knowledge, as well as knowledge about the content of the subject, should not be questioned. The process of acquiring technological pedagogical knowledge and especially pedagogical content knowledge is much more complex and often time-consuming. A teacher can only acquire this knowledge through appropriate professional development in which they learn from numerous examples of good practise combined with their own teaching practise to gain the desired knowledge.

6 Educational robotics as a tool for promoting diversity and student mental health

6.1 The multidisciplinary and transdisciplinary nature of robotics

Due to the complexity of its content, robotics is a very suitable area for integration into the primary school curriculum. The multidisciplinary nature of robotics requires a synergy of different contents in the teaching process in primary school. This content includes knowledge from science (physical laws, chemical and biological processes), maths (simple and more complex calculations, geometry, etc.), mechanical engineering (mechanical structures, elements, mechanisms, materials, technical design and construction, mechanical drives and actuators, etc.), electrical engineering (circuits, electrical, electromechanical and electrochemical drives and actuators, sensors, electrical and electronic elements and assemblies, electrical and electronic diagrams), computer science (computational and logical thinking, algorithms, computer circuits, interfaces and processes, microcontrollers and development platforms, programming) and information technology (information systems, data, applications and development environments, etc.). Such a wide range of content in educational robotics cannot be learnt and taught in a disciplinary way separately, but is acquired through the students' activities of conceptualising, designing, creating and solving problems during project-based teaching and learning. The content listed here actually shows that each student can be found in a certain part of these activities, some in all and some only in a very limited segment. For example, some students are extremely motivated and can design robots and predict solutions to problems, but they may not be good at building or assembling that solution, while others are good at designing a structure, selecting materials and building robots, but they may not be good at programming, etc. Therefore, it is important that students work in teams or groups and that their skills and inclinations complement each other in the realisation of a project or the solution of a particular problem. In this sense, the teacher cannot evaluate each student in the same way, but only their individual contribution in what they themselves have shown (as their performance), and the results of the students' group activities (solution, documents, presentation, etc.) should be evaluated. This complexity of content emphasises the importance of some neglected and less attractive sectors such as mechanical engineering, metalworking, construction, etc. (Purković et al., 2022), the importance of which students learn in this way and some of whom will even work in these fields.

The transdisciplinary nature of robotics suggests that robotics is now used in all areas of human activity, from agriculture, medicine and manufacturing to sport, arts and entertainment. This should serve as a guide for the teacher to find challenges, problems or examples to introduce and explain to students in robotics lessons. The teacher must therefore research the application, the possibilities, but also the problem situations that represent a motivating "trigger" for the students' thoughts and actions, and present them to the students in a sufficiently attractive way. This is also one of the important motivating factors in robotics lessons. For example, some students will respond positively and want to participate in topics related to sports, while others may be more interested in topics related to art or maths, etc. Therefore, the teacher's exploration and analysis of their own students' preferences is an important first phase of any teaching work (Purković, 2013; Purković et al., 2020).

6.2 The concept of teaching robotics in primary school

The concept of teaching robotics in primary school should first and foremost offer each student the opportunity for self-realisation, i.e. it should be a meeting of "different brains" that would achieve the intended teaching objectives through interesting, meaningful, fun and collaborative activities. It is also important that the teacher provides such activities where each student discovers their own preferences and weaknesses so that they can develop and take responsibility for what they are better at, but also so that they can rely on other students and the teacher for this development. It is therefore important to give students the feeling that they are successful and important in a certain area of performance (not in all), in order to promote their security and self-confidence, but also acceptance and respect for others and different students. In this way, teaching will also be a suitable means of preventing various mental disorders and inappropriate behaviour in pupils.

During the implementation of the lesson, the teacher needs to know why and which conceptual knowledge from the subject content is important for students. This primarily includes knowledge that includes the student's understanding of the basic concepts of the robot, its function, system, control and repetition (loop) in the relationship of Sense-Reason-Act (Slangen, 2016). When it comes to the concept of a robot, it should be treated as a material construction of sensors, processors, actuators and algorithms that performs predefined tasks in interaction with an external environment that is constantly changing (Wisse, 2008; Slangen et al., 2011). Research indicates that students often tend to approach robots as animated entities with human or animal characteristics such as will, consciousness, intention, emotions or reflexes, which can consequently hinder their understanding of robotics (Ackermann, 2000). Therefore, the teacher should help students to shift such a “more psychological conceptualization” towards a more technological conceptualization (Slangen, 2016). From a technological perspective, function is the action or purpose for which something is designed or that users attribute to it (Hacker et al., 2009). Function in robotics can refer to: the fundamental processes that make up the internal activity of a robot, the external activities or roles of a robot, the main goal as the sum of all internal and external functions, a contribution to a larger system, a feature for adaptation or reproduction (Mahner and Bunge, 2001). A well-developed concept of robot functions in the classroom helps teachers to support students in analyzing the actions that a robot must perform in order to serve its purpose (Slangen, 2016). A system is a group of interconnected or interdependent components that form a complex and unified whole (Anderson and Johnson, 1997), and a robot is composed of physical (material), interconnected and interdependent components, as well as intangible processes, interactions, relationships and information flows (Slangen, 2016). This approach should expose students to phenomena that help them develop insight into goals or functions, the order within and between the robot, its basic structure, the flow of information and relationships between elements and (sub)systems, and the feedback processes of the system. In this way, students will understand that systems have inputs, processes and outputs and that the system is a dynamic structure in which actions are the result of its design. The teacher should help them to explore and analyse phenomena related to the effects of the system and to discover and recognise patterns (Slangen, 2016). The concept of control is based on an understanding of the specific nature of automated or robotic systems and refers to the process or ability to influence the actions of the system, its components or related systems. Control also refers to a device used to regulate the system, such as a microcontroller or computer, where the state of the system is regulated by comparing the value of preset variables to the actual input values and executing predefined algorithms that produce the output. The student's understanding of the concept of control means that the student is able to translate the intended functionality into a rule, sequence or algorithm, regardless of whether the software solution has been created completely correctly. The cycle of recognising, reasoning and acting is based on the robot's perceptual abilities (sensors), reasoning built into the programme and acting (executors, actuators) according to a given algorithm, all of which are repeated and the robot interacts with a changing or (partially) unknown environment (Slangen, 2016). This also means that the robot's senses (sensors) constantly generate new information that flows into the process and enables the robot's actions as a result of this process. In this segment, the teacher can compare the process with what happens in a human being, but must not identify the two processes.

However, the concept of robotics alone is not enough to teach robotics in primary school. It is necessary to choose appropriate strategies and approaches that take into account the developmental age of the students, their interests, preferences and abilities. It is important to consider what the key motivating and demotivating elements of the lesson are. Students' interest and success will certainly motivate them to continue their activities, while failure, boredom and cognitive over-saturation are likely to be demotivating. Implementing software solutions is often referred to as something that can be challenging for some students, but for most of them (and for most teachers) it is often a matter of frustration and failure, and thus demotivating. In this sense, modern technology, such as the available artificial intelligence (AI) systems, is emerging as a successful tool for students' learning, but also for teachers' teaching (Chiu et al., 2023). AI technology can be used by teachers to select adaptive teaching strategies and suggest teaching content and tasks that meet the needs of the teaching (Standen et al., 2020; Adelman et al., 2021). It can also be used to improve teachers' teaching skills and help them manage lessons (Jarke and Macgilchrist, 2021; Zhang, 2021). This technology can also support teachers' professional development and improvement (Li and Su, 2020; Gunawan et al., 2021) by enabling AI agents to provide teachers with suggestions and comments on their teaching based on the analysis of real-time data from the classroom. This can relate to teachers' behaviour, their question and answer skills and diagnostic tests of their pedagogical content knowledge (Chiu et al., 2023). In the learning process, AI can contribute to the individualisation of tasks and a personalised learning environment tailored to the student's competencies and characteristics and their progress dynamics (Yang and Shulruf, 2019; Hirankerd and Kittisunthonphisarn, 2020). The student can talk to a chatbot and thus develop their communication skills (Vazquez-Cano et al., 2021). In learning, AI can be used to provide guidance and feedback to students based on the analysis of their work and learning process (Fu et al., 2020) and to increase adaptability and interactivity in digital learning environments (Westera et al., 2020; Chiu et al., 2023). Current research also suggests that students' computational thinking skills, programming self-efficacy and motivation to learn can be improved by using AI technology in learning (Yilmaz et al., 2023). In other words, students should have the opportunity to search for solutions using AI technology as it can accelerate classroom activities. Instead of spending a lot of time correcting common syntactic errors, they should develop their metacognitive skills to ask the “right” questions to such a system. However, the application of AI for learning requires students to have certain skills in using such systems and fast writing skills (Yilmaz et al., 2023). The teacher should therefore allow and enable the possibility of using such systems, but also leave this to the students' interests and abilities.

Among the strategies that are more suitable for primary education and introduce students to robotics technologies and concepts, those that emphasise the importance of providing multiple 'entry points' into robotics should be highlighted. Such strategies have been shown to be successful in engaging a broad range of students and include (Rusk et al., 2008):

1) focusing on themes, not just challenges;
2) combining art and technology;
3) encouraging storytelling;
4) organising exhibitions, not competitions.

The above strategies enable young people to design and programme artistic creations that integrate light, sound, music and movement (Rusk et al., 2008). They are particularly appropriate for students at a younger developmental ages (1st to 6th grade) and for those students who are much more motivated to engage in activities through arts. Depending on the students' preferences, the teacher can also choose other motivating content instead of arts to guide the students in the activities. Practical experience shows that such strategies are also suitable for older students, as the level of difficulty can be adapted to the level of cognitive skills developed by the students.

7 Conclusion

Educational robotics is now emerging as a popular, sophisticated and comprehensive "tool" for the holistic development of students, as research has shown in many areas. However, research shows that robotics education primarily emphasises achievements related to computational thinking, programming and certain technical knowledge and skills, while neglecting diversity, mental health and student achievement across the broad spectrum that robotics encompasses.

From analysing the current research, it can be concluded that educational robotics in primary school should be used as an inclusive and connecting (transdisciplinary) lesson based on the basic concept of robotics and strategies that appeal to a wide range of students. Such teaching should also encompass a much broader range of targeted student competences and skills than the acquisition of knowledge in programming, mathematics or technology. Student activities should not be limited to managing and programming pre-built circuits, but should offer opportunities for all students to act collaboratively and constructively, to learn insufficiently attractive content in attractive ways, and to succeed in the segment in which the student can succeed. This assumes, of course, that students have enough time to adapt, to perform complex activities, but also to showcase their own success. Such an approach should be a departure from the existing consumerist, elitist, populist or conformist approach to technology and, by demystifying technology and solving appropriate and meaningful problems and challenges for them, develop students' mental mechanisms and thus contribute to their mental health. Modern technologies, such as AI systems, can not only contribute to the development of students' skills and motivate them to work, but also make it easier for teachers to prepare, plan and manage the teaching process in this complex field.

However, on a technical level, teachers still need to find and complement platforms that meet the pedagogical requirements but also improve their own knowledge and skills. Given the pedagogical potential of robotics, concepts for an appropriate and acceptable integration of educational robotics into the primary school curriculum must continue to be developed.

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