JURNAL VARIDIKA
Vol. 35, No. 1, 2023, pp.1-12
p-ISSN 0852-0976 | e-ISSN 2460-3953
Website: http://journals.ums.ac.id/index.php/varidika

How Can Educators Effectively Be Trained to Teach Coding and Robotics in STEAM Field Programs?

Thelma de Jager
Tshwane University of Technology, South Africa
*Corresponding author's email: dejagert@tut.ac.za

DOI: 10.23917/varidika.v1i1.20840

Submission Track:
Received:
13 December 2022
Final Revision:
25 January 2023
Available online:
26 January 2023

ABSTRACT

Robotics is predicted to become the fastest-growing market that could contribute to global socio-economic prosperity. The increasing unemployment rate and demand for 21st-century skills dictate the development of coding and robotic skills in STEAM fields. Schools are implementing the development of coding and robotics skills in curricula, but educators are not effectively trained to teach these skills. Therefore, a case study using a qualitative approach was employed to detect how educators (n=22) of a higher education institution could be effectively trained in coding and robotics. Data were collected from observations of trainers during training sessions and educators' reflections in open-ended questionnaires after the training sessions. The results showed that educators preferred working collaboratively in small groups, enjoyed the training activities, observed and understood the application of theory into practice, still required hard copy manuals, found robotic kit components too small to work on, were dependent on individual support during the training sessions and required additional training sessions. The significance of this study shows that in training coding and robotics: ensure technical and pedagogical knowledge is connected and applied to real-life practices; divide trainees into basic and beginner classes, and sub-divide them in pairs where they can work collaboratively and interactively in completing their coding and robots; clarify the advantages and disadvantages of robotics in society; create fun activities during the training; and ensure sufficient support is available after training to assist those still not at ease with coding a robot.

Keywords: *Coding, robotics, training, feedback, support, collaboration*

INTRODUCTION

Globally, the modern workforce is increasingly changing to science, technology, engineering, arts, and mathematics (STEAM) careers as there is a growing need for creative technology experts, computer programmers, and software engineers (Ahmed, Alharbi & Elfeky 2022). Many South Africans, including graduates, are unemployed (32,9%) as they have not acquired the required 21st-century skills (staying abreast with new technologies, and developing problem-solving, critical thinking, communication, decision-making, teamwork, and creativity skills) or studied in STEAM fields (Suarta, Suwintana, Sudhana & Hariyanti 2018). Graduates who have studied STEAM fields can adapt and apply creative ideas in making decisions and solving problems to prosper in these ever-changing economies (Colucci-Gray et al. 2017).

Additionally, Ge, Ifenthaler, and Spector (2015) point out that STEAM could assist ethnic minority groups**,** girls, and disadvantaged students who show more interest in studying the arts to express their creative ideas in decision-making when solving problems. According to García-Carrillo, Greca, and Fernández-Hawrylak (2021), the essential learning outcome of STEAM is creativity, where students can integrate and apply knowledge to technology such as coding and robotics and create innovative products. The significance of coding and robotics is that it develops the fine motor skills of students through a hands-on and student-centered approach and allows them to gain a better understanding of how technology is integrated into reality (Schina, Esteve-González & Usart 2021).

In preparing learners of South Africa for 21st-century skills, coding and robotics, which were piloted in Grades R to 3 and Grade 7 in 2021, will be introduced into the school curricula in 2023. Curricula topics of coding and robotics focus mainly on pattern recognition, algorithms, and coding, which includes physical coding activities, robotics skills, and internet and e-communicating (RSA 2021). To teach STEAM subjects, educators need to be well-trained in integrating and teaching technologies such as robotics, coding, and 3D printing in all the STEAM fields and not in isolation (García-Carrillo et al. 2021). However, most educators are not sufficiently trained to teach new technologies (Winter, Costello, O'Brien & Hickey 2021). Limited research has been conducted on how effectively educators are trained to teach coding and robotics curricula. Therefore, the following research question guides the study:

"How can educators be effectively trained to equip STEAM students with robotic and coding skills?

The study focused on the South African context as a lack of research exists regarding the readiness of educators to teach student teachers robotic and coding skills. In response to the demand of technology changes in society, we need to adjust our teaching methods and strategies to teach coding and robotics in an information-driven world (Sisman & Kucuk 2019).

Decades ago, John Dewey maintained that the social context influences how we teach the curriculum we find ourselves. He stated, "If we teach today as we taught yesterday, we rob our children of tomorrow." (Peake 2010). Colucci-Gray et al. (2017) argue that science, technology, and mathematics (STEM) fields are currently taught with a lack of creative, critical thinking. Integrating the arts could assist students in developing emotional, cognitive, intellectual, creative, self-expression, critical thinking, and problem-solving skills (Ge et al. 2015). Studies have indicated that learning arts enhance memory retention as more pathways are created when applying visual, aural, and kinesthetic modes when engaged in fun activities while learning (Land 2013). Thus, STEAM education could enhance the learning of STEM subjects as it addresses students' learning preferences where each student can express their innovative ideas and focus on computational skill development. Computational thinking allows students to examine and divide a problem creatively into simple steps and seek solutions. Computational thinking is the step that comes before coding in robotics and is a simple and highly efficient approach to discovering pattern recognition problem-solving, abstraction, and algorithm design (Fergusson & Wild 2021).

Rajan and Saffiotti (2017) state that education in coding and robotics is essential for all human beings, and that robotic technology has been integrated into nearly all facets of human lives for centuries. As early as 300-400 B.C., technical manuscripts indicated the building of automated machines by human beings. The term "robot" originated from the Czechoslovakian word "robota," meaning "heavy work" or "forced labor" (Reilly 2011). In 1945 the first language used for coding/programming, Plankalkül, was developed by a German Civil engineer Konrad Zuse to operate the first working computer, the Z3.

The beginning of "industrial robotics" dates to the 1950s, although some kinds of automatization such as steam power and electricity appeared during the industrial revolution. According to Zamalloa, Kojcev, Hernandez, Muguruza, Usategui, Bilbao and Mayoral (2017) the development of industrial robots can be divided into four periods, the first three from the 1950s to the end of the 1990s and the fourth generation ranging from 2000 till today. The first generation accessed the robot at a very primitive level. The second generation developed more advanced motion control, sensor interface capabilities, inter-robot communication, and even some limited artificial intelligence. The third generation no longer focuses on specific language but a combination of programs and features used for automatic 3-D world models, task-level programming (e.g., to move boxes around), and understanding global warming. The fourth generation is characterized by high-level "intelligent" structures that include the ability to perform advanced computations, deep learning, complex strategies, logical reasoning, and collaborative behavior (Gasparetto 2016).

In South Africa, the Department of Basic Education's annual plan states that all children should be taught coding and robotics from a young age to enhance job opportunities once they have completed their studies (RSA 2021). Robotics can be defined as the intelligent connection of perception to action using electronics, mechanics, and coding as the software to program robots to do specific jobs (Ingrand & Ghallab 2014). Teaching and learning how to code robotics are considered a transfer of skills for the future, where curricula will focus on developing innovative entrepreneurial and technology skills that encourage job creation (Gasparetto 2016). The coding and robotics curricula should equip learners with the necessary knowledge and skills to become creators of innovative technologies that could affect the global community (Sisman & Kucuk 2019). Therefore, educators need effective training to change their teaching and learning methodology and integrate technology skills when teaching STEAM.

Studies conducted on educator training globally have revealed that most educators have not been effectively trained to teach coding and robotics. For example, educator training programs are based on a theoretical or pedagogical approach and focus primarily on constructivist theory (Alimisis 2019). In addition, several studies do not refer to learning theories or pedagogical approaches (Kay & Moss 2012). In a study by Göksoy, Vayvay, Yılmaz, and Yılmaz (2014), educators teaching information technology stated that coding and robotics courses increased their multidimensional thinking skills, improved the analytical thinking skills of their students, and enabled them to comprehend the logic of algorithms. Schina, et al (2021) found that there was no uniformity in their study regarding the duration and requirements of training and suggested that successful practices of effective training in coding and robotics could be based on the following pillars: *collaboration, teaching materials, pedagogy, practice, feedback, and support.*

Agatolio et al. (2017) observed that educators collaborated in a motivating learning environment during training sessions to develop the final project. Sisman and Kucuk (2019) mentioned that educators compared their solutions and assisted each other on how to solve problems in a non-competitive manner. Alimisis (2019) emphasizes the creation of a positive learning atmosphere by promoting fun activities while teaching coding and robotics. Kay and Moss (2012) underline the importance of sufficient teaching materials to display in the class and to demonstrate practical concepts while practicing in class. Sisman and Kucuk (2019) highlight the application of *innovative pedagogy methods and strategies* to teach coding and robotics and integrate them across STEAM fields. It is suggested that a hands-on approach be used where educators apply into practice both technical and pedagogical knowledge they have acquired during the training program (Agatolio et al. 2017).

Furthermore, Gilkes et al. (2014) recommend establishing the level of training sessions, regarding difficulty, from beginner to advanced classes and that before training commences, it is important to emphasize the significance of coding and robotics in society. Training courses should proceed from the basic concepts and gradually progress to more abstract concepts (Negrini, 2020). Goodale (2013) emphasizes that sufficient time should be allocated so that educators learn at their own pace while familiarizing themselves with the robotic equipment (Agatolio et al. 2017). Negrini (2020) adds the importance of displaying final projects as a creative works of art and the importance of support and feedback during and after the training session/s for those who still need more clarification and assistance.

Coe, Aloisi, Higgins, and Elliot Major (2014) agree that well-trained educators are essential to effective teaching and learning. Therefore, developing educators' professional growth and pedagogical practices is vital for successful teaching and learning coding and robotics in STEAM. However, Dewey cautions that although the educator is indispensable to learning, technology development, in this case, coding and robotics, could replace the teacher in the future and contribute to isolation rather than socialization (Rich & Reeves 2006).

METHOD

The data for this study was collected using a case study and applying a qualitative approach. Participants were observed during the training sessions and reflected on their experiences after the training sessions by completing a questionnaire consisting of open-ended questions and engaging I n interviews. Volunteering educators teaching student teachers (n=20) of a disadvantaged university and two trainers from the private sector in South Africa participated in the research. The study aimed to observe the training of educators in coding and robotics and to detect "good" and" bad" practices from educators' experiences during training sessions that could affect the effective implementation of coding and robotics curricula in STEAM fields.

The researcher and the two trainers observed participants during the training sessions to identify where more support or training was needed. The observed participants included males (40%) and females (60%) with diverse teaching experience ranging from less than five years (30%) to above 20 years (10%). The most extended term of teaching experience was 5-10 years (60%). Permission to conduct the study was obtained from the institution and all participants. After the training sessions, participants completed a questionnaire to indicate "good" and "bad" practices during the training sessions, followed by interviews conducted with sampled trainees and the trainers concerning observations made during the training sessions.

Trainers and training sessions

A private company experienced in training educators in coding and robotics was contracted to conduct the training sessions. The validity of the training sessions and the observation results deriving from these sessions can be attached to the trainers' experience, including training coding and robotics of more than 300 educators within 120 schools and higher education institutions and 30 000 students registered on the online support platform within three countries. Before the training commenced, trainers requested the participants to indicate their knowledge and experience of coding and robotics. Only two of the participants had previous experience in coding and robotics. The others had either minimal experience or no experience. Based on previous experience, participants were divided into two groups: an introductory skills development class and a more advanced one. Training sessions were conducted in English as the official language of instruction; therefore, there was no need to translate during the training sessions. The training sessions were conducted during a two-day face-to-face course, and extra support was provided in registering all participants on an online platform where additional questions and answers could be posted after the training sessions. Training was thus an ongoing process where trainers attended to individual questions to ensure all participants stayed on track. Before the first training session commenced, participants were requested to download the "Arduino application" to code the microcontroller, which uses a programming language to learn the basics of coding so that educators could engage in hands-on activities of coding when building the robotic car.

The observation instrument was constructed from positive findings derived from studies based on the successful training of educators by Alimisis, Karatrantou, and Tachos (2005); Kay and Moss (2012) and Dewey's theory contributed to the validity of the observation results. The framework for observing trainees during the training sessions included the following components: interactive collaboration, a socially centered approach, teaching materials, pedagogy, practice at own pace, feedback, and support. These components were highlighted and explained to trainees before the training sessions commenced and applied as themes to discuss the result.

RESULTS AND DISCUSSION

Result

Observations

Three participants showed significant interest in coding and had previous experience in the field. Some even pre-read articles on the coding and robotics programs before classes commenced, while others did not pre-read any articles on coding and robotics and commenced their training with no background knowledge at all. Based on the pre-assessment of participants' familiarity with coding and robotics they were divided in two groups of 10 each, a basic and an advanced group. However, participants in each group sub-dived themselves in pairs to work collaboratively with their colleagues next to them during the sessions. The reason could be that they were not familiar with the programming of robotic materials and needed extra support from their peer to complete the hands-on class activities successfully. The trainers consistently provided support during the class, but it was difficult for trainers to attend to all participants individually. Consequently, more extra time was needed than was initially planned to complete the training course. Most participants needed individual support during all sessions, which necessitated an extra class or even more.

Although it was observed that not all educators completely mastered all the technical skills, it was clear that their interactive involvement during the training session and the hands-on approach with their peers did contribute to laying the foundation for how to teach coding and robotics in STEAM to their student-teachers. Feedback and support were consistently given during and after the training sessions and online to ensure that all participants were well-trained to code a robot. During the training sessions, it was alarming to observe that some of the educators teaching STEAM subjects were not acquainted with the coding of robotics and requested consistent repetition from trainers to ensure understanding of how to code correctly.

In reflection after the training sessions on the effectiveness of the training, participants were requested to point out 'good' and 'bad' experiences during the training sessions. Reflections from their experiences were completed on the questionnaires, and more in-depth knowledge gained from individual interviews were grouped into the following themes: collaboration; training materials, practice; feedback and support, and others.

Open-ended questionnaires and interviews

1. Collaboration

“I worked with my peers. This helped me and guided me when I got stuck, we worked together, shared ideas, and discussed problems we encountered while coding and together we found the solution to our problem. What I did not know, my peers explained it to me.”

“The coding was difficult as I had no previous experience in coding and as a team my colleague assisted me sometimes and I assisted him again in how to code and upload data instructions for robots. We shared ideas and clarified where there was a need. This improved my understanding while we explored coding and robotics together.”

“Working with another colleague really forced me to focus and concentrate to code accurately and understand why a faulty connection is not working and assisted me to understand why certain aspects work in a certain manner. I will definitely remember to divide my class in groups as this was the best option for me during the training session.”

“Although I liked asking questions to my colleague sitting next to me, I enjoyed doing the training by myself and to work on my own robotic kit that was provided to me. I wanted to build the car by myself although my colleague assisted me when I was lost.”

2. Training Materials

“The robotic kit made it easy for me to understand the theoretical presentations of the trainer. Thus, in building my own robot practically in a hand on approach, I was able to understand the theory and practice it as well.”

“I did not like the kit that much as I battled to apply the small components on the electronic board. The tools in the kit box are also very small for my handling.”

“We need training manuals and extra video clips or videos to refer to for additional practice in my spare time, I am concerned that if I don’t practice the coding and robotics I learned the past two days I will forget important information and will not be able to teach my class effectively.”

“I could not install the software required on my laptop because my institution block all applications. The internet connection in the building was very poor and slow and the facilitator worked too quick for my mind to absorb all the new content.”

“I felt that the information was too much to grasp in a two-day workshop as I had no previous experience with coding. I suggest at least a four-day training workshop and a pre-preparation by means of videos and a refresher training course afterwards every two months so that I can ask questions where I really got stuck and could not proceed.”

3. Practice

"During the training I learned how to apply programming with content of my subject field. I developed basic coding skills which encouraged me to conduct research on robotics learning in my classes."

"…outstanding for me was the electrical connections I learned of a car, how to code that will enable sensors to work. However, I realized I am not ready to teach coding and robotics yet as I need more training and must be able to code a robot on my own. I preferred working with a colleague during the training but realized I should have done the practical on my own to gain more confidence in coding."

"The practical helped to train my student-teachers coding and robotics, I would also train them in how to use Tinkercad to simulate electric circuits in class. This will help student teachers not to struggle when they go to schools that does not have laboratories to conduct experiments and teach coding and robotics in class."

"I enjoyed both the practical and theoretical components. The section helped me to put theory into practice and see the output of all the projects in real life situations."

"Working with circuits and learning how to make robots move, being creative and to design a robot car and programming it to move was more interesting because one can see the final product of the training."

"During the hands-on sessions, I developed electronic, technical skills and technology skills. I learned how to write or set up a code and detect if it works. I also learned how some robotics are applied in cars"

"The training enabled me not only to learn programming but also assisted me in working in a team and thinking creatively in finding solutions to finalize the final project, the robotic car."

Other participants said coding helped them understand the concept they had learned. Connecting circuits practically and creating programs encourage creative and critical thinking and technology skills. Another pointed out that he had developed motor and analytical skills.

4. Support and feedback

"The facilitator was very patient with everyone; the training session were pitched at the appropriate level."

Despite some educators' indications during the pre-assessment that they were acquainted with coding and robotics, some still indicated it was difficult for them to understand coding and to build a robotic car from scratch. They also reflected those terminologies used in coding and robotics were difficult, and the names of the different components as they were not familiar with the terminology and the functions of each component. The participants also indicated that there was too much information to grasp and that much practice and support were required.

Many felt that because they were unfamiliar with the coding language, trainers progressed too quickly to the next concept without allowing them to practice what they had learned. They wanted more practical activities where they could practice one concept at a time and work at their own pace. Some realized they were not progressing fast enough and consistently needed extra assistance from the trainer.

Discussion

The rapid growth and integration of coding and robotics across all spheres of society and education in recent years have emphasized the need for developing 21st-century skills through STEAM study fields to enhance economic growth (Gasparetto 2016). Integrating and implementing robotic and coding skills in STEAM education is not a recommendation but a prerequisite for achieving outcomes in curricula as set by the Department of Basic Education (RSA 2021). As of 2023, coding and robotics will be implemented in South African schools, but the concern is that not all STEAM educators have been successfully trained to teach these fields, especially those teaching in rural areas and disadvantaged education institutions.

In finding best practices for teaching coding and robotics effectively in STEAM fields, the study focused on observing how educators interacted during training sessions and their reflections on 'good' and 'bad' experiences of training sessions. Based on their experiences in STEAM and coding and robotics, participants were divided into two groups: an advanced and a beginner group. Although the two trainers were assisting and supporting all in small group training, 10 in a class, it was interesting that the educators sub-divided themselves into groups of two or three where they worked collaboratively and interactively with one another. The reasons could be that the group size of 10 might still have been too large for individual training, the trainer could not assist all in the group quickly enough, and lecturers required more 'one-on-one' training. Participants pointed out they needed quick assistance and regarded collaboration with their peer as valuable in assisting them if a component of the robotic equipment did not work correctly. Agatolio et al. (2017) agree that collaboration between educators assists them in completing the final product. Additionally, Schina et al (2021) highlights the importance of a student-centered learning environment where students work collaboratively with their peers on practical activity. In contrast, two participants indicated that they realized afterward they should have completed the practical on their own to gain more confidence in coding and robotics.

In agreement with Agatolio et al. (2017), participants experienced the hands-on activities during the training sessions as enjoyable, and these encouraged them to read more to gain more knowledge, develop creative teamwork skills, and assist them in connecting technology to real life in STEAM fields. Thus, it can be concluded that best practice in a coding and robotics training session is where both pedagogical knowledge and technical skills are integrated and can be applied to reality. The concern of previous studies was that training was not always effective and mostly based on either the theoretical aspect or the pedagogical approach and not integrated as one (Kay & Moss 2012). However, most participants indicated that they could apply theory to practice, which clarified abstract and unknown concepts to them.

In the teaching material, the Arduino microcontroller was used as a programming language to teach educators how to learn the basics of coding theoretically while creating 'hands-on' a robotic car with various sensors practically. Thus, the training session enabled educators to use the program to develop theoretical knowledge by coding the robotic car to execute movements in practice. The program is considered adequate for basic and beginner programming. On the negative side, some felt that the program could not be downloaded on computers before the classes commenced because they lacked the competency to download it alone. Participants agreed that working on a robotic kit assisted them in putting theory into practice, but some complained that the components were too small to build. Alarmingly, older and more experienced STEAM educators requested hard copy manuals and videos to guide them. This directly conflicts with what 21st-century skills advocate – teaching STEAM with new technologies. This could indicate that they were not well acquainted with technology or willing to use e-technology.

Most of them found the practical sessions interesting as they better understood simulation and how necessary coding and robotics are in curricula. The hands-on activity where each participant was building his/her robotic car was experienced as exciting. It encouraged extra reading to gain more knowledge, developed creative teamwork skills, and assisted in connecting technology to real life in STEAM curricula. Agatolio et al. (2017) agree that the best practice in a training class is when both technical and pedagogical knowledge is integrated and applied to real-life practice.

Significance of the study

The results indicate that when training novice educators in coding and robotics it is essential to:

1. Divide trainees into a basic and a beginner class
2. Sub-divide them into pairs (a class of 10 is too large) where they can work collaboratively and interactively on one robotic kit.
3. Clarify why robotics is essential in society and the advantages and disadvantages of these technologies before the training commences (Gilkes et al. 2014).
4. Create fun activities during the training to enhance interest and creativity.
5. Present what they have built as a proud piece of creative work of art once the robot has been completed (Negrini 2020).
6. Provide consistent online support to assist educators when teaching coding and robotics in their classes.
7. Address challenges such as a lack of laboratories by integrating 'Tinkercad' to simulate coding and robotics in class. This will assist student teachers in not struggling when they go to schools that do not have laboratories to conduct experiments and use coding and robotics in class.

Limitations of the study

The study focused only on training sessions for educators teaching student-teachers at a higher education institution and not on in-service teachers who need to implement the new curricula which include the development of coding and robotics skills. More studies are required where teachers teaching in rural areas with limited technology resources are engaged and reflect on their experiences.

The results indicated that lecturers teaching STEAM subjects were not at all acquainted with coding and programming skills and reflected that they were not ready to teach coding and robotics as they needed more training sessions.

CONCLUSION

Training sessions should ensure that educators work in small groups, interactively and collaboratively with their peers, learning new technologies such as coding and robotics. This enables them to learn from each other and assist one another in understanding abstract and unclear concepts better. Working together and engaging in exciting and fun activities ensure that they stay focused to assist one another in completing the robot project successfully. Therefore, during training sessions, it is essential to create a positive learning atmosphere and to provide sufficient support and additional training sessions, if required, to ensure all educators can teach coding and robotics. Schina et al (2021) emphasize that practical training in coding and robotics is critical to confidently teaching and successfully integrating robotic and coding skills in STEAM fields. This influences the successful implementation of curricula on coding and robotic skills development. Thus, possible challenges and shortcomings in training educators should be detected beforehand to ensure practical training sessions.

REFERENCES

Agatolio, F, Pivetti, M, Battista, S, Menegatti, E & Moro, M. 2017. A training course in educational robotics for learning support teachers. In: *Educational robotics in the makers era*. D. Alimisis, M. Moro, & E. Menegatti, Eds. Cham: Springer. 43–57.

Ahmed, ESAH, Alharbi, SM & Elfeky, AI. 2022. effectiveness of a proposed training program in developing twenty-first century skills and creative teaching skills among female student teachers, specializing in early childhood. *Journal of Positive School Psychology*. 6(6):4316–4330.

Alimisis, D. 2019. Teacher training in educational robotics: The ROBOESL project paradigm. *Technology, Knowledge and Learning*. 24(2):279–290. doi.org/10.1007/s10758-018-9357-0.

Alimisis, D, Karatrantou, A & Tachos, N. 2005. Technical school students design and develop robotic gear-based constructions for the transmission of motion, Eurologo 2005. In: *Digital Tools for Lifelong Learning, Proceedings*. Warsaw, Poland. 76–86. Available from: https://eurologo2005.oeiizk.waw.pl/PDF/E2005AlimisisEtAl.pdf.

Coe, R, Aloisi, C, Higgins, S & Major, LE. 2014. *What makes great teaching? Review of the underpinning research, Project Report*. Sutton Trust: London. Available from: https://www.suttontrust.com/wp-content/uploads/2014/10/What-Makes-Great-Teaching-REPORT.pdf.

Colucci-Gray, L, Trowsdale, J, Cooke, CF, Davies, R, Burnard, P & Gray, DS. 2017. Available from: https://jotrowsdale.files.wordpress.com/2017/11/bera-research-commission-report-steam.pdf.

Fergusson, A & Wild, CJ. 2021. On traversing the data landscape: Introducing APIs to data-science students. *Teaching Statistics*. 43(S1):71–83. doi.org/10.1111/test.12266.

García-Carrillo, C, Greca, IM & Fernández-Hawrylak, M. 2021. Teacher perspectives on teaching the STEM approach to educational coding and robotics in primary education. *Education Sciences*. 11(64):1–10. Available from: https://doi.org/10.3390/.

Gasparetto, A. 2016. Robots in history: Legends and prototypes from ancient times to the industrial revolution. In: *Explorations in the history of machines and mechanisms. History of Mechanism and Machine Science*. 32, 39–49. doi.org/10.1007/978-3-319-31184-5_5.

Ge, X, Ifenthaler, D & Spector, J. 2015. Moving forward with STEAM education research, in emerging technologies for STEAM education. In: *Educational Communications and Technology: Issues and Innovations*. 383–396. doi.org/10.1007/978-3-319-02573-5_20.

Gilkes, T, Radix, C & Ringis, D. 2014. A study of robotics in Caribbean education. In:

Proceedings of 2014 IEEE Frontiers in Education Conference (FIE. Madrid: IEEE. 1–5. doi.org/10.1109/FIE.2014.

Göksoy, A, Vayvay, O, Yılmaz, BO & Yılmaz, A. 2014. Electronic collaboration in strategic decision-making processes: An application in a global leading company. In: *Collaborative communication processes and decision making in organizations (pp.217-239). IGI Global*. doi.org/10.4018/978-1-4666-4478-6.ch012.

Goodale, T & A. 2013. The influence of a ROV themed engineering design workshop on in-service teacher self- efficacy. In: *Proceedings of 2013 IEEE integrated STEM Education Conference (ISEC*. Princeton: IEEE. 1–5. doi.org/10.1109/ISECon.2013.6525202.

Ingrand, F & Ghallab, M. 2014. Robotics and artificial intelligence: A perspective on deliberation functions. *AI Communications*. 27(1):63–80. Available from: https://hal.archives-ouvertes.fr/hal-01138117/document.

Kay, JS & Moss, JG. 2012. Using robots to teach programming to K-12 teachers. In: *Proceedings of 2012 Frontiers in Education Conference Proceedings*. Seattle: IEEE. 1–6. doi.org/10.1109/FIE.2012.6462375.

Land, MH. 2013. Full STEAM ahead: The benefits of integrating the arts into STEM. *Procedia Computer Science*. 20:547–552. doi.org/10.1016/j.procs.2013.09.317.

Negrini, L. 2020. Teachers' attitudes towards educational robotics in compulsory school. *Italian Journal of Educational Technology*. 28(1):77–90. doi.org/10.17471/2499-4324/1136.

Peake, J. 2010. If we teach today as we taught yesterday, we rob our children of tomorrow. *Agricultural Education Magazine*. 83(3):4. Available from: http://www.questia.com/library/journal/1P3-2224323171/if-we-teach-today-as-we-taught-yesterday-we-rob%5Cnhttp://files.eric.ed.gov/fulltext/EJ1020956.pdf.

Rajan, K & Saffiotti, A. 2017. Towards a science of integrated AI and robotics. *Artificial Intelligence*. 247:1–9. doi.org/10.1016/j.artint.2017.03.003.

Reilly, K. 2011. From automata to automation: The birth of the robot in Rossum's Universal Robots (RUR). In: *Automata and mimesis on the stage of theatre history*. London: Palgrave Macmillan. doi.org/10.1057/9780230347540_6.

Rich, P & Reeves, TC. 2006. A significant contributor to the field of educational technology. *Journal of Educational Research*. 99(3):131–142.

RSA. 2021. *Republic of South Africa's Department of Basic Education: Proposed amendments to the Curriculum and Assessment Policy Statement (CAPS) to make provision for coding and robotics. Grades R- 9.Curriculum and Assessment Policy Statement Grades R-3, Coding and*. Available from: https://www.education.gov.za/Portals/0/Documents/Legislation/Call for Comments/draftcodingandroboticscurriculum/Grade R-3 Coding and Robotics Draft CAPS Final 19Mar2021.pdf?ver=2021-03-24-164612-000.

Schina, D, Esteve-González, V & Usart, M. 2021. An overview of teacher training programs in educational robotics: Characteristics, best practices and recommendations. *Education and Information Technologies*. 26(3):2831–2852. doi.org/10.1007/s10639-020-10377-z.

Sisman, B & Kucuk, S. 2019. An educational robotics course: Examination of educational potentials and pre-service teachers' experiences. *International Journal of Research in Education and Science*. 5(2):510–531. Available from: https://files.eric.ed.gov/fulltext/EJ1205775.pdf.

Suarta, IM, Suwintana, IK, Sudhana, IGPFP & Hariyanti, NKD. 2018. employability skills for entry level workers: A content analysis of job advertisements in Indonesia. *Journal of Technical Education and Training*. 10(2):24–57 2582.

Winter, E, Costello, A, O'Brien, M & Hickey, G. 2021. Teachers' use of technology and the impact of Covid-19. *Irish Educational Studies*. 40(2):235–246. doi.org/10.1080/03323315.2021.1916559.

Zamalloa, I, Kojcev, R, Hernández, A, Muguruza, I, Usategui, L, Bilbao, A & Mayoral, V. 2017. Dissecting robotics – historical overview and future perspectives. *ARXIV.org*. doi.org/10.48550/arXiv.1704.08617.