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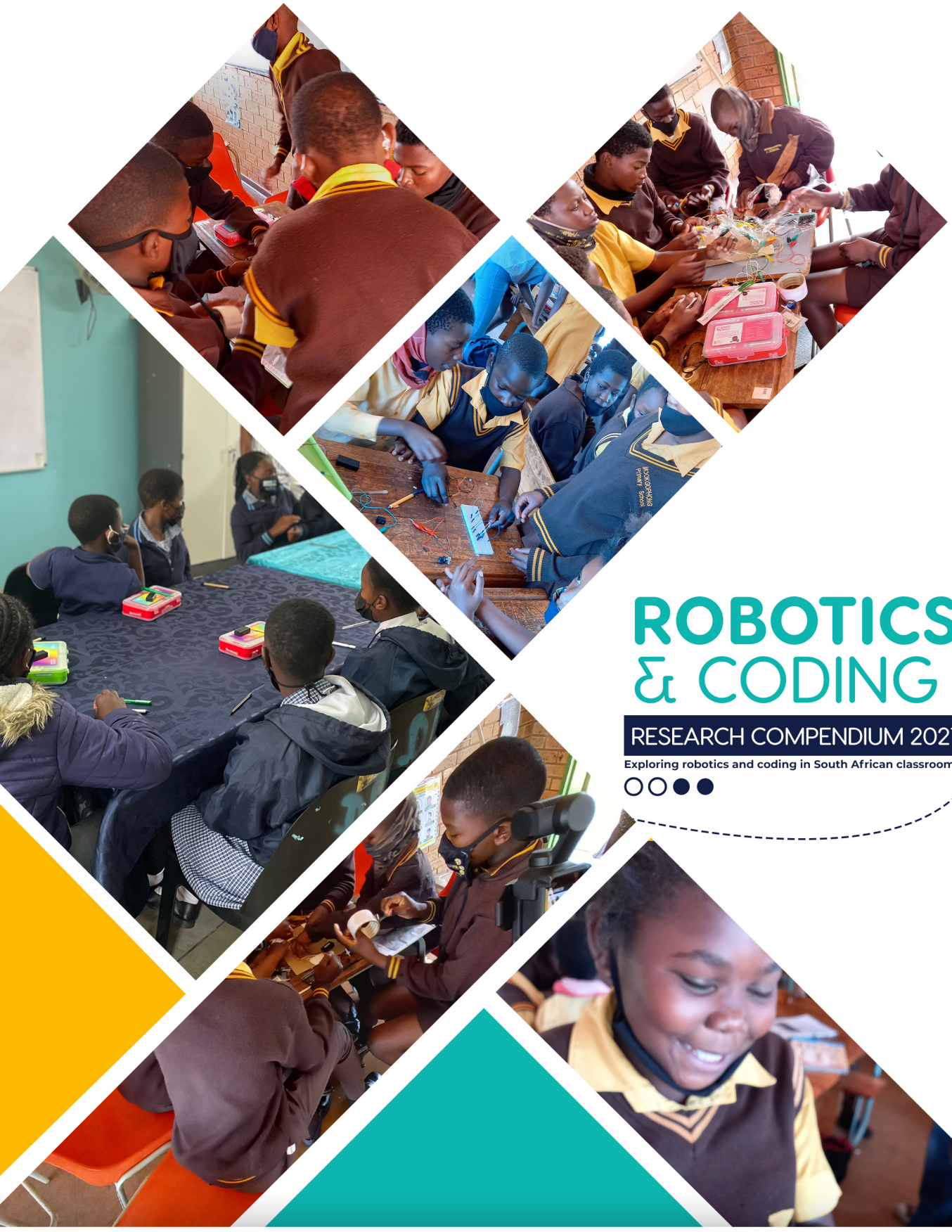

ROBOTICS & CODING

RESEARCH COMPENDIUM 2021

Exploring robotics and coding in South African classrooms

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Robotics & Coding Compendium

Introduction

In recent years, the Department of Basic Education has actively explored incorporating robotics and coding into the national curriculum. In parallel to this process, with the hope of enhancing our collective understanding of integrating robotics and coding into teaching and learning practices, the NECT Edhub has collaborated with the University of Johannesburg in conducting 4 robotics and coding pilots in public school classrooms and with the pre-service teachers. Through these studies, it was possible to explore how robotics and coding may help build competencies for a changing world in learners, such as critical thinking, collaboration, creativity and communication. The exploration extended into preparing pre-service teacher with skills to integrate robotics and coding, as a tool, into their practice. This compendium is a collection of short articles sharing the emerging learnings from these pilots.

This summary offers ten key insights derived from the four case studies presented in this compendium focusing the on areas of teaching and learning robotics and coding in the classroom and the need for teacher development.

1. Effective teacher training is an essential pre-requisite to the integration of robotics and coding into schools.

2. Robotics and coding should be introduced in initial teacher development programmes to adequately prepare future teachers.

3. Extending student-teachers' preparation through coding clubs was an important mechanism to build their confidence in coding and they learnt additional skills.

4. Through coding clubs, student-teachers learnt that teaching: can be fun; it should be flexible; and that teacher demeanour is important.

5. Learners develop good attitudes towards scientific inquiry as they design and make various workable learning artifacts using robotics and coding resources.

6. Collaborative learning as a preferred pedagogical strategy when using robotics kits provides learners with an opportunity to develop and improve their communication and collaboration skills, creativity, computational thinking, and critical thinking in solving problems. Collaborative learning also promotes positive interdependence, accountability, group processing and the development of good social skills.

7. Robotics and coding can intentionally be used as a mechanism to teach subject related content and simultaneously afford learners opportunities to develop competencies for a changing world through the design of mindful engaging learning experiences.

8. Participating in coding and robotics activities stimulate positive learner sentiments with an observable increase in learner excitement, and happiness.

9. Teachers view learners in a new light as previously unobserved learning potential is revealed during robotics and coding activities.

10. Appropriate yet ergonomic resources must be made accessible to learners within schools to ensure the content is taught in the most engaging manner to stimulate not only 21st century learning, but also positive sentiments and intrinsic motivation amongst learners.

These key ideas invite debate, engagement and action by education policy makers and educational professionals, teacher training institutions as well as learners and stakeholders at all levels.

1 Introducing Robotics & Coding into CAPS to foster 21st Century Learning

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By Nthato Moagi (CRSP dsgn) and the NECT, EdHub.

21st-century learners need to be inquisitive, creative, explorative, reflective, and agile in learning – these competencies and skills are developed through the execution of certain actions. However, in the South African context, socio-economic challenges faced by some learners directly impact their ability to access the resources necessary to develop these required skills and competencies for a fast-changing world. The belief that learners innately possess these qualities, together with a belief that access to technological resources is the right of every 21st -century child, has formed part of the foundational desire of CRSP dsgn to develop a mechanism that can support learners to develop the competencies for a fast-changing world through mindful and engaging learning experiences.

Description of Intervention

With the above in mind, CRSP dsgn and the NECT Edhub conducted several pilot studies from 2018-2021 to: (1) determine if learners' working with robotics kits facilitates the development of competencies for a fast-changing world, such as critical thinking, communication, curiosity, and problem-solving techniques; (2) understand the nature of collaboration among learners in project-based learning; (3) observe teachers' uptake of and experience with the R&C kits we provide them.

Sandbox R&C Pilot and Intervention Key Metrics

METRIC	2018	2019	2021
Schools	5 Primary schools	2 Primary schools	4 Primary schools
Phases	Intermediate & Senior Phase	Intermediate Phase Only	Intermediate Phase Only
Grades	**2 grades:** ○ Grade 6 ○ Grade 7	**2 grades:** ○ Grade 4 ○ Grade 6 ○ Grade 7	**1 grade:** ○ Grade 6
Subjects	● Natural Science & Technology (Grade 6) ● Technology (Grade 7)	● Natural Science & Technology (Grade 4 - 6)	● Natural Science & Technology (Grade 6)
Dosage	**Variable (based on term's ATP):** ○ Related informal lessons ○ Related mini-PATs ○ 75 total lessons in 2+ terms	**Variable (based on term's ATP):** ○ Related informal lessons ○ Related mini-PATs ○ Additional coding sessions ○ 82 total lessons in 1+ term	**Variable (based on term's ATP):** ○ Related informal lessons ○ Related mini-PATs ○ Additional coding sessions ○ 8 total lessons in 1+ term
No. of kits	20 per School (100 Kits in total)	50 per School (100 Kits in total)	22 per School (88 Kits in total)

No. of learners	± 1600	± 891	± 320
No. of teachers	19	10	8
Type of training	○ In-person ○ Synchronous	○ In-person ○ Synchronous	○ Synchronous ○ Asynchronous
Support type	● WhatsApp group chats ● Worksheet preparation ● Demonstration lessons	● WhatsApp group chats ● Worksheet preparation ● Demonstration lessons ● Increased on-site support visits	● WhatsApp group chats ● Worksheet preparation ● Demonstration lessons
Training methodology	○ Grouped school workshops ○ Individual school workshops	○ Individual school workshops ○ Individual teacher sessions	○ Group teacher sessions
Training sessions	● 18x total training workshops ● At start of Term 2 ● At start of Term 3 ● Ad-hoc sessions during school downtimes (post exams, prior to school closures).	● 4x workshops at start of term 2 ● Continuous support visits throughout pilot (± 22 sessions)	● 13x total training and support workshops ● Middle of Term 2 ● Continued in Term 3

In 2018, the NECT Edhub and CRSP dsgn implemented an exploratory R&C pilot where LCERT kits were used to test the integration of Robotics & Coding content into Grade 6 Natural Science & Technology CAPS and Grade 7 Technology CAPS classrooms. This pilot was further improved in 2019 to collect an extensive amount of both qualitative and quantitative data in order to assess the educational impact of CRSP dsgn's learning approach and LCERT resources within two of the schools from the 2018 pilot study. The research evidence from the two pilots suggested that the CRSP dsgn's approach and educational robotics resources could be successfully integrated into traditional classrooms to support and enhance the existing Natural Science and Technology CAPS. The DBE's draft Grade R-9 Coding & Robotics CAPS curriculum represented a unique opportunity to fully integrate robotics into mainstream classrooms without compromise; therefore, the findings and learnings from the 2018-2019 pilot studies were utilized to develop the strategic and technical approaches for the 2021 Sandbox Robotics & Coding intervention.

Above are images of the CRSP Low-cost Educational Robotics Toy (LCERT)

Key insights

The following key learnings and findings emerged from the implementation of the Robotics & Coding pilot studies:

Inadequate digital literacy a bottleneck to effective teacher training

Insights gathered from 2018-2021 pilot studies have demonstrated that digital literacy levels are very low amongst teachers, which presents a big stumbling block for teacher development and support in Robotics & Coding. Improving teachers' digital literacy and designing effective means of teacher training are essential prerequisites to the integration of Robotics & Coding into schools. WhatsApp emerged as the most effective digital tool for remote teacher support and communication. At various stages of the intervention, teachers requested that most of the content (i.e., lesson plans, worksheets, website links and videos) be shared via WhatsApp. Shorter videos shared via WhatsApp yielded greater engagement and positive sentiments from teachers; the videos were most effective when shared right before the teachers needed to implement the specific content that the videos covered (i.e., Just-in-Time training).

Practical tutorials were more effective teacher development tools

While teachers did not experience too much trouble building simple electric circuits using conducting wires, the majority of them experienced difficulty grasping the fundamental concepts behind building circuits using breadboards. Despite a number of training sessions and tutorials spent on this topic, it proved challenging to reach an adequate level of competency. Shifting training session focus to practical tutorials, instead of theoretical lectures, proved to be a more effective teacher development strategy since it facilitated the identification of and provision of assistance to address troublesome areas.

Majority of learners expressed positive sentiments toward the R&C group project

Most learners expressed that using R&C kits during the group project elevated their curiosity, excitement, and happiness. Robotics & Coding resources, lessons and projects stimulate positive sentiments amongst learners, with excitement and happiness being recorded from 62% and 30%, respectively. In addition, more than 94% of learners expressed intrinsic motivation toward Robotics & Coding after engaging with the content and resources during classroom lessons. Younger learners were identified to be more responsive towards robotics and coding content and resources, when comparing grades 4, 5 and 6 - which indicated the following trend: levels of positive sentiment and motivation increase with a decrease in age (grade).

Robotics & Coding facilitates the development of competencies for a fast-changing world

Results and observations from the 2018-2019 pilot studies support the claim that robotics & coding facilitates the development of competencies for a fast-changing world in learners. During the pilot studies, it was observed that in general more learners exhibited competencies for a fast-changing world such as Critical Thinking and Creativity when engaging in informal lessons (i.e., play, and exploration), and less when completing formal and project-focused lessons. Nearly 80% of teachers observed increases in learners displaying higher levels of learning (Bloom's Taxonomy), while 95% of them observed higher and better learner collaboration and communication when implementing Robotics & Coding lessons. Furthermore, it was observed that younger learners exhibit competencies for a fast-changing world such as Critical Thinking, Curiosity and Creativity more frequently than older learners.

Adequate dosage and ergonomic resources are required to improve learning outcomes

Although evidence from the pilot studies demonstrates that Robotics & Coding can effectively be integrated into Natural Science & Technology CAPS, especially during Terms 3 and 4 of Grades 4-7. The studies have also indicated that having a stand alone Robotics & Coding subject is essential since this will ensure adequate dosage and consistent implementation throughout the academic year. Furthermore, learners and teachers have reported that plug-and-play modular electronic components are more ergonomic than discrete breadboard electronics components.

Conclusion

The CRSP dsgn Robotics & Coding pilots have successfully demonstrated that integrating Robotics & Coding into CAPS may be an effective means to foster 21st-century learning amongst learners to prepare them for a fast-changing world. Various considerations such as effective teacher training and support, and adequate dosage of learners' exposure to R&C kits will need to be addressed to facilitate the effective implementation of Robotics & Coding into CAPS classrooms. Once these have been addressed, appropriate yet ergonomic resources will need to be made accessible to learners within schools to ensure the content is taught in the most engaging manner to stimulate not only 21st-century learning, but also positive sentiments and intrinsic motivation amongst learners. Once all these conditions are met, these learners will develop into citizens that are empowered to innovate and create solutions that contribute to the upliftment of their communities and broader society in the future.

Learners showing amazement during a robotics demonstration

2 Exploring the Nature of Collaboration in Grade 6 Natural Sciences and Technology Robotics and Coding Learner Group Projects

2 Exploring the Nature of Collaboration in Grade 6 Natural Sciences and Technology Robotics and Coding Learner Group Projects

By Patrick Makhubalo (Master's student in ICT in Education at the University of Johannesburg Faculty of Education).

When learners work together to solve problems using robotics kits, they often explore beyond the task itself evoking multiple possible solutions before settling on the most variable option. Through such projects, learners develop good attitudes towards scientific inquiry as they design and make various workable learning artefacts. Using robotics kits in group projects enables learners to develop skills such as problem-solving as they engage in the learning experience, generating new ideas whilst supporting other learners that struggle in using robotics thus enhancing collaboration. This research study was conducted to answer the question: What is the nature of collaboration in Grade 6 Natural Science and Technology robotics and coding learner group projects? Research evidence suggests that learners can develop competencies for a fast-changing world, such as collaboration and computational thinking, through collaborative learning with robotics kits. As such, the research aimed to fully understand the various patterns of collaboration and what these patterns tell us about learning Grade 6 Natural Science and Technology using robotics kits.

Description of the Intervention

Four schools participated in the Edhub Robotics & Coding intervention, three in the Waterberg district of Limpopo and one affiliated with the University of Johannesburg. The intervention comprised of training of teachers in Robotics & Coding applications and the in-lesson integration of this knowledge and technology; provision of lesson plans of the curriculum-prescribed practical tasks that the teachers had selected to do with the learners; teacher support throughout the implementation process; provision of Robotics and Coding kits which Grade 6 learners used in Natural Science & Technology (NS&T) small group projects in class. Eight teachers were trained in four online workshops and forty (40) Grade 6 Natural Science and Technology learners were selected to participate in small group projects using robotics kits. Data collection comprised of eight video observations of project-based activities involving eight groups of five learners each, as well as four individual teacher interviews. The teachers were interviewed at the end of each classroom observation to gain their impressions of learner collaboration as observed during group work involving the use of robotics kits.

CRSP ROBO Micro:bit V2.0 Kit shown in silver colour

Emerging Key Insights

The nature of collaboration with robotics and coding in Grade 6 Natural Sciences and Technology was observed and analysed based on verbal communication, non-verbal communication and knowledge on robotics and coding. To fully understand the nature of collaboration when learners use robotics kits in Grade 6 Natural Science and Technology group projects, we rely on the Computer-Supportive Collaborative Learning (CSCL) framework in the analysis of observations. The main findings and insights from implementing the robotics and coding intervention include:

Learners freely shared ideas without fear of failure

One of the teachers made a point to encourage learners to put their ideas together and to give each other a chance. She reinforced the message that it was good to try different things even if it did not work. Another teacher commented: "Engagement was good simply because they were free and wanted to be seen to be working together and not to just dismiss an idea before trying it. Let us not tell each other that it will not work, try it first. If it does not work, let us start afresh. There is nothing wrong with getting it wrong as long as in the end, it works."

Learners increasingly became invested

As the task became more serious and artifacts started to be constructed, the learners' interest intensified. One of the teachers stated: "They were so creative and invested. They even asked for more time to keep going at the end of the lesson." A teacher observed some competition between groups and within groups: "If you are telling them what to do, they do not have a view for themselves. You need to tell them what you want in the end, not how to do it. They need to figure it out for themselves and say to each other that when my idea is not working, someone else must get a chance to try as they compete with each other. They were eager to get good results compared to other groups. If all subjects were as practical as the robotics kits, our learners will go far. They touch, they put things in practice, and they get so happy when they get a result."

Learners gained their teacher's respect

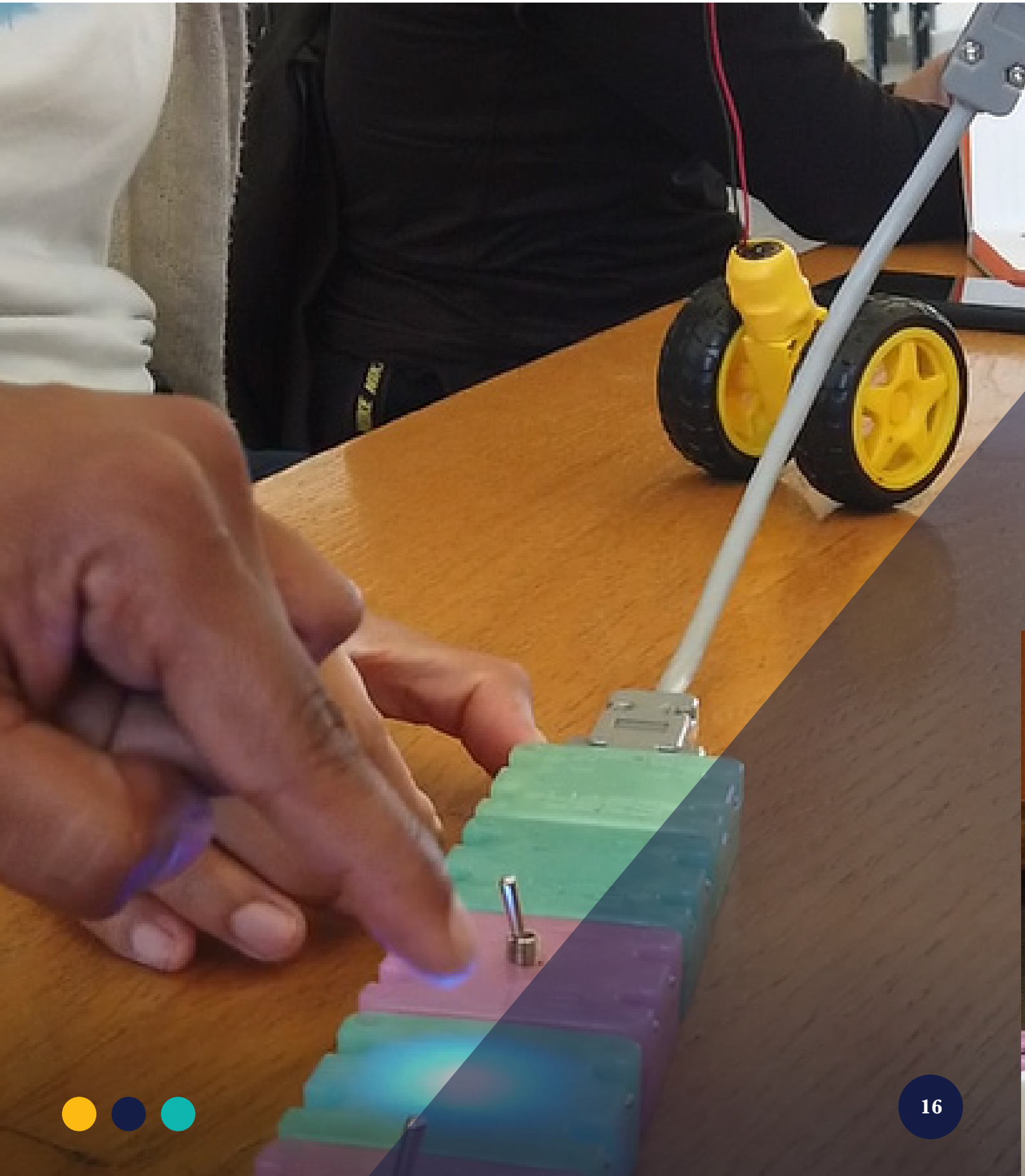
A teacher was surprised by her learners and said: "Some of these learners have talents and can go very far using these robotics materials. They showed me as their teacher more than I knew what was possible. They were more knowledgeable than me and I learned something new from them. Because of this, I started to respect them more."

In subsequent data collection phases, we will delve deeper into the nature of collaboration and will focus more on the opportunities for project work using robotics and coding in grade 6 Natural Science and Technology. Learnings from this research project can help Initial Teacher Education (ITE) institutions, researchers, and practicing teachers understand the patterns of collaboration when learners use robotics kits in project-based tasks and thus strengthen the design of such activities. Lastly, the research insights can be used to inform the training for in-service teacher development in integrating robotics and coding learning tools in teaching and learning.

Conclusion

Collaborative learning has been seen as the learning approach where learners make meaning of their learning through sharing of ideas, building knowledge together as a team and finding innovative ways to solve problems. Research evidence also suggests that collaborative learning encourages learners to engage and participate effectively in their learning. Our research findings highlight that collaborative learning with robotics kits, provides learners with an opportunity to develop and improve their communication and collaboration skills, creativity, computational thinking, and critical thinking in solving a problem. Therefore, we recommend that the South African Department of Basic Education (DBE) provides training to teachers on how to incorporate collaborative learning in teaching and how to teach STEM subjects with robotics kits as a learning tool.

3 Using Practical Robotics Experiences to Develop Student Teachers' Knowledge for Integrating Robotics in STEM Lessons



3 Using Practical Robotics Experiences to Develop Student Teachers' Knowledge for Integrating Robotics in STEM Lessons

by Kenneth Baloyi (PhD student, Faculty of Education, University of Johannesburg).

Educational robotics have affordances for teaching STEM-related subjects and developing competencies for a changing world. Teachers and pre-service teachers need to be trained to use educational robotics to teach content and develop learner competencies. This research was conducted to answer the question: What are the emergent learning design principles derived from a robotics intervention with pre-service teachers to incorporate competencies for a changing world when teaching STEM subjects? The research aimed to derive learning design principles from a robotics intervention to guide lesson design of intermediate pre-service teachers in STEM subjects. Furthermore, it sought to explore how pre-service teachers integrate robotics knowledge when planning Natural Sciences and Technology lessons.

Description of Intervention

Twelve final-year intermediate phase pre-service teachers at the University of Johannesburg were selected to participate in the research. All the participants specialized in Natural Sciences and Technology as a subject in their third year of study. Four workshops were designed over two months to introduce participants to educational robotics; to provide them with practical experiences with the low-cost educational robotics kits; and allow them to incorporate robotics activities when designing NS and Tech lessons.

Key Emerging Insights

Six learning design principles were initially derived from literature and then refined in the study. The learning design principles were grouped under knowledge areas based on the Technological Pedagogical Content Knowledge (TPACK) framework. Findings revealed that pre-service teachers' experiential acquisition of robotics knowledge precedes their knowledge to integrate robotics when teaching Natural Sciences and Technology content.

Participants gained knowledge of robotics affordances for teaching and learning

Participants reported that before they participated in the research, they had no knowledge of or previous training in educational robotics. However, based on their interactions with the robotics kits during the intervention, they reported having learned what educational robotics is and how it could be used to teach subject content and develop competencies for changing world in learners. Although they engaged only with the robotics kit chosen for the study, they felt that what they learned could be used with other similar robotics kits. Therefore, what they learned was transferable to other robotics kits.

Collaborative learning was the preferred pedagogical strategy

The lesson plans revealed that when pre-service teachers design lessons that incorporate robotics, they prefer using learners' collaboration. The lesson plans revealed that they created ample opportunities for collaboration. Participants also felt that learners should be given enough shared resources and must be allowed to manage their own time when completing group projects.

Robotics was intentionally used to teach subject content and develop competencies

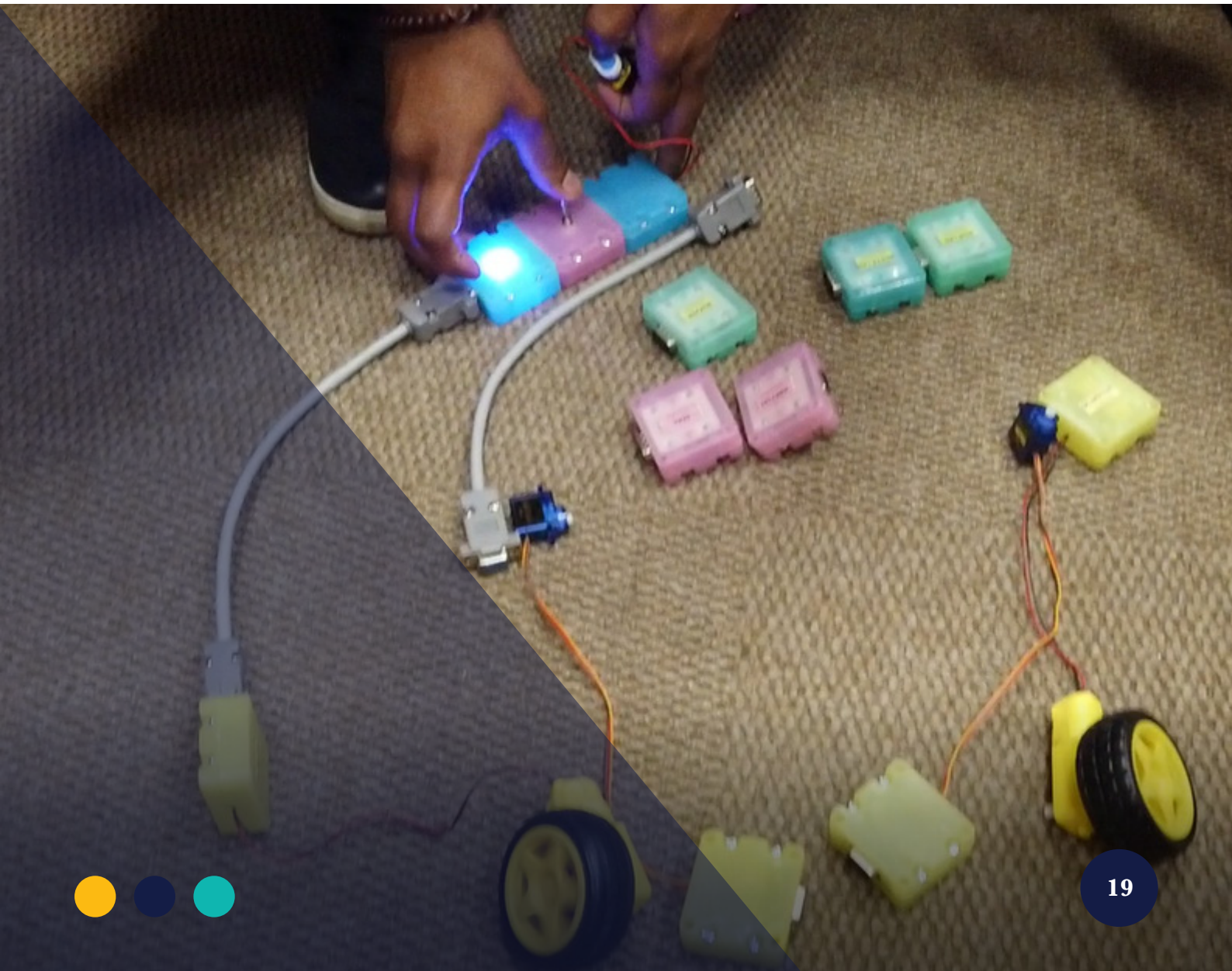
Participants were able to align the robotics kit to the content and competency objectives. When they integrated robotics into the NS and Tech lessons, they first considered the affordances of the robotics kits. After that, they scanned the subject content to match the robotics kit to relevant topics in the subject. The lesson plans also showed evidence of a solid intent to develop competencies. As already stated above, they saw collaboration as the best strategy to develop the competencies such as critical thinking and metacognition.

Practical experiences develop the required knowledge for integrating robotics

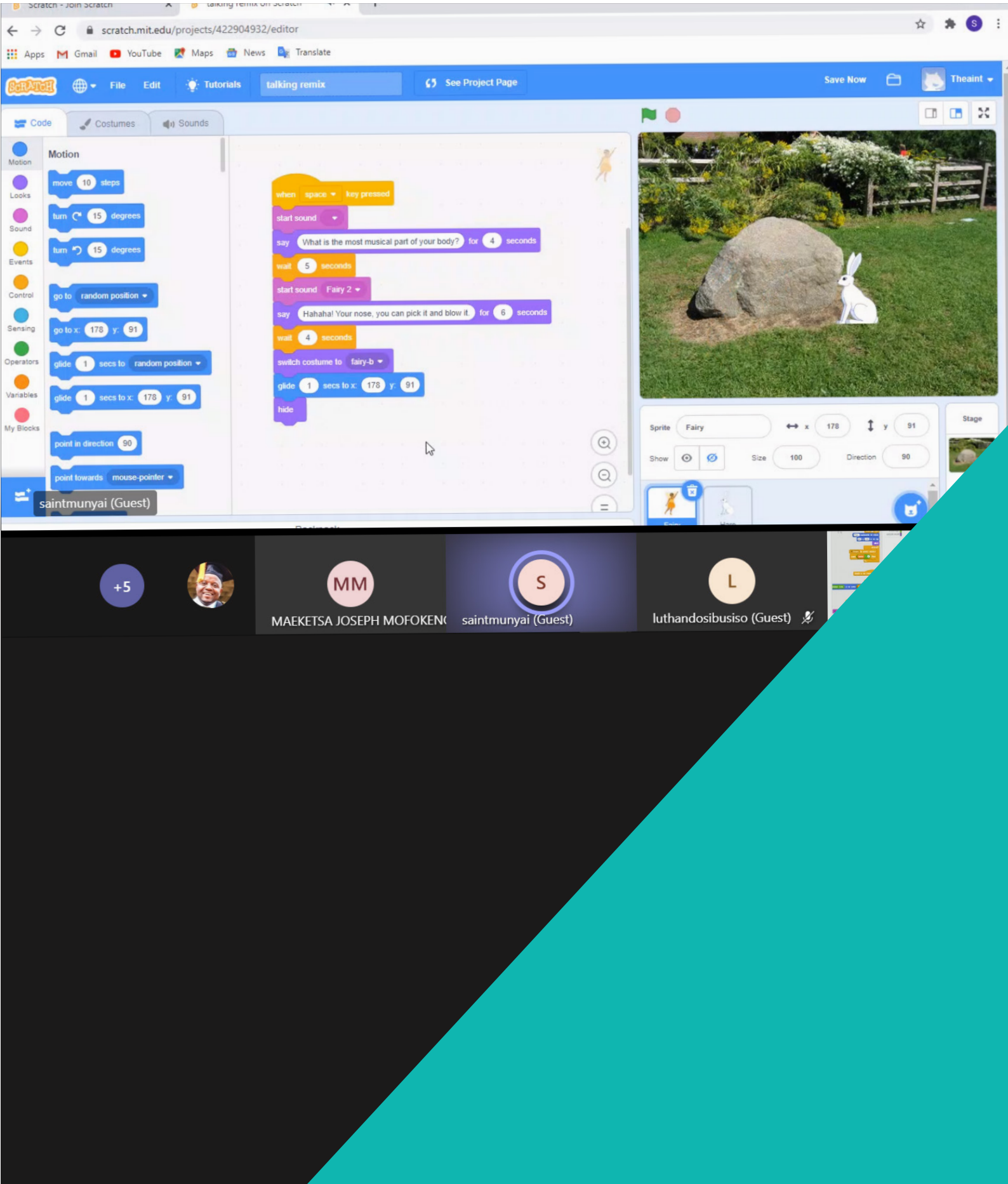
The majority of the participants felt that they gained knowledge of robotics and integrated it to teach content and develop competencies because they had playfully interacted with the robotics kits. Their experiences resulted in the ability to incorporate robotics. Participants further advocated for training that would allow teachers to experience robotics and provide opportunities for reflecting on their experiences. Through reflection, they could transfer their learnings when integrating educational robotics.

Concluding remarks

This research established that pre-service teachers acquired knowledge about the nature and affordances of educational robotics. They learned that educational robotics is helpful for teaching content while also developing competencies for a changing world through collaborative learning as a pedagogical strategy. Furthermore, participants' experiences with robotics kits led them to explore creative ways to integrate robotics into their lessons. Teachers of the robotics curriculum and those seeking to use robotics as a tool within the already existing subject can benefit from the learnings derived above. The findings can also inform the training of pre-service teachers and advance in-service teachers' professional development in teaching with robotics. However, the design of such robotics interventions should create an environment for teachers to learn through experiences with the robotics kits.



4 Empowering Student Teachers to bring the Fourth Industrial Revolution (4IR) into the Classrooms



4 Empowering Student Teachers to bring the Fourth Industrial Revolution (4IR) into the Classrooms

by Linford Molaodi (PhD student, Faculty of Education, University of Johannesburg).

With the onset of the COVID-19 pandemic, the University of Johannesburg (UJ), like many other institutions, implemented a recess that led to students' departure to their respective homes. Teaching was paused while academics prepared for emergency remote teaching and learning. During the full lockdown period, an informal online Scratch coding club (SCC) for pre-service teachers at the Faculty of Education was introduced. Creating an informal SCC was inspired by student teachers' request for a program that could address the anxieties, isolation, and boredom they experienced during the lockdown period. The feedback from the student teachers on their experience with the SCC was overwhelmingly positive. The lessons learnt during the implementation of the informal club informed the formal establishment of the project, Creative Coding @ UJ Faculty of Education (CC@UJFE), in the 2nd semester of 2020. This project was simultaneously conceptualised as a research project and this research study was intended to address the following question: What do student teachers learn from their participation in a "Scratch Coding Club" that could enhance their preparation for teaching?

The interest of the Faculty of Education in teaching creative coding to teachers, using the graphical programming language Scratch, stems from wanting to prepare teachers for a rapidly changing world mainly due to the exponential advancement in technology, including artificial intelligence – the fourth industrial revolution (4IR).

This study investigated what student teachers learnt from their participation in the SCC to enhance their preparation for teaching. The student-teachers were registered in both PGCE and B.Ed programs of the institution's Faculty of Education – specialising in varied phases of schooling (foundation, intermediate, senior and FET) and subjects. The areas of specialisation (subjects) included African languages, English, Mathematics, Sciences and Commerce.

Description of Intervention

The SCC project sessions took place online on Saturday mornings, and Faculty of Education staff members and students facilitated the meetings. The facilitators are also available during the week to support the participants who require additional help with catch-up, should they miss a Saturday meeting. The students involved as senior facilitators and facilitators successfully completed an entire semester of involvement in the SCC (submitted portfolios), and they showed talent to be supportive and enthusiastic facilitators.

Data was collected from the 2021 and 2022 cohorts of student teachers who completed the 14-week duration of the SCC and submitted portfolios. There were 15 student teachers who submitted portfolios in the second semester of 2021 and 24 in the first semester of 2022.

Emerging key insights

The findings indicate that student teachers' participation in the SCC had a significant contribution to their learning experiences. Student teachers indicated that during their participation in the SCC they experienced: joy, received sufficient support from their peers (including facilitators), learnt several skills and lessons about teaching. This study is still in progress. Therefore, below are a few emerging findings:

Participating in the SCC was joyful

Students stated that participating in the SCC was a joyful experience. They asserted that their experience was fun, interesting, fulfilling, and exciting.

Student-teachers received ample support from facilitators and peers

Students felt they were cared for and supported by the facilitators and peers. Whenever they needed help, facilitators and peers were available to assist.

There were several skills learnt

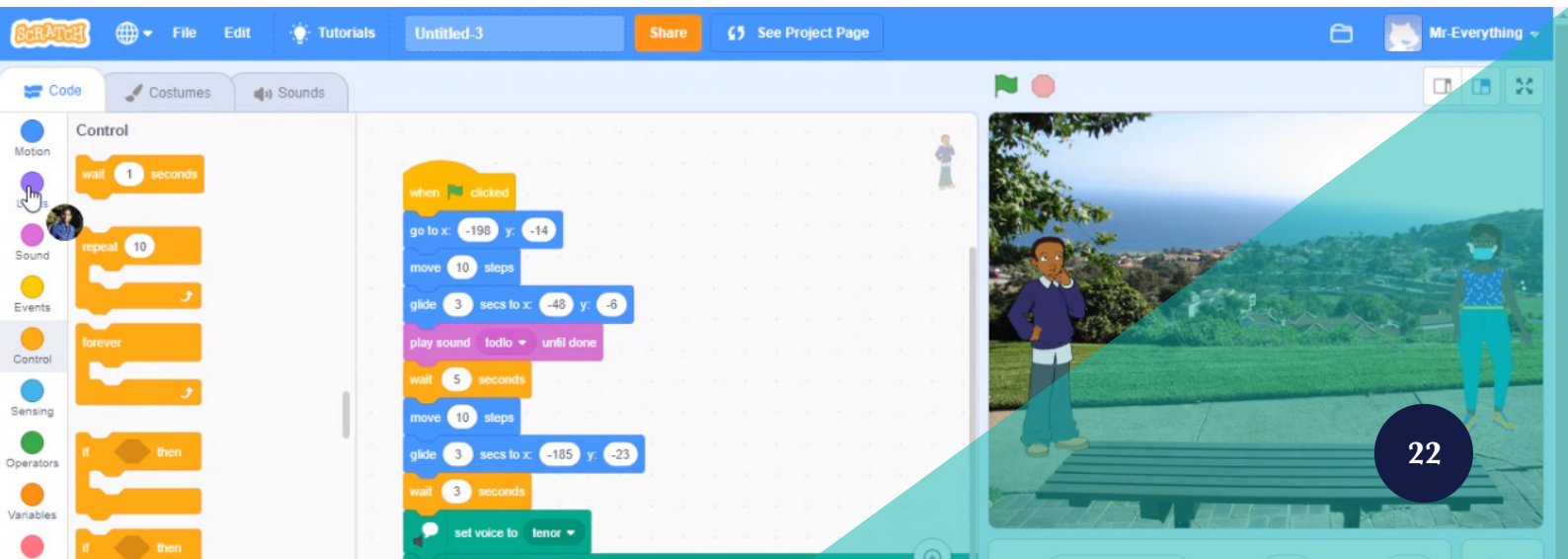
Students learnt several skills during the sessions. The skills include communication, problem-solving, collaboration and creative thinking; the latter two were predominant.

Student-teachers learnt some lessons about teaching

Student-teachers learnt that teaching: can be fun; it should be flexible, and that teacher demeanour is important.

Concluding Remarks

The establishment of the Scratch Coding Club – which initially commenced as an informal project to address anxiety and isolation during the full lockdown of the Covid-19 pandemic yielded positive results on the learning experiences of student teachers. Although the study is in progress, student teachers indicated that during their participation in the SCC they experienced; joy, received sufficient support from their peers (including facilitators), learnt several skills and some lessons about teaching. More student teachers will continue benefiting from these learning experiences as the SCC expands annually.



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