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DESIGNING AND IMPLEMENTING A SCIENCE TECHNOLOGY ENGINEERING ARTS AND MATHEMATICS PROGRAMME FOR PRIMARY SCHOOL TEACHERS

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Abstract

Globally, the transition from Science, Technology, Engineering and Mathematics (STEM) to Science, Technology, Engineering, Arts and Mathematics (STEAM) is being viewed as a change in education. A discussion on the issues linked to STEM and STEAM education, including the professional development of teachers and a model for a STEAM Programme, called Journeying into Steam focussing on Teacher Professional development and the school-based implementation is presented. A range of partners/organisations who worked with teachers in teacher projects/fieldtrips/ teaching were engaged in designing and implementing the programme to primary school teachers. The programme has three phases: teacher fieldwork; school-based and student and community focused Service-Learning.

Keywords: *primary school teachers, science education, service learning, South Africa*

Introduction

Globally, the transition from Science, Technology, Engineering and Mathematics (STEM) to Science, Technology, Engineering, Arts and Mathematics (STEAM) is being viewed as a change in education with the purpose to develop today's learners as future leaders, innovators, scientists, engineers, educators, entrepreneurs, and learners of the twenty-first century. Wade-Leeuwen et al. (2018) indicate the 22nd century skills – connection, care, community, and culture that learners may develop in the process of learning STEAM. In exploring the current thinking and actions, including information concerning STEAM in the South African context, a Google search in March 2022 provided the following topics: Time for SA Schools to Embrace Steam Education in 2020; Empowering our youth through education: STEM versus STEAM; STEAM education classes in South Africa for 100. The concern in the current South African context is, only 5% of South African schools provide art as a school-leaving subject (van Gaalen, 2020, p. 1). Also, STEAM is minimally introduced in all schools. The policies and practices for the development and implementation of STEAM programmes for capacitation of citizens is a priority in the SA context. The South African Department of Science and Technology, Basic Education and Higher Education in South Africa have indicated in their policy documents that STEAM education is important, is to be valued and it is required to boost socio-economic development in South Africa, including the development of learners for the twenty-first century. The purpose of this article is, firstly, to discuss the issues linked to Stem and STEAM education, including the professional development of teachers. Secondly, a model for a STEAM Programme – Journeying into Steam focussing on Teacher Professional development, school-based implementation, and community - is discussed.

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STEM and STEAM

STEM and STEAM both focus on scientific concepts through various approaches and strategies of inquiry and problem-based learning methods. The concept STEM education covers a broad range of contents and practices,

> it is a multi-disciplinary approach to learning that can be used to integrate knowledge from the separate STEM subjects into existing science, technology and engineering, or mathematics instructional programs using project-based learning, engineering design-based studies, or problem-based learning strategies (Sutaphan and Yuenyong 2019, p. 3)

STEAM education is viewed as curriculum reform and an alternative to STEM pedagogy. STEAM education includes the learning and use of Arts (humanities, language arts, dance, drama, music, visual arts, design, and new media) and adopts a transdisciplinary approach to learning. This alternative is viewed as a creative process and an inspiration for innovation (Liao, 2019). The STEAM approach is where risks are taken with collaborative engagements, experiential learning and perseverance in problem-solving and critical thinking skills are enhanced in learners (Education Closet, 2019). In this STEAM education process learners are thereby enabled to have a multifaceted, open-mind, and an inclusive way of thinking about the world around them. A significant aspect is the belief that children cannot be achievers in Mathematics and Science and be creative, is challenged (Mann, 2006). Furthermore, learning in STEAM, though should start early in the schooling career. Rosenberg (2021, np), "Research shows that early grades are a critical age to develop an interest in computer programming. It also shows that some of the strongest influences to attract girls to the computing fields is early exposure." So, "the main difference between STEM and STEAM is STEM explicitly focuses on scientific concepts. STEAM investigates the same concepts but does this through inquiry and problem-based learning methods used in the creative process" (Wade-Leeuwen, Vovers & Silk, 2018, p. 1).

STEAM and Teacher Professional Development

In working with STEAM, the role of the school community (teachers, learners, and stakeholders), is recognised. The collective engagement of the community, particularly the role of specialists in specific fields, in the enhancement and progress of teachers and learners, and the role that teachers play in learner progress, is critical. So, in addressing professional development of teachers in STEAM, certain aspects require attention: it is a new concept for both teachers and learners, how to engage teachers in learning about it through professional development programmes, how to entice and sustain teachers' interest in their continued use of it in the classroom and access to and use of resources. Furthermore, the teachers are expected to be able to: enhance the spark of learners to learn; have appropriate knowledge and skills on the use of equipment and technological processes; have a sustainable learning for life; foster knowledge and skill development in an inclusive manner where inquiry-learning and problem-solving of local environmental issues are engaged. What is to be achieved, is for teachers and learners to be inspired and knowledgeable, and as a learning community to be working with sustainable living, knowledge and practices. Herro and Quigley (2016) explored teachers' experiences in a STEAM programme. They established that participant teachers increased their understanding of how to teach STEAM contents

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and that the STEAM activities used during professional development helped to change the teachers' classroom practices. Also, teachers engaging with learners in science initiatives, for example a Science club, and scientific investigations may be conducted in a fun and engaging manner (Mintz, 2004).

The STEAM Programme – Journeying into STEAM

In South Africa, the schooling system comprises four phases: Foundation phase (Grades R – 3); Intermediate Phase (Grades 4-6); Senior Phase (Grades 7-9) and the Further Education and Training phase (Grades 10-12). In planning the STEAM programme, we considered engaging teachers and learners with the Intermediate phase. We consulted the South African Curriculum – Curriculum and Assessment Policy Statement (CAPS) for the Intermediate phase, wherein the statement written, "Science as we know it today has roots in African, Arabic, Asian, European, and American cultures. It has been shaped by the search to understand the natural world through observation, testing and proving of ideas, and has evolved to become part of the cultural heritage of all nations" (Department of Basic Education, 2011, p.8), served as the essential backbone for all the integrated disciplines in STEAM and to what and how the programme was to be planned. Also, the Intermediate phase is important for developing and challenging learners with more technical and academic skills and advanced assessments, as they have increased competences to learn and apply abstract thinking, in comparison to learners in the Foundation phase. Furthermore, the STEAM programme to be designed should consider teachers' knowledge and competences, use of alternative pedagogies, time frames, the competence and specialisation of the facilitators (who are they and the disciplines that they teach), including contextually and culturally relevant topics.

In deciding on the programme, the choice of partners that were to be engaged with the design and implementation of the programme was considered. The partners included University of KwaZulu-Natal, Science and Technology Education Centre (Stec@ukzn); Eskom Expo for Young Scientists; Centre for the Advancement of Science and Mathematics Education (CASME); Wildlife and Environment Society of South Africa (WEESA) and academics in the Science and Technology Education and the Mathematics and Computer Studies Education Clusters, University of KwaZulu-Natal. The partners were selected based on their specialisations and engagement with communities. The partners met to design and plan for the implementation of the programme and also to identify the schools to be selected. Eight schools in a rural area, approximately 200km from Durban were identified, as the Education District Manager requested that we work with schools in that district. All teachers teaching the various subjects in the Intermediate phase from each of the eight schools were selected, e.g., Languages, Natural Sciences, Social Sciences, Mathematics, Technology etc. Five to six teachers in each of the eight schools agreed to participate in the programme, a total of 40 teachers.

All partners collectively designed the programme and considered the basic principles of STEAM and the current curriculum for the Intermediate phase, as presented in CAPS for the Intermediate phase (Grades 4 – 6). The outcomes, nature and context, duration and time frame for the programme were considered.

The Outcomes of the Programme

1. Demonstrate an understanding of the knowledge and teaching practices in the context of the subjects - Science, Technology (Engineering topics are included here), Languages, Arts and Mathematics in the Intermediate phase.

2. Develop knowledge and practices of STEAM in a locally, relevant context with global significance.
3. Demonstrate an understanding of the knowledges (inclusive of western and indigenous) and practices, including the role of STEAM education for contributing to enhanced, transformative teaching and learning.
4. Reflect on the integration of knowledge and practices of STEAM and its integration in the CAPS curriculum.
5. Engage in the co-construction of sustainable projects with learners, school community and pre-service teachers.

The duration, nature and context, and timetable of the programme were informed by the literature and current programmes implemented in South Africa. The programme was over six months duration and had three phases. Phase one, Teacher fieldwork based referred to as Learning and Sharing was the start of the programme. Phase two, School-based referred to as Classroom practices was three months after phase one. Phase three was student and community-focused Service-Learning was planned for presented during months five and six. In working with the nature and context of the programme, aspects considered - there should be prolonged engagement, participatory active learning, the use of an inquiry-based approach in authentic contexts, writing of reflections, constructing the knowledge, and developing the skills of how to use and also use appropriate equipment and tools, the presence and guidance with professional learning communities (PLCs).

Phase One (Learning and Sharing) with teachers and all facilitators was over three days and two nights at an Environment Centre (Twin streams), approximately 10 kilometres from all the schools that were selected. Resources and training manuals were compiled, accessed and used, engagement of teachers with professional facilitators, use of an Inquiry-based teaching and learning approach, conducting investigations in ecosystems and demonstrations and applications of sustainable living technologies, were actioned. Also, this phase focused on how limited resources could be used to teach and for learners to use in projects, how Robotics and Coding may be taught as unplugged (coding without a computer, in areas where there is no electricity), art experiences of observing nature and representing it in a visual form, forming and engaging learners in e-Clubs and Eskom Expo for Young Scientists (where learners engage in identifying a problem in their environment and design investigations to solve the problem in an active engagement manner, using science process skills and inquiry-based approach.

The programme with the times, topics and facilitator names is presented in Table 1 below.

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Table 1
STEAM Programme – Phase One

STEAM	**PROGRAMME**
Time	**Actions and Roles and Responsibility**
22nd October 2021 13h30- 14h00	Teachers will be met by WESSA staff - Kevin Lakani and Raymond Ngubane to be transported to Twin Streams
15h30	Arrival, Settling in at Twin Streams and Ice-breaker
15h45 – 18h00	Session 1 – Finding our way in STEAM Education – Why, What and How? Training manual
18h00 – 19h00	Supper
19h00 – 20h00	Campfire Stories linked to STEAM and Marshmallow braai and Reflection session
23rd October	
8h00	Breakfast
9h00 – 11h00	Inquiry-based teaching and learning; investigations in ecosystems; sustainable living technologies. Instruction by professional instructors. Kevin Lakani and Raymond Ngubane
11h00 – 11h30	Tea and Reflections in a Journal Dr Angela James
11h30 – 13h00	Teachers (an icebreaker session). Teacher workshop using limited resources, robotics and coding unplugged (coding without a computer). Dr Tanja Reinholdt
13h00 – 14h00	Lunch
14h00 – 15h30	Eskom Expo for Young Scientists - Expo presentation and Discussion. Practical Investigation and Report Back. Ms Nalini Dookie
15h30 – 16h00	Tea
16h00 – 18h00	Fieldwork – Ecosystems and Art experiences Kevin Lakani and Raymond Ngubane
18h00 – 19h00	Supper
19h00 – 20h00	The Global Game – Environmental Sustainable Actions and Reflections Kevin Lakani, Raymond Ngubane and Dr Angela James
24th October	
8h00 – 9h00	Breakfast
9h00 – 11h00	Fieldwork – Ecosystems and Investigations Kevin Lakani and Raymond Ngubane
11h00 – 11h30	Tea
11h30 – 12h30	Fieldwork – Ecosystems and Investigations Kevin Lakani and Raymond Ngubane
12h30 – 13h30	Lunch and Reflections and Evaluations Kevin Lakani, Raymond Ngubane, Dr Tanja Reinhardt, Ms Nalini Dookie and Dr Angela James

Phase Two was school-based and concerned with classroom practices (implementation) and school-based sessions. The facilitators had to travel to the eight schools, on scheduled dates to visit the teachers and learners. A full session of approximately four hours was spent at each school. The plan was that teachers were to be observed implementing STEAM with the learners. The reality was that when teachers were informed that they will be observed they stated that they had completed some work and presented evidence – leaner activities in their books, models made by learners and drama activities presented to the class groups. The facilitators observed the books, models, etc. and had discussions with the teachers re the implementation and the required practices including revisions/ modifications to be made. The school initiatives in authentic contexts were included - the Science show for all learners; the observation and discussions re the WESSA on Wheels with teachers and how teachers could join the organisation and their schools could be Eco-schools including the demonstration of environmentally sustainable technologies and processes, for example,

a solar oven/cooker, a water heater, a water harvesting system. CASME Mathematics focused on hands-on learning experiences and the use of Maths games. The e-STEAM Club presentations and projects were explained and exhibited to the learners and teachers. There was an initiation and establishment of a Science club at some of the schools. The engagement with art in STEAM was also planned and implemented. The teacher capacity development and learner group enhancement for the Eskom Expo for Young Scientists planning, preparation, conduction and presentation of learner projects was planned, and ideas linked to problems in the particular school contexts, were shared.

Table 2
The Timetable for Phase Two – School-based Programme

	Classroom 1	Classroom 2	Classroom 3
	Grade 4	**Grade 5**	**Grade 6**
08h30	Arrival, Setup and Welcome	Arrival, Setup and Welcome	Arrival, Setup and Welcome
09h00 – 09h45	CASME	Eskom Expo	WESSA
10h00 – 10h45	Eskom Expo	WESSA	CASME
11h30 – 12h15	WESSA	CASME	Eskom Expo
12h30 – 13h00	Science Show – STEC Dr T. Outside (weather permitting)	Science Show – STEC Dr T. Outside (weather permitting)	Science Show – STEC Dr T Outside (weather permitting)
	Departure	Departure	Departure

Phase Three, student and community-focused Service-Learning was concerned with university students engaging with community members in a participatory manner to work with Service-Learning and Entrepreneurial experiences, where community activities for solving community issues were to be as presented and discussed. Students were expected to be of service with the community for 25 hours and to write reflections on their experiences in their reflective diaries. This phase did not take place due to COVID.

Summing-up

Many possibilities and challenges with the design and implementation of the STEAM programme were experienced. The disciplines of STEAM were represented by the various partners, and their experiences of having taught in the Intermediate phase was a strength to the development and implementation of the programme. Engaging these specialists in designing the programme was enriching for all present, as the ideation sessions were filled with relevant contextual actions and activities, some were used before in other settings, and others were collectively designed from the discussions and case scenarios presented. The programme designed was integrated across, with the environment as the common thread throughout. The three phases starting with teacher professional development were essential for them to learn about STEAM in a relaxed, fun and informative manner out in the field, away for the school setting, a different context, one they had never experienced before. The depth of learning, interest, active engagement and high spirits filled the air and provided much confidence and safe spaces to learn. The school-based phase required much planning and many suggestions on effective engagements were made focusing on time

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management for the various activities, learner engagements in the sessions – how could this be increased, language barriers when presenting to English second and third language speakers and the recognition for a translator to be present. In concluding, the two - phase programme was well received by all teachers and requests have been received from other schools – seeking engagement with the programme.

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