STEM practices in Science teacher education curriculum: Perspectives from two secondary school teachers' colleges in Zimbabwe

Christopher Mutseekwa

Bindura University of Science Education, Zimbabwe

Abstract: This study assessed how science, technology, engineering and mathematics (STEM) education is integrated in Science Teacher Education curriculum in Zimbabwe. An exploratory mixed methods research design, within the post-positivist paradigm, was used to guide the collection and analysis of data. Data were sourced from 18 Science teacher educators and 108 final year Science student teachers pooled from two secondary school Teachers' Colleges through a semi-structured questionnaire, follow-up interviews, focus groups and documents. From the findings, it was evident that although a lot was done to promote STEM literacy in the two colleges, integration of STEM education and practices into the science education curriculum was coincidental rather than planned. Participation in Science exhibitions at local and national level that was common and increased enrolment of teacher candidates in STEM subjects was viewed as major ways to promote the initiative in the Teachers' Colleges. However, support that targeted a teacher education STEM curriculum and integration/liaison with Engineering and industry was largely found lacking, suggesting the need for practices such as field-trips, work visits and partnerships that foster closer collaboration between colleges, schools, professional scientists and industry.

Keywords: *Industry liaison; Integration; STEM curriculum; STEM education; STEM literacy; Professional scientists*

Introduction

Many developed countries have embraced STEM (Science, Technology, Engineering, and Mathematics) in their educational reform agendas. Research (Andree & Hansonn, 2013; Anderson, 2014) has shown that STEM subjects are central to national economic development. Cognisant of this, developing nations such as Zimbabwe have put in place educational policies that prioritise and promote STEM in schools and teacher education curricula (Curriculum Framework for Primary and Secondary Education for Zimbabwe (CFPSE) (2015). A number of studies (e.g Cooke & Walker, 2015; Hasanah, 2020; Siregar et al., 2020; Tan & Leong, 2014; Thomasian, 2011; White, 2014) that have been conducted demonstrate the importance of studying STEM topics. Thomasian

(2011) provided the goals of the STEM agenda and articulated why STEM education is vital. The STEM agenda is double pronged: (i) increasing the number of students and professionals in STEM and (ii) increasing STEM proficiency for all students. According to Thomasian (2011, p.5):

> *The reasons are straight forward: STEM occupations are among the highest paying, fastest growing, and most influential in driving economic growth and innovation. Individuals employed in STEM fields enjoy low unemployment, prosperity, and career flexibility. In short, STEM education is a powerful foundation for individual and societal economic success.*

In other words, STEM education provides an opportunity for students to participate fully in an increasingly technology-based economy. STEM skills

are necessary to engage in a knowledge-based economy. Given the importance of the STEM agenda, research in the area should focus on the actual implementation of STEM education in teacher education colleges. If a firm STEM education foundation is laid in pre-service science teacher development, effective implementation of the initiative in primary or secondary schools is largely guaranteed. "New perceptions of and approaches to existing concepts by school-age children are dependent upon well-informed and well-trained teachers, and without such teachers, quality STEM education is unlikely to be successful" (Liu, 2020, p. 130). Thus, teacher education is key to the development and growth of the STEM initiative (Liu, 2020). There are several research studies that have been conducted that have focused on STEM education. For instance, the mapping of curriculum innovation in STEM schools (Tan & Leong, 2014) and perceptions of pre-service teachers about STEM approaches (Siew et al., 2015). Such research, replete with other issues on STEM has been carried out largely in developed countries. There is a paucity of literature and research on the subject in developing countries like Zimbabwe, particularly how the STEM initiative is perceived and handled within science teacher education curriculum.

The main contribution of this study is to assess how STEM education is integrated into the science teacher education curriculum in Zimbabwe and to demonstrate that its (STEM) full and effective integration requires deliberate infusion of practices and models for STEM. Integrating science, technology, engineering and mathematics remains something that is complex and challenging, and therefore requiring 'a new generation of STEM experts' (Hallstrom & Schonborn, 2019).

"Integrated STEM education is not just the grafting of 'technology' and 'engineering' layers onto standard science and mathematics curricula. Instead, integrated STEM education is an approach to teaching that is larger than its academic parts" (Rosicka, 2016. p. 4). STEM education is a relatively new initiative in many developing countries and its implementation is definitely in its infancy stage. Science teacher education in the STEM educational context aims to unpack the nature and understand it properly (Yildiz & Ozdemir, 2015). Capturing perspectives of those involved on how they conceptualize and implement STEM is therefore crucial. The study therefore focused on the major pedagogical approaches for STEM teaching, perceived requirements and expectations for STEM teacher education and how pre-service student teachers are specifically prepared to teach.

Literature Review

STEM includes all the umbrella disciplines of science, technology, engineering and mathematics. Cinar et al. (2016) posited that STEM is an interdisciplinary approach of teaching science, technology, engineering and mathematics using the engineering design process with ill-defined problems emanating in real-life (authentic) situations. Sanders (2009) as cited in Kelley and Knowles (2016) view integrated STEM education as an effort to combine some or all of the four disciplines into one class, unit or lesson basing on connections between the subjects and real-world problems. Integration can take many forms. Hurley (2001) in Guzey et al. (2016) presented five levels of integration; sequential (science and mathematics taught sequentially), parallel (science and mathematics taught simultaneously), partial (science and mathematics partially taught together), enhanced

(science or mathematics taught as major disciplines with the other used to support the teaching of the major) and total integration (science and mathematics taught together as major disciplines). Hurley's approach seems to limit integration to only two subjects, mathematics and science. Jacobs' (1989) six approaches elucidated in Guzey et al. (2016) are comprehensive. First, is discipline-based which entails separate subjects taught in separate classes. Second, is the parallel discipline in which separate disciplines are connected to the same themes or topic. Third, is the multidisciplinary approach where some disciplines are taught together. Fourth, is the interdisciplinary units in which deliberate connections are made among subjects. Fifth, is the integrated day where disciplines are taught under a theme or a problem emerging from the child's world. Finally, the sixth approach is a complete program. In this one total integration is achieved with a curriculum that is based on students' everyday lives. Jacobs says a combination of two or more of the approaches is possible (Guzey et al. 2016).

Integrated STEM education therefore entails combining the subjects, using one subject to support the teaching of the other, utilizing the thematic approach in teaching and finding connections amongst the disciplines. Some researchers (e.g, Crippen & Archambault, 2012; Tan & Leong, 2014) have viewed integrated STEM education as a way of thinking that cuts across all the STEM disciplines. Siew et al. (2015) highlighted the centrality of Design-Based Science in the STEM approach while Meyer and Jackson (2016) discussed the design-based Information Technology learning experiences. In this sense, STEM is regarded as a set of skills that one requires in order to engage fully in science, technology, engineering and mathematics. Parker et al.

(2015, p. 7) articulated on "high quality STEM practices". They proceed to identify eight practices of science and engineering as follows:

(i)   Asking questions (for science) and defining problems (for engineering);

(ii)   Developing and using models;

(iii)   Planning and carrying out investigations;

(iv)   Analaysing and interpreting data;

(v)   Using mathematics and computational thinking;

(vi)   Constructing explanations (for science) and designing solutions (for engineering);

(vii)   Engaging in argument from evidence; and obtaining, evaluating and communicating information.

Implicit in Parker et al. (2015)'s "high quality STEM practices" is the need to make use of STEM teaching models in curriculum design. According to Davies and Gilbert (2003) cited by Hallstrom and Schonborn (2019), a model is a representation of an idea, object, system, event or process conveyed through concrete, visual, verbal or gestural representation. 3D physical models, spoken/written description of model entities, chemical formulae, diagrams and animations and bodily representations of model entities are examples (Hallstrom & Schonborn, 2019).

Researchers have conducted studies that reinforce the notion that models and modelling can be used as a springboard for an integrated authentic STEM education. The aim of the Hallstrom and Schonborn's (2019) study was to synthesise key publications that investigated relationships between authenticity, models and modelling and STEM education. Their findings indicate that authenticity is the cornerstone of STEM literacy and that models and modelling are

processes that can bridge the gap between STEM disciplines. The authors argue that to promote an authentic model-based teaching approach, science teacher educators need to show their trainee students what representational entities constitute a model, demonstrate the scope and limitations of different models and their functionality in demonstrating a scientific concept and provide for model designing and construction activities. Developing curricula for pre-service chemistry and mathematics teachers, Akaygun and Aslan-Tutak (2016) used Collaboratively Learning to Teach STEM (CLT-STEM) modules while a STEM competencies-based approach was used by Tan and Leong (2014) to ensure curriculum alignment with STEM education. A STEM curriculum, is therefore one aimed at developing competences like collaboration, design, construction, communication, information and technology literacy, social and cultural awareness, creativity, critical thinking and problem-solving all anchored on the engineering design approach (Meyer & Jackson, 2016; Tan & Leong, 2014). The engineering design approach involves identifying and defining problems, gathering information, identifying alternatives, selecting, implementing, evaluating and refining solutions with communication at the centre of the process (Meyer & Jackson, 2016). Teacher education programmes and curricula thus need modification with an explicit view to expose pre-service teachers to training on engineering concepts by modeling them on how to integrate the same concepts into classroom practice (Akaygun & Aslan-Tutak, 2016).

Statement of the Problem

Planning a STEM education curriculum requires deliberate approaches for STEM teaching to ensure effective implementation. According to prior literature

such mechanisms include practices and models for STEM that should be incorporated in any science teacher education curriculum or science teaching endeavour (Akaygun & Aslan-Tutak, 2016; Parker, 2015). The absence of STEM teaching practices and models in science teacher education curricula would be cause for concern given the centrality and importance of such models as articulated in literature (Akaygun & Aslan-Tutak, 2016; Meyer & Jackson, 2016; Parker et al., 2015; Tan & Leong, 2014). While STEM education is increasingly driving science and science education in many countries, a closer look at the teacher education curricula practices in science shows inadequate coverage of STEM skills and practices, limited conceptualization of the STEM initiative and a reluctance by teacher educators to use STEM models and approaches in the design and delivery of curriculum instruction. Specifically, this study assesses how STEM education is integrated in Science teacher education curriculum in Zimbabwe.

Research Questions

The following research questions guided the present study:

a) What pedagogical approaches do science teacher educators utilize in STEM education?

b) To what extent does the science teacher education curriculum match the requirements for integrated STEM education?

c) How do experiences provided in the science teacher education curriculum prepare pre-service teachers for teaching?

Methods

Research Paradigm

The current study is located in the post-positivist paradigm. The paradigm is characterized by its

emphasis on meaning-making and creation of new knowledge, integration of theory with practice, and a balance of personal views of the researcher with professional and theoretical viewpoints (Henderson, 2011; Ryan, 2006). This paradigm allows for the use of a mixed methods approach for collecting and analyzing data. For Johnson and Christensen (2012), the triangulation of quantitative and qualitative approaches through the use of a mixed methods approach does not only result in the collection of multiple kinds of data but also in comparing and validating data collected through different venues. For these reasons, the present researcher found this paradigm to be very appropriate for the current study.

Research Design

A sequential explanatory mixed methods design was used to gather data. Quantitative and qualitative data were collected in a sequence, with qualitative data largely used to validate and cross –check observations made through quantitative data. Thus, this design had the advantage of permitting the triangulation of different data collecting instruments.

Participants

This study involved final year science pre-service teachers (SPTs) (*n*=108) obtained through random purposive sampling and all the science teacher educators (STEs) (*n*=18) in the two secondary school teachers' colleges (COL-A & COL-B). The sample of the student teachers (*n*=108) was representative given that the student population was 1,019. Thus, the student sample represented 10.5% and according to Van Dalen (2000), in descriptive research (which this study is), anything from 10% to 20% of the population is representative. All the science teacher educators in the two colleges were involved, providing a full

representation of the science teacher educators in the two colleges. For Creswell (2007), careful sampling of participants improves the validity of research results while a representative sample enhances the credibility of research results. Thus, random purposive sampling helped to achieve breadth and in-depth coverage of the study by focusing on a representative sample and on information-rich participants purposively selected from the two colleges.

Instruments

Data were collected through a semi-structured questionnaire, follow-up interviews, focus groups and documents. Through the semi-structured questionnaire, which contained open and closed–ended items, both quantitative and qualitative data was collected. Basing on the study's research questions the instruments sought data relating to the science teacher educators' pedagogical approaches for STEM education, requirements for integrated STEM education and the approaches the science teacher educators used in order to prepare pre-service teachers for teaching in STEM subjects. The non-imposing open-ended items allowed us to listen to the participants' views as much as possible but of course within the confines of the research design. On the other hand, closed items were useful in generating frequencies of responses that were statistically treated and reported in percentages.

Follow-up interviews, which were conducted after an initial analysis of results from the questionnaire, were meant to probe into subtle issues and to have obscure and unexpected responses clarified. These interviews also helped the researcher to determine the motivations of the participants and their reasons for responding the way they did. Focus group discussions

with both teacher educators and student teachers in addition to document analysis yielded qualitative data .While some of the qualitative data were categorized into themes and analysed accordingly, other qualitative data were used to buttress/ refute observations made through the questionnaire.

Results and Discussion

Basing on the study's research questions, findings and discussion of the results from both colleges (COL-A and COL-B) are presented.

Pedagogic Approaches That Science Teacher Educators Utilize for STEM Education

For students to be adequately prepared for careers in the STEM fields, teachers of science must engage in pedagogical practices that foster interdisciplinary, ill-defined problems that scientists face (Siew et al., 2015). In the present study, the STEM approaches that Teachers' Colleges used were sought. Table 1 below shows the frequency of use of some STEM approaches in science education curriculum.

Table 1

Mean Scores (%) Pertaining to STEs and SPTs' Frequency of se of Some STEM Education Approaches (1. COL-A n= 10; 59) (2. COL-B n= 8; 47).

Questionnaire variable	1. COL-A STEs' Mean Score (%)	COL-A SPTs' Mean Score (%)	2. COL-B STEs' Mean Score (%)	COL-B SPTs' Mean Score (%)
Problem-based learning	75	77	72	70
Inquiry-based learning	67	70	67	73
Findings are communicated in various ways.	77	68	78	64
ICT is used in teaching and learning	80	78	68	54
Visits outside college on science education	56	52	55	53
Involvement of engineering aspects in science instruction	46	42	48	43

Table 1 above shows that in general problem-based learning, inquiry and ICT enjoyed considerable use unlike visits outside college on science education and the involvement of engineering aspects in science instruction. SPTs in both colleges (52% in COL-A & 53% in COL-B) thought that visits outside the college focused on science education were limited. They also

felt (42% in COL-A & 43% in COL-B) the involvement of engineering aspects in science instruction was inadequate. The SPTs' views were largely the same as those of their teachers on the same aspects. The STEs were also aware of the limited use of visits outside college focused on science education (56% in COL-A & 55% in COL-B) and the lack of

involvement of engineering aspects in science instruction. These questionnaire findings were also echoed in the interviews with STEs and group discussions with the SPTs. In the SPTs' opinion, there were some skills in the preparation programme that remained undeveloped, and some teaching approaches that were rarely used, yet were crucial. The SPTs cited innovative skills and real innovations, modelling actual classroom teaching by lecturers, field trips and oral assessments. In that regard, SPT$_{12}$ said:

> *The field trips and educational visits are lacking. These ones are real situations in the learning. For instance, when I want to teach about hydro-electric power generated at Kariba hydro-power station, I haven't been there. I will teach it theoretically. I will rather express my knowledge through theory because I haven't been there. If I have more exposure, it means I have more detailed information to share with the learners.*

SPT$_9$ also said:

> *Sure! That one is a challenge because if you go out into schools, pupils are taken to where things are happening. That's the expectation. So, if we start here to be exposed to where things are happening like in factories and in industry, we do not give kind of cosmetic information because you have real knowledge. It will help us. It will be effective.*

The skills and approaches that were cited as missing from the SPTs' training programme were probably the most crucial for STEM. For instance, a number of studies accentuate the importance of innovative skills and real innovations in authentic teaching and learning contexts (Hallstrom & Schonborn, 2019; Kirschner, 2006; Semali & Mehta, 2012), field trips (Behrendt & Franklin, 2014), the use of engineering design approaches (Meyer & Jackson, 2016; Siew et al., 2015

and a focus on big ideas/concepts/themes, authentic scientific practices and an understanding of learners' misconceptions and worldviews (Thibaut et al., 2018). What therefore, seemed to emerge from the SPTs' was the view that creativity, innovation, problem-solving, construction of real knowledge through practical and real time activities, was important in science teacher education.

Table 1 also illustrates that the STEs frequency of use of problem-based learning (75% in COL-A & 72% in COL-B) inquiry (67% in COL-A & 67% in COL-B) was satisfactory. The findings matched three of Magnusson et al's. (1999) nine teaching orientations. Magnusson et al. (1999) argued that process, academic rigour, didactics, conceptual change, activity, discovery, problem-based learning and inquiry guided science-teaching approaches. In line with Magnusson et al.'s views (1999), the STEs in both COL-A and COL-B therefore, involved their science students in activity learning through practical laboratory work and finding solutions to authentic problems through problem-based learning. Mudavanhu's (2015) findings differed widely from the current study's. Mudavanhu's (2015) study explored identities commonly used in teacher education and student teachers' motives for becoming teachers and the frequently used pedagogical approaches. Mudavanhu (2015) revealed that, while a variety of approaches was used, the single dominant approach used was the exposition or lecture.

The STPs in this study were only satisfied that findings were communicated in various ways (68% in COL-A & 64% in COL-B). Paradoxically, this result seemed to confirm Mudavanhu's (2015) findings that the single dominant approach used was the exposition or

lecture because the lecture approach does not normally require students to communicate anything besides taking notes and listening. These results where SPTs felt only satisfied that findings were communicated in various ways was worrisome given the importance of the same aspect to STEM approach. According to prior literature (e.g Liu, 2020; Meyer & Jackson, 2016; Parker et al., 2015; Tan & Leong, 2014), communication of findings is at the heart of learning in STEM education. For instance, at every stage of the engineering design process articulated by Meyer and Jackson (2016), learners are required to communicate findings using a variety of approaches inclusive of Information Communication Technology (ICT).

While STEs and their SPTs in COL-A said ICT was frequently integrated in curriculum experiences in science education (STEs 80% & SPTs 78%), those in COL-B had a slightly different perspective. STEs and SPTs in COL-A felt ICT was used less frequently in the teaching and learning processes (STEs 68% & SPTs 54%). SPT_{27} advised that science laboratories be equipped with computers so that the two, science and technology, are integrated. The student teacher's sentiments rhymed with what his Head of Department, STE_8, had said about the state of the laboratory at COL-B:

> Science is a practical subject. So, we insist to all our lecturers conduct practical sessions with the students. So, a lot of experiments should be done. We boast of four laboratories here, with a lot of equipment. We thank the administration for the support they render to the department. However, I am not happy with the laboratory set-up. The labs are set up like classrooms. I will show you when we go down. The set-up is not good. They should be set up like workshops that we find in the Tech-Voc (Technical and Vocational) area.

The argument that seemed to emerge from the STEs and SPTs' sentiments was that the traditional science laboratory should evolve into a 21st century set-up that integrates technology with science teaching and learning. In such a set-up, a science laboratory is converted into a 'hybrid laboratory' that is fully equipped with science apparatus, chemicals, models, computers, sensors and other technological gadgets related to science learning. The argument that the traditional science laboratory should evolve into a 21st century set-up coincides with Childs and Limerick's (2016) new concept of a laboratory. Childs and Limerick (2016) posited that in the 21st century, the use of ICT in teaching and learning has led to the rise of the e-laboratory, where data-logging, simulations, graphic designs and other micro-computer-based lab tools are part of the instructional materials. Similarly, the set-up of the proposed 21st century laboratory agrees with Yednak's (2016) idea of a vibrant science class. The activities that take place in such science classes require learners to simulate some experiments, use computer applications to analyze experiment results and communicate their findings to others through multi-media set-ups.

The Match Existing Between Science Education Curriculum and the Requirements for STEM Education in COL-A and COL-B

The current study's second research question sought to establish the match existing between science education curriculum and the requirements for STEM education in COL-A and COL-B. In line with the research question, the study's questionnaire elicited respondents' opinions on perceptions regarding the match between science education curriculum and the requirements for STEM education. The findings on

this aspect are dealt with in this section. Table 2 illustrates the STEs' and SPTs' perceptions regarding the match between science education and the requirements for STEM education.

Table 2

STEs and SPTs Perceptions Regarding the Match between Science Education and the Requirements for STEM Education. 1. (COL-A n=10; 59) 2. (COL-B n= 8; 47)

Questionnaire variable	1.STEs' Mean Score (%)	SPTs' Mean Score (%)	2.STEs' Mean Score (%)	SPTs' Mean Score (%)
Syllabi focus on STEM competencies	68	70	70	64
Teaching follows an interdisciplinary approach	76	78	78	76
Science teaching is guided by empirically based international trends	84	78	74	80
Follow approaches suggested in research	80	78	78	82
Syllabi suggest STEM teaching models	54	40	70	62
Syllabi suggest holistic (hard, soft & practical skills) assessment approaches	70	80	82	88

Table 2 shows high mean scores indicating that the STEs and SPTs in both colleges possessed high perceptions regarding the match between science education and the requirements for integrated STEM education. For instance, science teaching guided by empirically based international trends were recorded (STEs 84% & SPTs 78%) in COL-A and (STEs 74% & SPTs 80%) in COL-B. The importance of international trends on science teaching and scientific literacy in mapping standards on science teacher education is highlighted in prior literature (DeBoer, 2000; Coll & Taylor, 2009; Feinstein & Kirchgaster, 2014; Pruitt, 2014). While data from the two groups of respondents' questionnaires were generally aligned, it was not the same for data gathered through interviews and focus group discussions. The interview and discussion data demonstrated that the STEs and SPTs in both colleges held different perspectives concerning the issues of science teaching that was guided by empirically based international trends. The SPTs felt they were not sure if teaching in the colleges was guided by empirically based international trends because they were unaware of these trends. Pruitt (2014) found that empirically based international trends represented performance expectations and competencies that are demonstrated through scientific and engineering practices, a deep understanding of scientific knowledge and ability to integrate scientific concepts within and across disciplines. According to Pruitt (2014), research is at the centre of this approach. Although the respondents in the present study thought that, largely their teaching followed approaches suggested in research (STEs 80% & SPTs 78% in COL-A and STEs 78% & SPTs 82% in COL-B), their

views obtained from interviews and group discussions were different.

The STEs felt that, despite the importance of research to their work, the responsible government ministry did not support it adequately. On the aspect of research, STE$_6$ made the following observations.

> *Science lecturers must do a lot of research. When research is done, a lot is improved on. As an individual, you ask yourself, 'Am I meeting the goals of the department?' You evaluate your own work through research, even presenting research papers. Nevertheless, people are not doing research, maybe because of lack of support.*

Findings from this study seemed to suggest that the STEs in COL-B, like those in COL-A, were fully aware of the importance of carrying out own research in order to improve science teaching and learning. As highlighted earlier, research is an important component of successful teacher education STEM programmes. Collins and Gillespie (2009) outlined four over-arching goals for an effective teacher education programme, as follows: (i) bringing together current research in science teacher education and their varied perspectives to the facet of the secondary science teacher continuum; (ii) identifying knowledge gaps in the current programmes and interrogating why and how such knowledge is important; (iii) putting in place a reform agenda proposal to fill in the gaps and address the challenges or the weak links; and (iv) establish quality field experiences that offer the science student teachers opportunity for student teaching placements, observations and internship, in which the novice teacher receives guidance and professional leadership from an expert mentor.

Interviews with respondents and their documents also revealed that modeling various STEM teaching approaches to the SPTs, holistic (hard, soft & practical skills) assessment and STEM competencies were some of the practices that were inadequately covered. An examination of some of the SPTs' Attachment Teaching Practice (ATP) files indicated that the science lessons that were planned and taught were directed by instructional objectives that predominantly elicited low order thinking from the learners. STEM competencies and process objectives such as hypothesise, infer, predict, generalize, draw summary, conclude, interpret, record, observe, design, analyze, communicate, among others, were missing in most of the detailed lesson plans observed. This finding ran contrary to expectations of a science lesson as recommended by both Magombe (2012) and ZIMSEC Ordinary Level Physical Science Syllabus (5009)(2015). The two sources recommend planning, organising, experimenting, observing, measuring, recognising (variables), recording, drawing (conclusions), generalising and analysing, as objectives for science learning. The absence of such process skills consequently compromised the quality of assessment and lesson activities that could be done out of a preponderate use of low order cognitive objectives. According to Vingsle (2014), a teacher should be grounded in specific skills for practising formative assessment through: creating the assessment conditions, utilizing student self-assessment, interpreting evidence of student learning, and matching instruction to the diagnosis. The overall findings seemed to suggest that the STEs in both COL-A and COL-B needed to do more to equip the SPTs with instructional design and assessment skills for STEM lessons before they proceeded to ATP.

Curriculum Experiences That Prepare Pre-service Teachers for STEM Practices in COL-A and COL-B.

For STEM education to succeed in the secondary school initial teacher training programmes should adequately equip the pre-service teachers with skills in science, technology, engineering and mathematics (Akaygun & Aslan-Tutak, 2016). The third question of the present study sought to find out some of the Curriculum experiences that prepare pre-service teachers for STEM practices in COL-A and COL-B. Table 3 below shows the STEs' and SPTs' mean scores on the level of satisfaction with some STEM practices that prepared pre-service teachers for secondary school teaching.

Table 3

STEs' and SPTs' Mean Scores on the Level of Satisfaction with Some STEM Practices that Prepared Pre-service Teachers for Secondary School Teaching. 1. (n=10; 59) 2. (n= 8; 47)

Questionnaire variable	1.STEs' Mean Score (%)	SPTs' Mean Score (%)	2.STEs' Mean Score (%)	SPTs' Mean Score (%)
College participates in science fairs at all levels	78	76	74	80
College demonstrates the importance of science educational tours	54	78	70	60
Students are taught how to use interdisciplinary approach in teaching	64	72	70	78
College tutors and mentors collaborate in workshops that emphasise STEM approaches	68	74	60	68
There is collaboration with experts such as engineers in science teaching	68	74	58	54
SPTs are offered adequate knowledge on the use of STEM approaches in teaching	78	76	68	78
Attachment Teaching Practice assessment instruments are STEM compliant	70	54	64	78

Table 3 shows that both colleges largely participated in science fairs at all levels (STEs 78% & SPTs 76% in COL-A and STEs 74% & SPTs 80% in COL-B).

This result agreed with what the STEs and SPTs said in interviews and focus group discussions. The STEs from both college talked at length of the fairs they hold

for schools and their participation at national exhibition fair like the Zimbabwe International Trade Fair (ZITF) and Research and Intellectual Expo (RIO-SET). In fact, to them these fairs together with increased enrolment in STEM subjects (Sciences, Mathematics and Computer Studies) seemed to represent a major way in which the colleges were adopting the STEM practice. The results in same table above also show somewhat satisfaction with collaboration of college tutors and mentors regarding workshops that emphasised STEM approaches (STEs 68% & SPTs 74% in COL-A and STEs 60% & SPTs 68% in COL-B).

In the group discussions, the SPTs said no such workshops were ever carried. They insinuated that the few workshops carried out with mentors were of a general nature not targeting STEM education. This observation echoes Tirivanhu's (2014) observations on the preparedness of school-based mentors in supervising student teachers on Teaching Practice in Zimbabwe. Tirivanhu (2014) argued that although the lecturers from both universities and teachers' colleges were not satisfied with the assistance the student teachers were getting from the school- based mentors they themselves were not doing enough to collaborate with and educate mentors on the correct mentoring skills. The lack of collaboration that was reported for mentors was also found with experts such as engineers in science teaching and professional scientists. The case was more worrying for COL-B where the STEs and SPTs felt there was limited collaboration with experts such as engineers in science teaching (STEs 58% & SPTs 54%). This was the case despite the importance acclaimed to STEM education by Siew et al. (2015). STEM professional development workshops and collaboration with professional

scientists can provide insights into the support required for pre-service teachers to adopt innovative, effective, project-based STEM approaches to teaching science in the schools (Siew et al., 2015)

Table 3 also shows that the STEs and SPTs were only satisfied that students are taught how to use interdisciplinary approach in teaching (STEs 64% & SPTs 72% in COL-A and STEs 70% & SPTs 78% in COL-B). In a similar way all respondents were satisfied that SPTs are offered adequate knowledge on the use of STEM approaches in teaching (STEs 78% & SPTs 76% in COL-A and STEs 68% & SPTs 78% in COL-B). The results on the interdisciplinary nature of STEM differed with results from Siew et al.'s (2015) study. Pre-survey results revealed that of the 25 pre-services teachers, only 28% perceived STEM as an integrated approach which showed connectedness in the teaching and learning of science, technology, engineering and mathematics that promote higher-order thinking. However, acknowledging the usefulness of STEM approaches in the same study by Siew et al. (2015, p. 6), one of the respondents said, *"STEM approach in teaching science is an approach that requires students to be more active, particularly in 'hands-on' activities through project-based learning. This approach also requires students to think critically and creatively".*

However, when documents were analysed for interdisciplinary teaching, little was found. The documents revealed compartmentalization of subject areas-biology, chemistry and physics. This result pointed to the challenges that the two colleges faced in their attempt to implement integrated STEM education. The structure of the curriculum was such that the Information Technology (IT) department

operates as a separate entity with its own syllabus, the Science department (Physics, Biology and Chemistry) on its own and Mathematics the same. No Engineering department and no engineering-related materials was found in the students' notes or curriculum documents. According Thibaut et al. (2018), such segregation of subjects goes against the requirements for integrated STEM education. Similarly, the interviews revealed challenges to do with availability of materials and resources for STEM teaching and learning. Thibaut et al. (2018) avers that STEM integration requires numerous materials and resources such as construction tools, electronic materials and other design tools which are largely unavailable in traditional science laboratories. These findings suggest that some STEs in COL-A attributed less priority to practices such as the ability to integrate science concepts within and across subjects could be a hindrance to science learning using the STEM approach. One wonders how the student teachers were expected to excel in teaching practices when some activities were not given their due prominence by the STEs. This is despite the fact that earlier research has already pointed to challenges student teachers face in the same areas. For instance, Dhindsa and Anderson (2004) found that science student teachers in the USA had challenges in organizing knowledge structure for chemistry teaching, were poor at creating necessary connections between and amongst concepts, and lacked the skills to develop content thematically. In another study, Britton and Tippins (2015) found that student teachers lacked skills in maintaining and sustaining pupils' interest on task and creating a curriculum or learning situations that catered for every learner's needs.

Conclusion

The teacher educators in this study engaged their trainees in laboratory-based practice and, to some extent, integrated their teaching with ICT. However, despite the importance placed on research-based practices by many scholars (Goodwin et al., 2014; Loughran, 2014; Porayska-Pomsta, 2016), the science teacher educators in this study engaged in limited research activity. The view that they engaged in limited research activity meant their teaching approaches were not research-based and resultantly, the creation of new science teaching knowledge and utilization of STEM approaches that are anchored on project-based learning and research was therefore greatly compromised.

STEM education has benchmarks and standards that speak to how science should be taught. Therefore, it follows without saying that science teacher educators' practices need to be guided by certain standards and expectations. Findings from this study showed that the teacher educators in COL-A and COL-B followed guidelines from the respective subject syllabi. However, these curriculum documents do not spell out clearly how STEM approaches such as the engineering design approach and STEM teaching models can be made use of in the teaching and learning of science. The finding meant the science teacher educators in these two colleges were not supported by policy and curriculum documents to teach integrated STEM education and therefore limiting their abilities to contextualize concepts and expose students to socially and culturally relevant STEM contexts. Integration in STEM education requires support through international and national policy frameworks that challenge educators to teach their content in ways that engage students in meaningful, real-world settings

(Guzey et al., 2018). Further, Thibau et al. (2018) noted that teachers do not often have expertise in curriculum design and therefore making Professional Development (PD) in STEM education a necessity. The authors argue that teachers must have deep knowledge of the four discipline areas plus specialized pedagogic content knowledge to teach STEM content.

The other finding suggested that science teacher educators did a lot to prepare student teachers for teaching practice but did less with regard to preparing them for STEM teaching in schools. Much of what the science teacher educators did largely fitted the traditional framework of science teaching-an emphasis on content acquisition, routine laboratory work and other non-STEM approaches. The findings reported limited use of field trips, the near absence of partnerships that foster closer collaboration between colleges, schools, professional scientists and industry and the limited use of the interdisciplinary approach was evidence to a dearth of the STEM approach in the teacher education curriculum. It meant other teaching approaches important to integrated STEM education were rarely used. Such approaches as authentic scientific practices, writing for reflection, open-ended, real-world and authentic problems, collaborative learning, big ideas/concepts/themes and translation of representations from different STEM disciplines, as espoused by Thibaut et al. (2018), was largely missing.

Consequently, the pre-service student teachers went out on teaching practice and eventually as new graduate science teachers without adequate grounding on integrated STEM education.

Recommendations Based on the Findings of the Study

Based on the above findings and conclusions, the following recommendations are made:

- Science teacher educators in both colleges need to provide pre-service teachers with support that targets particular aspects of the STEM education. Such aspects include utilization of 'high STEM practices', the engineering design process, Collaboratively Learning to Teach STEM (CLT-STEM) modules, and other STEM competencies-based approaches to curriculum instructional design.
- There is need for professional development on integrated STEM education to support science teacher educators' STEM curriculum design and implementation skills.
- There is need to adopt practices such as field-trips, work visits, intercollege student seminars and partnerships that foster closer collaboration between colleges, schools, professional scientists and industry.

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Corresponding Author Contact Information:

Author name: Christopher Mutseekwa

Department: Curriculum and Management Studies

Faculty: Science Education

University, Country: Bindura University of Science Education, Zimbabwe

Email: chrismutseekwa@gmail.com