INSTRUCTIONAL PRACTICES AS PREDICTOR OF STEM EDUCATION

Julius Fomboh (ICT University, julius.fomboh@ictuniversity.edu.cm), Foluso Ayeni (Metro State University, foluso.ayeni@metrostate.edu)

Abstract

There is a global focus on Science, Technology Engineering Mathematics (STEM) as an engine of economic prosperity and significant research has developed instructional strategies that ease integrated STEM teaching. These instructional practices are not implemented by teachers and relatively fewer students successfully engage in STEM education. But the extent to which current reform-based instructional practices contribute to STEM education is not known. This study explores STEM education in Cameroon and establishes evidence of the degree to which current practices contribute to integrated STEMs. Data is collected through review of literature, interviews, focus group discussions with secondary school teachers of STEM disciplines knowledgeable in the Competency-Based curriculum pedagogic practices. STEM perspectives are analysed and instructional practices are modelled to explain teacher progression from current practices to those of integrated STEM. The study contributes to knowledge by establishing how STEM educational practices can build on existing curriculum and teacher pedagogical practices, thereby, removing barriers usually encountered when change is introduced in a process. Findings will broaden STEM research and contribute to the current discussions on STEM education as a core factor for sustainable growth and economic emergence.

Key words: STEM education; Instructional practices; Boundary objects; Reform-based pedagogy; Integrated STEM.

Introduction

The notion of Science, Technology, Engineering and Mathematics (STEM) has gained global focus as an engine of economic prosperity and governments and agencies bring to prominence the importance of STEM education. For instance, the 2013 report from the Committee on STEM education highlights that the jobs of the future belong to STEM, with STEM competencies in demand outside of specific STEM occupations. Also, the African Union places Science, Technology, and Innovation at the core of the continent's strategy to achieve inclusive and sustainable development (STISA, 2024).

Initially conceived as SMET (Science, Mathematics, Engineering and Technology), STEM was introduced by the National Science Foundation (NSF) of the United States of America (US) in 1990s in response to the need to produce more qualified professionals in engineering and technology (Murphy 2023; Timms et *al*., 2018; PCAST 2012). STEM gained prominence following innovative discoveries powered by expertise in Science and Technology in United States of America (USA) after World War II and this led to strong economic performance, good jobs, and thriving new industries (PCAST 2012). This growth had to be sustained in order to guarantee economic stability and competitiveness in the global market. Hence, STEM education was encouraged with the objective to produce more STEM professionals.

Remarkably, various initiatives are engaged by different countries and Agencies to promote STEM education. For example, the Presidential Council of Advisers on Science and Technology was set up as a think-tank to recommend strategies that promote STEM (Oslon & Riodan 2012). Also, in 2014, UNESCO crafted a global action to deliver gender-responsive STEM education and to increase the participation of girls in STEM fields (UNESCO 2014). Furthermore, in Cameroon, Science and Technology are placed at the center of the strategy to become and emerging economy (Cameroon 2035 Vision) and beside STEM education initiatives, the government has set-up a unit to coordinated the development of STEM education (Cameroon 2035 Vision).

That notwithstanding, relatively fewer students successfully engage in STEM disciplines (Cameroon 2035 Vision; Kinge et *al*., 2021). But there is evidence that *integrated* STEM instructional practices improve students' motivation and learning outcome (Mustafa et *al*., 2016; Wang et *al*., 2011). In this study, instructional practices of current *reform-based* pedagogy enacted in schools are examined and scaled-up with integrated STEM practices to strengthen STEM education, hence, produce more qualified professionals in engineering and technology.

STEM Education and Instructional Practices

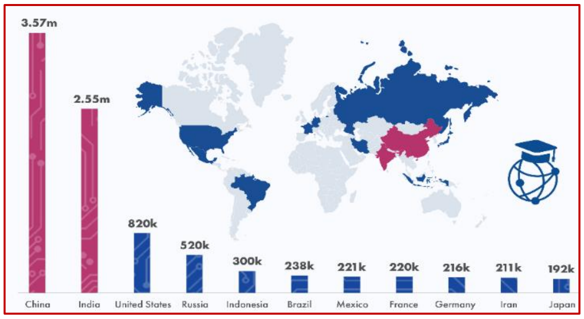
Remarkably, educators coined the phrase *STEM Education* (Breiner 2012) in response to the drive for STEM to be integrated into the education system agenda (Oslon & Riodan 2012). Introducing STEM education necessitated developing a STEM curriculum and also, teachers adopting instructional practices that promote STEM education (Stohlmann et *al*., 2012). By reason of integrated STEM approach, it was possible to explain STEM education instructional practices within the constructivist and social constructivist learning theories (Bell et *al.,* 2011; Thibaut et al., 2018). Noteworthy is the fact that, instructional practices are described as actions taken by the teacher in developing the lesson as it unfolds and progresses in the classroom (Saleh & Jing 2020) and are viewed as what the teacher and students do as they co-construct knowledge (Williams et *al*., 2015).

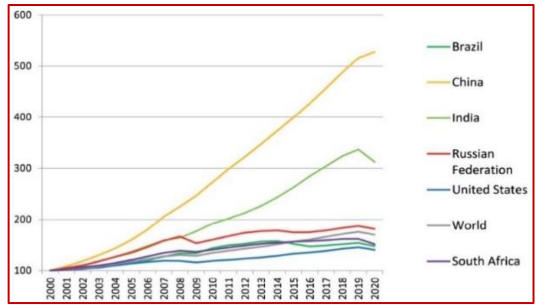
This study broadly refers to STEM Education as an approach that brings together the content and skills of four specific disciplines of Science, Technology, Engineering and Mathematics in an interconnected learning paradigm, employ reform-based instructional practices and build a cohesive whole with STEM subjects and other subjects such as Arts (Sanders 2012).

STEM Education and Emerging Economies

Undoubtably, the growth of STEM education is associated to its contribution towards economic upliftment (Blackley & Howell 2015). Curiously, there is a positive correlation between STEM education and emerging economy (Croak 2018**).** So far, leading *emerging economies* are Brazil, Rusia, India, China and South Africa, referred to as BRICS (Mardiros & Dicu 2016). Worthy of note is the fact that, these emerging economies are among the top ten countries in the world with high number of STEM graduates (World Bank data 2022). And today, countries like China and India are topping the world in the number of STEM graduates (figure 1). Furthermore, there are also amongst the top five fast-growing most industrialized nations on the planet (figure2) (World population Review 2024).

Figure 1 & 2: *L-R:* Top countries by no. of STEM graduates in 2020; BRICS labour markets growth





Source: L-R: OECD and the statistical yearbooks of Rusia, Indonesia, Iran, and China; World Bank data (2022) respectively

At the current time, STEM whose conception had a vocational and political undertone (Breiner et *al*., 2012) has evolved from an American catchphrase to a global slogan adopted by governments, agencies, educators, and industry leaders to communicate an urgent need for preparing young people towards employability in today's job market and to guarantee future workforce (Bacovic et *al*. 2022). In fact, STEM education communicates an urgent need for a kind of education that prepares students to be creative, critical thinkers, inventors, good communicators and problem solvers (Thibaut 2018; Blackley & Howell 2015). Hence, they can find solution to current challenges such as energy crises, global warming, food security and contribute to the economic growth of their communities and still stay useful for future challenges that are unknown today.

Importantly, and possibly motivated by the economic advancement of the emerging countries (BRICS), a number of Sub-Saharan African countries have set out road-maps aiming at being *emerging economies* (Mardiros & Dicu 2016). For example, Cameroon intends to be an emerging economy by the year 2035 (Cameroon vision 2035). Hence, improving the quality of STEM in secondary schools so as to produce large number of qualified STEM professionals is crucial as these Sub-Saharan African (SSA) countries gaze to sustainably develop their secondary industry sector (Cameroon 2035 vision) and possibly join the ranks of emerging economies.

Issues of STEM Education

STEM Education Frameworks: Remarkably, the STEM ideology resonates with our daily living and provides opportunities for less fragmented experiences for learners since real-world problems are not fragmented in isolated disciplines as they are taught in schools (Thibaut 2018). Also, integrated STEM instructional practices can improve students' motivation and non-cognitive learning outcomes (Wang et *al.*, 2011) and are adopted world-wide by education systems to produce qualified STEM professionals (PCAST 2012). However, the instructional practices of teachers are not well grounded in STEM education frameworks credited to prepared qualified STEM professionals (Thibaut 2018).

Pedagogic Content Knowledge of Teachers: Literature reiterates that there is a separate set of pedagogic knowledge to teach integrated STEM that significantly influences teaching and learning outcomes (Park & Oliver 2008). Building competences in integrated STEM instructional practices can be more challenging (English 2016). Though teachers undergo an initial training, they may be skilled only in the pedagogy of their respective disciplines, but they may not be effective as teachers in an integrated STEM context. Also, they are already faced with challenges as they sought to master the Pedagogical Content Knowledge (PCK) in their specific disciplines (Wang et *al.*, 2011). Besides, epistemic difficulty is also encountered when conceptualizing STEM education given that each STEM discipline has its Content-Knowledge boundaries and teaching practices (Leung 2020). Hence, the need to develop a wide-ranging STEM teacher instructional strategy to support delivering of high-quality teaching. To this effect, teachers' PCK is fundamental to their practice and emphasised in the context of teaching (Morley 2015).

Attrition and Retention of Students in STEM Education: Encouraging many students to engage in STEM education may be a lot easier than keeping them successfully engaged in it (Li et *al*., 2022; Sithole 2017). Research attributes students dislike of STEM to their disagreeable experiences during STEM classes (Li et *al*., 2022; Sithole 2017), poor instructional practices by some educators, inadequate institutional support mechanism; and on the part of the students, lack of persistence, no self-interest and the influence of their social backgrounds (Cheryan et *al*., 2015). Besides, there is negative stereotyping of STEM-related programs which buttresses an already culturally deep-seated perspective that the "Sciences" are difficult subjects and only few persons with very high intellect can succeed in them (Rogers & Ford 1997). However, teacher instructional practices are emphasised as fundamental to mitigate some of these biases and improve STEM retention (Sithole 2017).

STEM Education and Reforms in Education Systems: Adopting STEM education frameworks by education systems has been varied and less systematic (*Nite et al., 2017).* This is attributed to various factors and one of those factors is the fact that countries have adopted different pedagogic approaches to drive their education reform agendas. For instance, reform-based approaches adopted in Cameroon addresses pedagogical practices in a holistic manner, hence, impacting all components within the education system (MINESEC 2014). But STEM education is viewed as emphasizing certain subjects (Science, Technology, Engineering, and Mathematics) at the exclusion of other disciplines (English 2016). Consequently, implementing a school-wide instructional reform to address STEM education has been challenging.

Inclusive Practices in STEM Education: Inclusive practices should give attention to the diverse social, economic, and cultural landscape across many communities (Tikly et *al*., 2018). Nonetheless, students with disabilities still have challenges accessing STEM disciplines (Tikly et *al*., 2018). For instance, students with visual impairment lamented their inability to study mathematics even though available technologies such as talking calculator could have facilitated their learning. Besides, even though inclusive STEM education is emphasised, gender disparity still exists in STEM education (Takwe 2019; UNESCO 2018). Globally, the success rate for girls in STEM disciplines is much lower than for boys (Tikly et *al*., 2018). Takwe (2019), asserted that the majority of those enrolled in the STEM and STEM related fields in Cameroon universities are boys. Moreover, girls account for just 35% of students in STEM disciplines in Higher Education (UNESCO, 2017). Thus, inclusive gender sensitive teacher practices in STEM teaching are imperative in the classroom.

Problem Statement and Justification

Current efforts to promote STEM education have not significantly increased the number and quality of students successfully engaging in STEM disciplines. For example, only 42% of students passed STEM subjects and related disciplines in the 2023 Cameroon GCE Advanced level (GCE Board 2023). And only 38% of students who enrolled in universities in Cameroon for the 2023 school year were in STEM and related fields (MINESUP 2023). The low trend of students successfully engaging in STEM fields (Cameroon 2035 vision) and specifically, a much lower number for female students (Kinge et *al*, 2021), is viewed as significant setback to science and technology-based development efforts. Hence, there is a greater concern that the number of qualified STEM professionals prepared by the education system will not adequately meet the workforce demand (Cameroon 2035 Vision).

Nonetheless, studies have identified and examined challenges on implementing integrated STEM practices credited to improve STEM education outcome (Leung 2020; Honey et *al*., 2014; Vasque et *al.*, 2013). And frameworks informing instructional practices in secondary education are provided (Thibaut et *al*., 2018). But these instructional models have not been adopted by education systems and teachers. Curiously, these models are silent on how current instructional practices of teachers within the reform-based pedagogic context can contribute to their instructional progression to achieve integrated STEM.

Therefore, it is imperative to examine and establish how teachers can smoothly transit from current reform-based instructional practices to adopt practices credited to improve STEM education outcome given that new pedagogic practices occasionally encounter resistance from teachers (Sánchez-Prieto *et al*. 2019).

Aim of research

The study examines instructional practices in a secondary school setting and advances strategic options for strengthening STEM education. Remarkably, relatively fewer students successfully engage in STEM disciplines and there is evidence that *integrated* STEM practices improve STEM students' motivation and learning outcome. But these integrated practices are not adopted by teachers of STEM subjects. This study examined literature, explored STEM teacher practices and further scale-up instructional practices in reform-based pedagogy with those of integrated STEM so as to enable a smooth transition to integrated STEM practices and hence, prepare more qualified STEM professionals.

Research Questions

The study specifically addressed the following questions about STEM education in Cameroon:

1. *To what extent do the instructional practices of teachers of STEM subjects contribute to Integrated STEM instructional practices?*
2. *What strategic choices to improve STEM education can be made given current reform-based practices in STEM disciplines?*

Study context

Cameroon is a lower-middle-income country in SSA with a population of over 27 million (2022). The population growth rate is estimated at 3%, and children of school-age (ages 6-19) comprise 37% of the population, both well above the global averages of 1% and 25%. The majority of the population (58%) are found in urban areas (World Bank, 2022).

From an economic outlook, Cameroon's economy is characterised amongst others by export of raw materials and heavy import of finished goods (Cameroon Market Overview 2024) leading to negative trade balances (*Cameroon Market Overview* 2024). For instance, in 2021, export of goods and services stood at $5.9 billion and import was $7.8 billion, resulting in a negative trade balance of $1.9 billion. Also, inflation rose to 6.2% in 2022 from 2.3% in 2021, above the Central African Economic and Monetary Community (CEMAC) target of 3%. The increase was attributed largely to higher import costs (African Economic Outlook 2023). Notably, is the absence of a developed secondary industry sector (Cameroon Market Overview 2024) and though its agriculture market is estimated at USD 11.26 billion (2023), and is expected to reach USD 13.57 billion by 2028 (INS, 2023), this sector lacks machinery and quality STEM professionals to enable a vibrant secondary industry sector (Cameroon 2035 Vision).

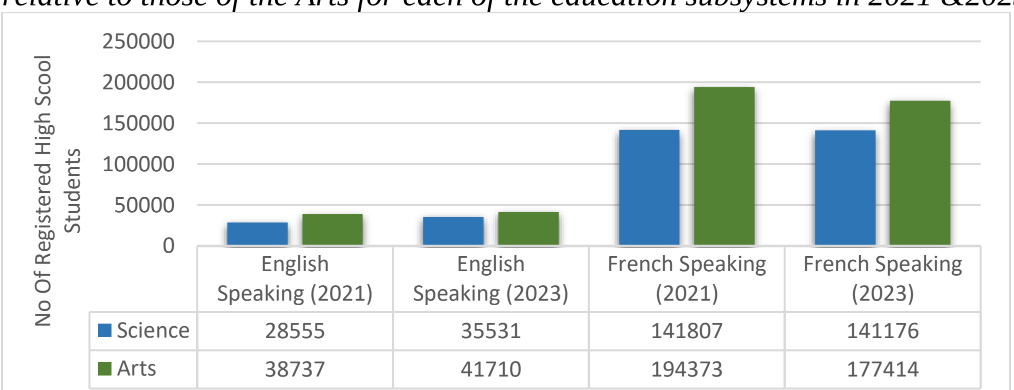
This need to develop the industrial sector has been articulated in the National Development Strategy paper (Cameroon 2035 Vision). It outlines developing an industry-core spanning multiple sectors, and ensuring that industries lend themselves amongst others to enhanced and improved performance founded in the most part on endogenous technology (Cameroon 2035 Vision). Remarkably, producing more qualified engineering and technology professionals is emphasised for the achievement of these goals. Hence, the question on how to improve the quality of STEM instruction in secondary schools is preoccupying.

Secondary Education: Education in Cameroon is characterized by two distinct education systems: the English-speaking and the French-speaking subsystems inherited from either the British or the French colonial regimes (Tambo 2003). The provision of education is fractionalised within five ministries and the Ministry of Secondary Education (MINESEC) is in charge of general, technical secondary education and teacher training colleges.

Curriculum and teaching: Remarkably, a reform in the secondary education curriculum introduced the Competency-Based Approach (CBA) grounded in the reform-based practices (MINESEC 2014). This was aimed at improving the quality of education and to provide secondary school graduates with more employable prospects (MINESEC Statistic year book, 2023). STEM education actions within the CBA curriculum that are articulated in secondary schools are focused on improving the teaching of discrete STEM disciplines, typically, Science subjects and Mathematics (MINESEC Statistic year book, 2023). Mathematics and Science (Physics, Chemistry, Biology) are the STEM focus disciplines in secondary general education subsystem while all the STEM disciplines (Science, Technology, Engineering and Mathematics are evident in the secondary technical schools (MINESEC Statistic year book 2023).

Curiously, relatively fewer students are engaged in the Science and Technology disciplines in the secondary schools (Figure 3).

Fig*:3 Number of students enrolled in the high school in the science & mathematics disciplines relative to those of the Arts for each of the education subsystems in 2021 &2023.*



Source: (MINESEC Statistics Year book, 2021, 2023.

Worthy of note is that fact that fewer girls are engaging in STEM disciplines unlike the boys, and lesser number of boys are engaging in the Arts and Social Science disciplines in comparison to the girls (MINESEC Statistic year book 2023). Remarkably, these statistics raise questions as to how teacher practices are handling gender sensitive STEM practices in particular and student STEM engagement as a whole.

Reform-based Practices in Secondary Schools: The CBA curriculum in schools allows concepts and skills to be learned separately in each STEM discipline. It *also makes use of instructional practices such as project-based learning, experiential teaching and other modern teaching strategies and practices (reform-based teaching and learning) (Nite et al., 2017).* Teachers make use of a real-world problem or scenario based on a lesson topic or competency. Meanwhile, students analyse and find solution to the problem with the guidance of the teacher, and thus learning the necessary content knowledge and developing the required competences. This context enables the linking of concepts and skills through a real-world problem-solving context. This study claims that, there are significant teacher practice of the current *reform-based* pedagogy that can contribute to integrated STEM teacher practices in secondary schools.

Review of literature

Instruction, Practice and Theory: Theories are useful tools that enable us to understand and explain the world we live in (Cishe et *al*., 2015). Theories provide fundamental orientation for reflection on practice in education (Bueger, & Gadinger 2018). Practice in education is contemplated as, teachers' behavior concerning educational matters, within and outside the classroom, based on theories that the teacher sees as valid which can lead to the achievement of set goals and objectives (Cishe et *al*., 2015). Nevertheless, depending on their uniquely situated experiences and life in classrooms, teachers frame their own ideologies which may influence their practices (Flores, 2020; Keay et *al*. 2019; Davis & Sumara 1997).

Regarding instruction, there are typically two instructional models: *teacher-centered* approaches which involve more direct instruction to students, such as lecture, questioning, demonstration and *learner-focused* methods that give more attention to students allowing for more student input and collaboration (Susanne & Wilson 2016). Student centre practices include, discussions, debates, problem-solving and collaboration (Susanne & Wilson 2016).

Nonetheless, teachers employ these strategies variedly. For instance, in teaching Engineering, instructional strategies of direct instruction are used for teaching facts, rules, and action sequences, while strategies of indirect instruction are used for teaching concepts, patterns, and abstractions (Rüütmann & Kipper 2011). Hence, we refer to instruction as handling the classroom situation appropriately and in such a way that the desired learning goals are achieved (Susanne & Wilson 2016; Orlich et *al*., 2010). This study is focuses on two types of teacher teachingl practices: reform-based and integrated STEM practices.

On the one hand, reform-based practices are viewed as a radical shift from traditional teaching practices. Unlike traditional practices characterised by teacher-centre practices that render the students' passive learners (Emaliana 2017), reform-based practices are characterised by a learning context/environment that is related to real life and learners build multidimensional competences to enable them successfully navigate life (Thibaut 2018). These practices empower students to examine critically their thinking and actions, develop good problem-solving skills, be creative and innovative and can work in teams (Slavich & Zimbardo 2012). And importantly, students in *reform-based* pedagogy understand more about their own learning and thus have a greater capacity to use the knowledge in new contexts.

On the other hand, integrated STEM teacher practices are those that emphasised that students make connections between the different STEM disciplines (Thibaut, 2018). Integrated STEM practices refer to teaching and learning between two or more STEM subjects or between a STEM subject and a non-STEM subject such as the Arts (Sanders 2012). Several approaches are framed to achieved these connections and various terminologies are used to describe these approaches such as: multidisciplinary, interdisciplinary, transcapillary and disciplinary (Vasque et *al*, 2013; Wang et *al*., 2011).

Theoretical grounding of teaching practices: Instructional practices must be theoretically grounded (Steward 2024). For example, social constructivism (Vygotsky 1978, 1986) provides the theoretical anchor of personalized attention and feedback; a core teacher practice (Campbell et *al*., 2007). Personalised practices require that teacher emphasis be on students' needs, rather than on the content to be taught, and so the teacher recognises what experiences are most supportive to student learning (Farnsworth et *al*., 2016). Furthermore, explaining personalised learning, theoretical perspectives such as: 1) Bandura's Social Cognitive Theory of learning, emphasises that teachers give students appropriately difficult challenges, and also focus attention to students' personal capabilities and how they should use them to achieve success (Bandura 1997, 2012); 2) Transformative Learning Theory, insists that teachers should promote learning by guiding students through the process of identifying and cultivating a reflective mind set (Mezirow 2018; Taylor 2007); and 3) Intentional Change Theory, emphasises that the teacher assists students to identify their current strengths and weaknesses, develop a personalized vision, prepare learning plans tailored to their vision, and provide them with exercises that allow them to practice new skills and achieve their ideal self (Boyatzis 2009; Boyatzis & Akrivou 2006; Manfra 2019). Consequently, teachers make the most out of students' potential for personal and collective growth, by combining aspects of these theory and perspectives in establishing classroom practice.

Methodology

Research design: This study adopts an exploratory research design (Creswell, 2006; Kaplan & Duchon, 1988) to document and provide evidence about STEM teacher instructional practices in a given context. The research philosophy adopted brings out a consistent set of beliefs and assumptions that guide the choices of research methods and strategy, data collection techniques and data analysis procedures (Sanders 2019). For example, interpretivist perspective adopted claim that humans are different from physical phenomenon because they create meaning, and since people of different cultural background interact at different times in different situations, they create different meanings and experience different social realities (Sanders 2019). Hence, research using such perspective introduces richness when it considers these differences and individual context. For example, male and female teachers of STEM subjects may experience teaching differently. This perspective was evident in the qualitative technique that ensured a critical analysis of documents, systematic review of literature, interviews and focus group discussions. Data was recorded as field notes or *memos,* transcripts of recorded interviews and discussions.

Target population and sampling: The population for the study included secondary school teachers of STEM disciplines using CBA reform-based practices. Only those who have been teaching for a minimum of two years were considered. Informants consisted of other actors of the STEM education process. Purposive sampling was adopted as a sampling technique to select schools and participants for qualitative data (Kerlinger & Lee 2000). This type of sampling enabled the researcher to select cases whose qualities or experiences allowed for an understanding of the phenomena in question and are therefore valuable (Creswell 2006). Those interviewed were selected based on a criterion established by the researcher in function of their availability and ability to provide the widest range of information related to STEM teaching and STEM-based initiatives. Table 1, profiles participants for One-To-One interview (participants (A-F) and Focus Group Discussion (FGD 1&2)

Table 1: Profiling table for participants for both interview and focus group discussions

Participant ID	Description of participants	No. reached	Experience (yrs)	Female (F)	Male (M)
Focus Group					
FCD 1	Pedagogic inspectors of STEM disciplines	**8**	**>20**	**4**	**4**
FCD 2	Teachers of STEM disciplines	**9**	**>10**	**5**	**6**
Individual Interview					

A	Senior education official in charge of Pedagogy	**2**	**>10**	**1**	**1**
B	National STEM Coordination committee	**2**	**>4**	**1**	**1**
C	Senior education official for STEM Pedagogy	**1**	**>20**	**0**	**1**
D	STEM-based initiative A (officials & student)	**2**	**>2**	**1**	**2**
E	STEM-based initiative B (officials & graduate)	**2**	**>2**	**2**	**2**
F	STEM-based initiative C (official & graduate)	**2**	**>15**	**1**	**1**

Protocols for Interview and Focus Group Discussion: The protocol for the focus group discussion focused on questions that sought to comprehend STEM education; what STEM is and how STEM education is represented and enacted in the classroom. Interview protocols were open-ended giving room for follow-up questions to gain deeper insight into the phenomenon being researched (Kerlinger & Lee 2000). Interview protocols addressed a number of key questions organised around classroom practices (activities, strategies, expectations for students and strategies that the teacher uses to meet those expectations). The research protocols were developed by the researcher and reviewed by experts following initial review of literature.

Data collection

A review of literature provided the basis for secondary data while primary data was collected through interviews and focus group discussions. A structured approach (Okoli 2015) was used to determine the relevant literature for the review. The review examined integrated STEM frameworks, theories, STEM teacher practices with the objective to establish similarities and differences between the reform-based practices and integrated STEM practices.

Focus group discussion and one-to-one interview: The focus group discussion was engaged in an attempt to capture and present the current thinking in STEM education. It sought to determine the various orientations and perspectives of STEM education. Focus group discussions examined the progression of teachers of STEM disciplines from current practices to integrated STEM practices. Open-ended questions allow for emerging themes.

Comparative Review of Reform-based & Integrated STEM Instructional Approaches

This review was carried out to address research questions two (RQ2) required to establish the extent to which the instructional practices of teachers of STEM disciplines contribute to integrated STEM instructional practices. Standard (systematic) reviews (Okoli 2015) involve establishing a detailed and comprehensive search strategy with the goal of reducing bias by identifying, appraising, and comparatively synthesizing all relevant studies on a particular topic (Uman 2011). This review emphasised "explanation of differences and of similarities" and this helped to establish relationships between the two approaches. Articles for the review were obtained from two databases: google scholar and Web Science. The databases were browsed using four different combinations of search terms: "integrated STEM education + reform-based education"; integrated STEM practices + reform-based practices; "STEM education + competency-based education", "integrated STEM practices + reformed-oriented practices". A total of 146 articles were located. The number of articles retained was further scrutinized using four criteria. Firstly, all selected articles had to be peer-reviewed journal articles or book chapters written in English, conference papers and dissertations were excluded. Secondly, the articles had to focus on Competency based teacher practices or STEM education teacher practices. Finally, all articles had to describe theoretical perspectives that informs instructional methods and instructional practices in each case. After applying the criteria only 12 articles were retained in the sample. This number was small and the “snowball approach” was used to retrieve additional articles (Doust et al., 2005). In doing so, the reference lists of all previously discarded articles were inspected and four more articles that met the inclusion criteria, resulting in a total of 16 articles. Each article was analysed separately and summarized in a table. They were categorised under two main headings (1) CBA and (2) integrated STEM approach, the existing evidence extracted from literature were related to theoretical roots, theoretical perspectives, principles of instruction, methods of instruction and instructional practices (Gervais, 2016). A cross-case analysis was done (Miles and Huberman, 1994) and a comparison of these features brought out the similarities and differences on the two approaches. *Review and Analysis of Integrated STEM Models*

In a second review, frameworks and model explaining integrated STEM education were examined. Selected models describing instructional practices in integrated STEM were scrutinised with the objective to find out the extent to which these frameworks and models harbour reform-based representations. To do this, the researcher made an initial claim that: “*integrated STEM models are sufficiently reformed-based, hence practices prescribed by integrated STEM frameworks are significantly reform-based”*. Thus, two integrated STEM models focusing on teacher practices were examined with the objective to establish the existence of reformed-based practices within them. They were selected based on relevance to topic, journal ratings and citation index. These models are: disciplinary, multi-disciplinary, interdisciplinary, and transdisciplinary integration (Vasque et *al.*, 2013); and synchronization-based, thematic-based, project-based, integrated, cross-curricular-based, specialized school-based, and community-focused STEM education (Hong et al., 2023).

The model framed by Vasque et *al*. (2013) describes four integrated STEM practices: Disciplinary, Multi-disciplinary, Inter-disciplinary, and Trans-disciplinary. An analysis of these descriptions revealed that, *disciplinary* practices were similar to reform-based practices: whereby knowledge & skills learned from a discipline are applied to real-world problems. *Multi-disciplinary* practices were found to harbour reform-based practices though not explicitly implemented. For example, Mathematics concepts are found in science disciplines but are not considered as integrating mathematics and science and teacher practices do include multidisciplinary student activities but these activities may not necessary be specified in the curriculum. As for *inter-disciplinary* practices, mastery of discipline content is emphasised which is the core of reform-based practices. For instance, deeper content mastery is emphasised for effective integration (Thibaut, 2018) where knowledge & skills learned from a discipline are applied to real-world problems.

The model proposed by Hong et *al*., (2023) describes six approaches to instruction that should explain integrated STEM approach. These include: *synchronization-based; thematic-based; project-based*, *cross-curricular-based*, *specialized school-based; community-focused*. When analysed, the approaches described were also having similar practices to those of the reform-based. For instance, *specialized school-based; community-focused* is seen to address real-world problems as articulated in reform-based practices and also found in Vasque et al.’s transdisciplinary practices. Furthermore, *project-based* practices are central to reform-based practices. Also, *thematic-based* approach was also found to share reform-based or reformed-oriented practices though not explicitly implemented. This also similar to Vasque et al.’s multidisciplinary practices.

Findings, Discussions & Conclusion

Findings and discussions

The study findings are presented in three sections: section one highlights the STEM education landscape, section two discusses systematic literature review and integrated STEM model analyses, discusses implication on STEM education and further presents a teacher instructional model for STEM education, and the third and last section handles recommendations, limitation and conclusion.

1) *STEM Education Landscape in Cameroon*

STEM education definition: The study revealed that there is no common understating of what STEM is or what it should be among actors and teachers of STEM disciplines. For instance, STEM is usually interpreted to mean Science and Mathematics; hardly does it refer to Technology or Engineering. Even though, Technology and Engineering are taught in Technical Secondary Schools, STEM actors, generally, did not refer to STEM as being evident in technical schools.

STEM education practices: Regarding practices, STEM education actions articulated in Secondary Schools are focused on enhancing the teaching of discrete STEM disciplines, typically, Science subjects and Mathematics. Some actors of STEM implement processes that are still focused on the teaching of discrete STEM subjects. For example, the AIMS Cameroon Mathematics Teachers STEM Program enhances the pedagogic capacity of Mathematics teachers; the STEM program of the University of Bamenda graduates "STEM" teachers but these teachers teach discrete STEM subjects in schools. Meanwhile, actors involved in popularizing STEM education are engaged in activities such as coding, gamification, booth camps, workshops, webinar, etc.

Remarkably, STEM actors were found to have varied perspectives of STEM and STEM education. Educators were unable to identify connections between current reform-based practices and those of integrated STEMs. The study findings suggest that, there is no clear agenda or motivation to engage specific practices required by STEM education.

STEM-based initiatives: Worthy of note is the existence of STEM based initiatives. For example, the African Institute for Mathematical Sciences (AIMS) is a pan-African network of centers of excellence for post-graduate training in mathematical sciences, research and public engagement in Science, Technology, Engineering and Mathematics. The overall Goal of the AIMS global network is to increase access and opportunities for STEM education at the tertiary level especially for girls. AIMS Mathematics Teachers Training Program has as primary objective to improve the quality of mathematics education in secondary schools by enhancing the pedagogic skills of secondary school mathematics teachers to enable them make mathematics teaching and learning appealing to students.

In another STEM initiative, the University of Bamenda runs a three-year program leading to Bachelor of Education in STEM. Students who enrol for this program take courses in STEM instructional strategy, and engage in micro teaching in STEM subject area. Upon graduation, they teach their STEM subjects since there is no discipline in the school system as STEM or integrated STEM. Based on their motivation, they make use of STEM instructional strategies to make their teaching more appealing to students.

These STEM initiatives can serve as the engine to innovate and pilot instructional practices leading to integrated STEM practices. STEM initiatives are conceptualised in this study as entities that can develop and facilitated the use of *boundary objects* in integrated STEM practices.

2) *Integrated STEM Practices in Reform-Based Pedagogy*

Comparative Review of Reform-Based & Integrated STEM: The review revealed that Competency-Based and STEM education approaches share similar theoretical roots, the constructivist and social constructivist theories (Bada & Olusegen 2015; Boghossian 2000; Ertmer & Newby 1993). They each aim to enable students to increase their mastery of key course concepts while enhancing students' learning-related attitudes, values, beliefs, and skills. Same as integrated STEM, reformed based practices are informed principally by constructivist and socio-constructivist notions. Thus, a considerable overlap in practices is expected between the two approaches. However, *design-*

based, integrated based and boundary crossing instructional practices of integrated STEM were not found among the reform-based practices. Summarily:

- Reform-based and integrated practices have the same theoretical roots.
- Their practices are informed by active and student-centred learning principles.
- The two practices were found to have in common a number of methods of instruction: problem-based, experiential, inquiry, collaborative and cooperative. However, *engineering design, integrated and boundary crossing* methods were found only in integrated STEM methods.
- As a consequence of the instructional methods, practices of design-based, integrated and boundary crossing were only found among integrated STEM instructional practices.

Review and Analysis of Integrated STEM Models: Examining these models revealed that there are practices in reform-based pedagogy that are highlighted as core to iSTEM frameworks. Hence iSTEM practices could largely be described when "additional" practices are introduced within current ones. Since teachers are teaching STEM subjects, their progress from current practices and those of iSTEM need to be explicitly represented or framed. Nonetheless, models are silent on teachers transition from current practices to iSTEMs even when it is known that teachers often resist change. This study suggests a distinction between current reform-based practices and those of iSTEM for teachers to easily adopt iSTEM practices. This study therefore, models' instructional practices of teacher to enable transition from current Reform-Based to those of iSTEM.

Conceptualization of STEM education Practices

Reform-based and integrated STEM engage practices that evoke the principles of active learning and student-centred pedagogy. Furthermore, both approaches advocate that the teacher takes on the role of facilitator, coaching and directing students' mastery of subject content and attitude towards learning, while at the same time focusing on practices that guide the students in their pathways as they grow intellectually and socially. Hence, integrated STEM could largely be described when "additional" practices are introduced into current practices.

Therefore, by focusing on teacher instructional practices and establishing practices in Reform-Based pedagogy that are integrated STEMs' we can reinforce practices that strengthens STEM education. Hence, iSTEM (newer practices) could largely be described when "additional" practices are introduced into Reform-Based ones (current practices). And the model claims that the instructional practices of teachers of STEM disciplines within the Reform-Based pedagogical setting will contribute to integrated STEM practices and contextual factors will impact the outcome

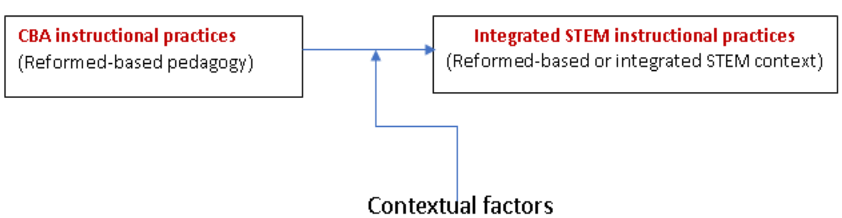


Figure 4. Model of STEM education instructional practices

The STEM education conceptualized model provides the basis for analyzing instructional practices of teacher of STEM subject in order to predict integrated STEM instructional practices. Interestingly, students centred instructional practices have been shown to directly influence learning outcome (Saleh & Jing 2020). The model (Figure 4) presents the instructional practices of teachers of STEM disciplines (*independent variable*) contributing to integrated STEM practices (*dependent variable*) and contextual factors (*control variable*) is seen to influence the outcome. *Contextual factors* are those variables that shape the way STEM education is understood and the environment (classroom) where STEM education is practiced in a context.

Framing Teacher instructional Progression

The study results show that it is not obvious how teachers are expected to progress from current practices to integrated STEM ones. Models are seen to rearrange various instructional approaches but are silent on teachers' progression even when it is known that teachers often resist change. This study has ascertained that there are integrated STEM practices in reform-based practices. But current models have not established how they can progress from this their current state (reform-based) to those of integrated STEM.

The study has established that the instructional practices of teachers of STEM disciplines within the reform-based pedagogical setting will contribute to integrated STEM practices. Hence, a teacher can progress from current reform-based practices to integrated STEM practices. Boundary objects (Leung 2020) are conceptualised as tools to enable this teacher progression.

Boundary crossing: Each STEM discipline has its pedagogical content knowledge boundaries and its classic practices that are welled established. Boundary crossing pedagogy is theorised to fulfil a bridging function (Star & Griesemer 1989) when conceptualising practices across disciplinary knowledge domains. For example, conventional knowledge domains in STEM are evident in: deductive reasoning in mathematics (Burton 1984; Stacey 2006), design thinking in engineering, enquiry in sciences and computational thinking in the fields of technology (Glancy & Moore, 2013). Leung, asserts that mediating objects are needed to bridge STEM discipline's pedagogical content knowledge (Leung 2020). Star and Griesemer (1989) assert that it would be acceptably to create a boundary object that goes across the boundary between STEM disciplines and serve to negotiate, combine, and translate from different contexts to achieve integrated STEM.

Boundary objects therefore, are artifacts that do the crossing of disciplines bridging them to facilitate boundary crossing learning process. Boundary objects are framed across two or more disciplines covering authentic real-word problems or projects concepts and serve as tools in teacher progression to integrated STEM practices.

Recommendations, Limitations & Conclusion

Recommendations: STEM education faces challenges with regards to the availability of STEM teachers. Besides retention of students in STEM, they may also be a need to focus on retention strategy for STEM teachers. These may include among others, making their job more attractive since those with adequate subject knowledge go into other more attractive careers, introducing fast-track teacher training programmes and to developing new study programmes for this purpose. Approaches like these have been implemented in some SSA countries: Senegal, Zambia and Côte d'Ivoire. Also, contemplating higher salaries, differentiated salaries, smaller class sizes and mentoring to retain teachers.

Furthermore, building an ecosystem may also advance the development of STEM education. Undoubtably, greater investment will be required to enable an effective STEM education especially in teacher professional development. Meanwhile, further research will be needed to establish a theory change (Reinholz1 & Andrews 2020) that can be implemented to facilitate teacher smooth transition from reform-based practices to include those of integrated STEM.

Limitations: Teachers who were investigate are those teaching STEM disciplines since integrated STEM programs have not been formally introduced within the school system and they may not be fully informed of STEM education practices. Furthermore, study focused only on teachers but "democratically", a voice was not given to the students, although they also play an important part in classroom instruction.

*Conclusion***:** STEM education is variedly understood and implemented worldwide. This study comes to a similar conclusion. Thus, the study highlights a perspective that responds to national development goals the study context. This study advances our understanding by establishing integrated STEM instructional practices within current reform-based pedagogic practices, thereby generating knowledge on how educational change happens and removing barriers usually encountered when change is introduced in a method. The central role of STEM education as the engine for an emerging economy is no longer questionable but the concern may be whether countries and their education systems are developing and adopting instructions frameworks and policies that will produce qualified STEM professionals to ensure sustainable development and emergence. As SSA countries race to join the ranks of emerging economies, this study establishes how teacher instructional practices can evolve to produce more qualified engineering and technology professionals needed by these emerging economies. In this wise, the status of STEM education in these countries could be raised to a national priority; the examples of the BRICS countries are abounded.

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