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Reinvigorating Inquiry-Based Instruction in Science Classrooms in Tanzania: Lessons from South Africa and the United States

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Abstract

Inquiry-based instruction (IBI) is widely renowned as one of the best approaches to teaching school science. Nonetheless, while science teachers in Tanzania might involve in teaching activities consistent with inquiry, IBI is not yet recognised as a formal approach to teaching science. Hence, this study investigated the extent to which IBI is promoted in Tanzanian secondary science curriculum documents. Additionally, it proposed suggestions on how to adopt IBI in the context of Tanzania. Using document analysis as a method of inquiry, six syllabi for secondary school science subjects in Tanzania were analysed to assess the extent to which they support IBI practice. Further, curriculum documents for secondary school science from South Africa and the United States were also analysed. This was done so as to compare between education systems that have recognised IBI as a formal approach to teaching science with that of Tanzania. Results indicated that while teaching methods, goals and objectives of education support the practice of IBI, a few aspects such as the time allocated and resources suggested for accomplishing investigative learning activities are the barriers to practising IBI. By reflecting on these results and lessons learned from the US and South Africa, the study provides recommendations such as allocating enough time for carrying out scientific investigations, changing teachers' beliefs, revision of some learning objectives, and promoting teacher professional development in case Tanzania wishes to adopt IBI.

Keywords: *classroom inquiry; curriculum documents; inquiry-based instruction; science education; scientific inquiry*

1. Introduction

Inquiry-based instruction (IBI) is not new, although in recent years there has been an increasing call to implement it in science classrooms (Areepattamannil, 2012; Cairns & Areepattamannil, 2019; Fang, 2020; Fitzgerald et al., 2019; Jiang & McComas, 2015; Manz et al., 2020; Schramm et al., 2018; Vhurumuku, 2011). The reason for such a call, in part, has to do with the nature of science itself.

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According to Edelson et al. (1999: 392), science, by its very nature, is a 'question driven' discipline. As such, it is envisioned that students in science classrooms should be constantly posing questions as well as searching for answers. This is to suggest that, to inquire is at the heart of science learning and practice. In fact, although scientific literacy cannot be achieved by relying on a single teaching approach, IBI still comes as one of the best approaches in science education (Areepattamannil, 2012; Cairns & Areepattamannil, 2019). Also, while results from researches on the effect of IBI on students' achievement has produced mixed findings, there is considerable evidence to suggest that IBI significantly enhances students' attitudes toward science, its enjoyment, interests, as well as its self-efficacy (Cairns & Areepattamannil, 2019; Fitzgerald et al., 2019). Moreover, IBI has been found to enhance students' self-regulation skills– skills that are not only life-long, but also help learners in goal-setting as well as in evaluating their academic strengths and weaknesses (Crujeiras-Pérez & Jimenez-Aleixandre, 2019; Moote, 2019). Other advantages of IBI have included development of students' higher-order thinking skills (Moote, 2019), interests and achievement in science (Kang & Keinonen, 2018), motivation for learning science (Lehesvuori et al., 2018) and enhancement of students' conceptual understanding (Edelson et al., 1999).

With respect to the practice of IBI, apart from other common barriers—such as time restrictions, insufficient training, and resources (Capps et al., 2012)—the main cited challenge facing the implementation of IBI is the lack of consensus on what constitute IBI (Dudu & Vhurumuku, 2012a, 2012b; Nadelson et al., 2013; Williams et al., 2019). In other words, there is no common understanding of what IBI actually is. As a consequence, many teachers have opted for the traditional, teacher-centred methods of teaching as IBI seems to be very hard to implement in actual classrooms (Fitzgerald et al., 2019). Indeed, according to Capps et al. (2012), many teachers confuse IBI with other student-centred techniques that do not necessarily expose students to inquiry such as hands-on activities, problem-based learning (PBL), and learning by doing. Additionally, teachers have tended to vary considerably on how they engage in inquiry in science classrooms (Dudu & Vhurumuku, 2012b).

Given that Tanzanian education system aims at developing inquiring minds among its citizen (MoEVT, 2005, 2007, 2009a, 2009b, 2009c, 2009d), IBI in science classrooms seems an ideal pathway to achieving those aims. Nonetheless, although there have been intensified efforts and reforms for adopting more learner-centred approaches through a competence-based curriculum (CBC) (Kitta & Tilya, 2010; Mkimbili et al., 2017), IBI—especially the

use of more open inquiry—is still a new practice in Tanzania (Mkimbili et al., 2017). In other words, while science teachers may involve in classrooms activities similar to those involved when engaging in scientific inquiry, it does not mean they are practising inquiry. Indeed, according to MoEVT (2009d: v) teachers are advised to use more participatory methods such as "... think-pair-share, group discussion, library search, stories, question and answer, class activities and demonstrations." However, as Capps et al. (2012) have warned, these methods do not necessarily reflect IBI. Worse enough, despite many efforts, traditional methods of teaching have tended to dominate in many secondary science classrooms in Tanzania (Kafyulilo & Tilya, 2019; Kinyota & Kavenuke, 2018; Kitta & Tilya, 2010), due to various reasons, including pressure to cover a science content (Kinyota & Kavenuke, 2018). To complicate the matter, teachers do not get enough opportunities of professional development (Anangisye, 2011; Kinyota et al., 2019; Komba & Nkumbi, 2008).

Regarding research on IBI, only a few studies (Mkimbili, et al., 2017) have investigated the use of IBI in Tanzania. Also, given that IBI is officially non-existent in Tanzania, there is a need for Tanzania to learn from other countries that have officially adopted IBI as a formal approach to guide the teaching and learning of science.

1.1 Study Purpose and Research Questions

The purpose of this study was to investigate the extent to which curriculum documents in Tanzania support practising IBI in science classrooms. In addition, the study intended to provide lessons for Tanzania in case the country wishes to adopt IBI as an approach to teaching science. To achieve these ends, literature on the subject of IBI was reviewed to establish an analytic framework. Furthermore, literature on the subject of policy borrowing and lending was reviewed to provide a framework of guiding IBI adoption. Specifically, the study addressed the following research questions:

(i) What are the main features of IBI?
(ii) To what extent do science curriculum documents in Tanzania support practising IBI?
(iii) How best can IBI be adopted in Tanzania science classrooms?

2. Inquiry-Based Instruction: A Theoretical Framework

IBI—or simply inquiry—is widely described as a method of teaching and learning where students learn school science similar to how it is practised by professional scientists (Dudu & Vhurumuku, 2012a; Vhurumuku, 2011). However, this definition has been attacked for not providing tips on how teachers should practice inquiry in science classrooms. As a response, four general types of

inquiry have been suggested as one way to address the confusions regarding what constitutes IBI. Fitzgerald et al. (2019: 544) summarise them as:

1. *Confirmation inquiry*: students are provided with the question and procedure, and the results are known in advance;
2. *Structured inquiry*: students are provided with the question and procedure, but have to generate an explanation supported by the evidence they have collected;
3. *Guided inquiry*: students are provided with the research question and they design the procedure to test their question and generate explanations; and
4. *Open inquiry*: students derive questions, design, and carry out investigations; and communicate their results.

The first two types of inquiry are common in many science classrooms (Capps et al., 2012), and include learning activities such as structured laboratory experiments where students follow teachers' guides or manuals to perform experiments. According to Windschitl (2003), these types of inquiry neither represent true inquiry nor are they effective in developing inquiry skills among students. Furthermore, while the above four types of inquiry represent the level of inquiry, with open inquiry indicating the largest extend of inquiry, they speak less about what activities constitute IBI. Thus, to distinguish it from other sets of pedagogies that encourage students to memorise information, IBI emphasises on developing an inquiring mind (Cairns & Areepattamannil, 2019). In practice, several other scholars (Anderson, 2000; Jiang & McComas, 2015; Cairns & Areepattamannil, 2019) have defined IBI as a set of learning opportunities that allow students to involve in methods and processes used by practising scientists. This kind of learning—or what Capps et al. (2012: 292) has called 'scientific inquiry—is said to be the best approach in introducing students to the real scientific life. In describing the activities associated with IBI, Cairns & Areepattamannil (2019: 3) avows that:

> ...inquiry-based teaching involves generating situations where students are required to observe and question phenomena, suggest explanations for the observations they have made, design and carry out experiments that provide evidence that support or contradict hypotheses, and analyse data and draw conclusions from data.

In general, IBI requires teachers to encourage students in generating questions, designing and carryout investigations, providing alternative explanations, communicating results, and doing hands-on activities.

Also, regarding students' learning of classroom science as it is practised by scientists, Dudu and Vhurumuku (2012a) argue that scientific inquiry as practised by professionals is very complex and involves both complex and expensive apparatus. That is to say, schools rarely have sufficient resources and time to engage in such kind of activities. Moreover, it is also recognised that the cognitive tasks involved when conducting professional scientific investigations are more complex than what students can manage in science classrooms (Dudu & Vhurumuku, 2012a; Kang & Keinonen, 2018). Nonetheless, while classroom inquiry cannot reach the exact level of sophistication of scientific inquiry, it can be modelled after scientific inquiry to incorporate aspects that can help students acquire inquiry skills (Capps et al., 2012).

While the above studies have focused on broad descriptions of inquiry, there have been efforts to break down the definition of inquiry into simple and observable tasks that teachers can easily implement in science classrooms (ibid.). Following this emphasis, inquiry in a science classroom has been viewed as a set of classroom activities that actively involve learners as opposed to what happens in traditional classroom where teachers dominate the teaching/learning process (Vhurumuku, 2011). In IBI, the role of a teacher is that of a facilitator. Students are actively involved in developing questions and problems, doing investigations, and finding solutions to those problems (Anderson, 2002). In that regard, Anderson (ibid.) identifies practices such as connecting science lessons to students' real-life experiences, hands-on activities investigations, and active participation (e.g., students give opinion about the topic) as activities that define an inquiry-based classroom.

According to the National Research Council [NRC]—a public policy advisory arm in the US)—inquiry-based science instruction should be at the heart of all science teaching and learning. In defining IBI, the NRC (1996: 2) puts it thus:

> When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations.

The NRC's conceptions of inquiry seem to suggest considering the goals of inquiry as a first step. According to Lehesvuori et al. (2018: 1050), inquiry covers three main domains: "... learning to do inquiry, learning about inquiry (conceptual understanding about inquiry), and learning through inquiry."

According to Vhurumuku (2011), the more the open-endedness, the greater the extent of inquiry. As such, for NRC (1996), IBI is considered to be that instruction that provides students with opportunities to pose and restructure questions that are researchable, design and conduct investigations, do data manipulation, as well as sharing results of their investigation. In fact, most of the advantages of IBI such as promoting students' scientific reasoning are attributed to open inquiry (Dudu & Vhurumuku, 2012b; Vhurumuku, 2011; Moote, 2019). For that reason, open inquiry is suggested as a practice that science education should adopt in Tanzania. However, it is important to note that, in practice, students will not have opportunities to engage in open inquiry all the time. But at least they must be given an opportunity to do so occasionally; say, once a week. Also, as Dudu and Vhurumuku (2012b) have found that teachers tend to vary considerably on their practice of open inquiry in science classrooms. Thus, following this review and in response to the planning of the first research question, the features of IBI of 'posing researchable questions' 'investigations', 'designing investigations' and 'communicating results of investigations' will be used as analytic tools to assess the extent to which IBI is promoted in curriculum documents.

3. Methods

3.1 Research Design

This study was informed by the embedded case study design, which is a type of case study involving more than one sub-unit of analysis (Yin, 2003). Generally, according to Yin (2003) a case study is a research design that seeks to gain an in-depth understanding of a case being studied. Thus, in this study, the embedded cases design was conceptualised using two sub-units of analysis, namely: curriculum documents, and the three countries from which the curriculum documents are used. Subsequently, this design informed the choice of document analysis as a research method. Document analysis is a qualitative research method that involves a systematic procedure to evaluate documents (Bowen, 2009; Wee & Banister, 2016). According to Bowen (2009), data from documents such as books, journals, manuals, and maps can be examined to elicit meanings and gain an understanding of a given phenomenon.

3.2 Selection of Documents and Cases

In answering the research questions, document analysis (Bowen, 2009; Wee & Banister, 2016) was used as the main method. There were two sets of documents. The first set included literature related to IBI. For the purpose of this search, journal data bases such as Google scholar, SAGE, JSTOR, Taylor and Francis, and Science direct were used to retrieve journal articles used in this

study. These databases provide access to many science education journals that have empirical studies on the topic of IBI. The researcher used key phrases such as 'inquiry', 'scientific inquiry', 'inquiry-based instruction', etc. By limiting the search to peer reviewed articles, each of these searches resulted to more than 137 articles. By first reading abstracts and later all sections of the first four articles (Capps et al., 2012; Dudu & Vhurumuku, 2012a; Moote, 2019; Schramm et al., 2018), other articles were obtained through snowball sampling technique (Wee & Banister, 2016) using search phrases such as 'inquiry-based teaching in science', 'classroom inquiry' and 'features of inquiry-based instructions'. Also, to get literature from African countries, which are presumably more resembling with Tanzania in terms of context, a key phrase 'inquiry-based instruction in Africa [also substituting Africa with Kenya, Uganda, Ghana, Nigeria]' was used. This search resulted to 21 peer reviewed articles, but only 4 articles—3 in South Africa and 1 in Tanzania—were closely related to IBI. Given that research and practice of IBI is common in the United States, the case of the adoption of IBI in South Africa was also found relevant if Tanzania is to learn from elsewhere.

The United States was automatically purposely chosen because of long-time emphasis and practice of IBI (NRC, 1996). For the purpose of background information, other articles from other countries were also included. Phrases such as 'effects of inquiry-based instruction/ teaching/science', 'challenges/barriers of implementing inquiry-based instruction' were used in a search that resulted to more than 93 articles. By reading abstracts and skimming through, 9 empirical articles were finally selected. For these ones, a search was limited to empirical journal articles mostly published over the past ten years (2010-2020) to get more recent data of the effect and challenges of IBI. Thus, the final search resulted to a total 24 empirical journal articles on the subject of IBI. In addition to those, other 6 articles on broad topics in science education and general education in Tanzania and elsewhere—3 on research methodology, and 4 related to the topic of education borrowing and lending (2 articles and 2 book chapters)—were as well selected and used as data source under the first set of documents.

A second set of documents were curriculum documents from the three countries: Tanzania, South Africa, and the United States. In the case of Tanzania, six syllabi of science subjects—both for Ordinary and Advanced secondary levels—were selected and downloaded from the Tanzania Institute of Education (TIE) website (https://www.tie. go.tz/). These syllabi have information such as the aims of education, as well as specific goals of science education, specific subjects, and class level. In addition, they guide teachers and

students on the teaching and learning strategies and resources to use for each topic. This information permitted the researcher to investigate the extent to which IBI is promoted by Tanzania secondary education. This investigation was done using criteria such as 'planning investigations', 'conducting investigations', 'posing researchable questions', and 'communication of results' as listed in the theoretical framework. In the case of South Africa and the United States curriculum documents were analysed using the same criteria with the purpose of providing comparative lessons to Tanzania in case of adoption of IBI.

From the US, the study used the science and technology/ engineering curriculum framework of the State of Massachusetts. Given the decentralised nature of the education systems in the US, state curriculum documents offer more information needed for this study. However, given that all states are guided by the same national standards (NRC, 1996), curriculum frameworks among states do not differ that much. In the case of South Africa, the national curriculum framework for physical sciences was used. All these documents have information such as aims and objectives, and recommended teaching strategies for science subjects, which permit a comparative analysis to be conducted. Given that these documents guide teachers' day-to-day activities, they influence instructional outputs.

3.3 Analysis of Documents

All documents were subjected to document analysis (Bowen, 2009) where key terms such as 'inquiry', 'question', 'investigation' 'experiment', and 'practical' were used to search for key themes related to IBI. After searching, the researcher conducted a frequency count to determine the rate of occurrence while reading whole paragraphs. The purpose was to determine the extent to which the documents promoted IBI. Also, all statements of aims and objectives for each subject were gauged against the criteria of IBI as stipulated in the theoretical framework. For the case of Tanzania, the term 'inquiry' was not frequently used, which could be due to the uncommon use of the term in the education discourse of the country. Thus, to avoid missing themes that are related to IBI, the researcher went through the teaching/learning (T/L) activities suggested in the syllabi to determine if they are consistent with IBI.

3.4 Ethical Issues and Consideration

For ethical reasons, the researcher made sure the ownership of the original data—in this case documents—is acknowledged. Also, given that documents freely available on the internet for public consumption—such as syllabi—were not originally designed to answer the present research questions, a criteria or

analytic tool was established to evaluate the documents to minimise misinterpretations. The researcher also remained mindful to ensure that, in case documents had any harmful identifying information on participants, anonymization is done. In the present study, no identifying information on participant was reported.

4. Findings

4.1 IBI in Relation to Curriculum Documents: A Comparative Analysis

4.1.1 The Tanzanian Case

Views of scholars over the utilization of IBI in Tanzanian education system are of mixed feelings. For instance, although IBI might not be fully practised in science classrooms, there are available strong convictions -- particularly in the analysis of the syllabi -- indicating some aspects of IBI being advocated. That is to say, one among of the nine aims and objectives of education in Tanzania ("... to develop and promote self-confidence and an inquiring mind" (MoEVT, 2009d: iii) advocates for the promotions of inquiring minds. However, since aims of education tend to be very broad and unmeasurable, they cannot be used by teachers when making instructional decisions. Nonetheless, they imply that IBI is very important in science education since it can serve that role of enhancing students' inquiry and self-confidence. Thus, analysing the extent of inquiry would require looking into more measurable aspects such as objectives and suggested teaching strategies.

General Objectives and Teaching Strategies in Science Education

The Tanzania O-Level physics syllabus identifies the objectives to "... understand procedures of scientific investigation ... (and) ... develop the language of communication in Physics" (MoEVT, 2007: v). Likewise, for A-Level, students must be able to "... use the scientific method in designing and carrying out experiments in Physics... (and) ... communicate using the language of physics" (MoEVT, 2009d: v). These objectives from these two levels of physics syllabi were found to be consistent with IBI because they require students to design and conduct investigation as well as communicate the results. However, they fall short on the aspect of encouraging students to 'pose researchable questions'. Again, it is hard to tell how these objectives are translated into teaching and learning activities without observing teachers in practise. Notwithstanding these shortfalls, the suggested T/L were found to be closer to indicating what happens in classrooms. The following extract from the O-level physics syllabus expound this explanation:

> The teaching and learning strategies indicate what the students and teacher are expected to do in the process of teaching and learning. Students are encouraged to work in small groups for maximum participatory and cooperative learning.

> The teacher shall assume the role of a facilitator to promote, guide and help students' teaching and learning activities. The whole teaching and learning process should be participatory and interactive, where the student learns by doing a series of logical activities (MoEVT, 2009d: vi).

In addition, when emphasising that teachers should use participatory methods, the A-Level chemistry syllabus identifies commonly used methods as "... think-pair-share, group discussion, library search, stories, question and answer, class activities and demonstrations" (MoEVT, 2009b: v).

The above quotes, first, imply that teachers are encouraged to use more learner-centred methods: methods that are consistent with IBI. However, although teachers might have some level of autonomy in deciding T/L strategies, the physics syllabus explicitly indicates T/L resources and strategies as suggestions for teachers to use in each unit. It is on this basis the study focused on examining the extent to which the T/L strategies and resources that are consistent with IBI. Through computer search, cross-referencing indicated that the term 'inquiry' appeared only three times out of 1064 strategies listed in the O-Level syllabus, while it does not appear anywhere in the T/L activities suggested in the A-Level syllabus. For instance, the O-Level syllabus explicitly states that "... the teacher through inquiry deductive to guide students to deduce the equivalent resistance for both parallel and series connections" (MoEVT, 2007: 39). Nonetheless, the time allocation and the T/L resources, "circuit diagrams" (p. 39), would suggest that the same syllabus makes it hard for teachers and students to engage in IBI. Also, an analysis of specific objectives and the T/L strategies and resources throughout the physics syllabus seem to be suggesting more overemphasis on the coverage of content goals than process goals, such as inquiry. Moreover, while teachers are encouraged to do several experiments over the course of six years of secondary education, many schools might lack the resources required to perform such experiments.

The same pattern is repeated across other subjects (see Table 1), where analysis indicated that although some learning objectives are consistent with IBI, there seem to be an overall overemphasis on content goals than process goals (such as investigations and sharing results of investigations). For instance, in the A-Level chemistry syllabus, the term 'inquiry' does not appear at all in the suggested T/L strategies. Also, this syllabus indicates that students will conduct several experiments. However, in actual practice these experiments tend to be more structured, with students following the steps provided by teachers and/or a guiding manual (Mkimbili et al., 2017).

Table 1: Example of Objectives

A-Level physics	A-Level Biology	A-Level Chemistry	O-Level Biology
design and perform experiments in mechanics, heat, vibration and waves and electrostatics.	develop entrepreneurship skills in biological communication, creativity and problem solving communicate effectively using appropriate biological terminologies.	communicate well using chemical symbols, formulae, and equations as well as the language of instruction	to record, analyse and interpret data from scientific investigations using appropriate methods and technology to generate relevant information in biological science (p. v)
design and construct simple technological appliances.	develop the ability and desire for self-study, self-confidence and self-advancement in biological sciences and related fields;		General objectives as apply scientific skills and procedures in interpreting various biological data
	promote love for work, self and wage employment, self-reliant and improved performance in the production and service sectors through application of biological skills and biological scientific technology		

Source: Extracted from (MoEVT (2005, 2009a, 2009b, 2009d)

Furthermore, in continued efforts to assess the practicability of IBI in actual classrooms, the focus was then turned to analysing the suggested modalities of assessment in the syllabi. These suggested assessment modalities (Tables 2 & 3) permitted an investigation of factors such as time allocation, instructional priorities, as well as students' expectations. Across all science subjects, a general pattern indicates an overemphasis on standardised examinations as opposed to assessment activities that are consistent with IBI.

Table 2: Guide for Assessment in A-Level Biology

Types of Assessments	Assessment measure	Frequency				Weight (%)	Total (%)
		Form V		*Form VI*			
		Term 1	*Term 2*	*Term 1*	*Term 2*		
Continuous assessment	Tests	2	2	2	–	10	
	Practical tests	2	2	2	–	10	
	Research projects	–	1	–	–	5	
	Individual assignments	2	2	2	–	5	
	Field work	1	1	–	–	5	

	Term exam	–	–	–	1	15	
Final exam	National exam	–	–	–	1	50	50
Total Marks							**100**

Source: Modified from MoEVT (2009a: viii)

For instance, A-Level students are assessed using paper-pencil tests by 75% (national examination, terminal examinations, and tests), while only 10% and 5% of assessment weight is allocated to practical and research projects. In that regard, it implies that regardless of whether practical and research projects embody the features of IBI, overall, there is less emphasis on assessment of T/L activities that are consistent with IBI.

Table 3: Guide for Assessment in A-Level Physics

Types of Assessments	**Assessment Measure**	**Frequency**				**Weight (%)**
		Form V		***Form VI***		
		Term 1	***Term 2***	***Term 1***	***Term 2***	
Continuous assessment	Practical	2	2	2	–	10
	Tests	2	2	2	–	10
	Individual assignments	2	2	2	–	5
	Portfolios	1	1	1	–	5
	Research project	–	–	1	–	5
Examinations	Terminal examinations	1	1	1	–	15
	National examination	–	–	–	1	50

Source: Modified from MoEVT (2009a: viii)

While less emphasis on assessing activities that are consistent with inquiry does not prohibit teachers from implementing IBI, it may alter their priorities by pressuring them to cover the syllabi contents. In other words, instead of focusing on practising IBI, teachers and students might be forced to focus on the preparations of examinations.

4.1.2 The United States Case

The 2016 science and technology/ engineering curriculum framework for the State of Massachusetts was used for this analysis. This curriculum framework provides information such as the goals, suggested instructional strategies, and competences of science and technology/engineering from kindergarten through the 12th grade. In addition, the framework has appendices that have step-by-step guidance for how teachers should teach different subjects. The framework recognises five subjects—earth science, biology, chemistry, introductory physics, and technology/engineering—making it suitable for a comparative analysis. This analysis was limited to information covering grades 8 through 12 to match

the equivalent of secondary school level in Tanzania. Just as with the Tanzanian case, listed competences and statements of intent were extracted to investigate the extent to which they promote IBI. Such an extraction, the researcher believed, would help readers make an informed comparative analysis.

The framework of the Massachusetts Department of Elementary and Secondary Education (MDESE, 2016: 97) explicitly identifies "eight essential science and engineering" classroom practices:

1. Asking questions (for science) and defining problems (for engineering).
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analysing and interpreting data.
5. Using mathematics and computational thinking.
6. Constructing explanations (for science) and designing solutions (for engineering).
7. Engaging in argument from evidence.
8. Obtaining, evaluating, and communicating information.

In addition, inside the framework document, the phrase 'inquiry' appears 53 times. Furthermore, IBI is officially identified as the formal teaching strategy in science, engineering, and technology. At the same time, IBI is well-defined inside the document with enough guidance provided to teachers on how to implement it for different topics. The framework (MDESE, 2016: 66-67) also lists the following competences:

(a) Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.
(b) Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyse systems, and/or solve problems.
(c) Plan and conduct an investigation, including deciding on the types, amount, and accuracy of data needed to produce reliable measurements, and consider limitations on the precision of the data.
(d) Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific questions and engineering problems, using digital tools when feasible.
(e) Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a

model 'makes sense' by comparing the outcomes with what is known about the real world.

(f) Apply scientific reasoning, theory, and/or models to link evidence to the claims and assess the extent to which the reasoning and data support the explanation or conclusion.

(g) Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, and determining what additional information is required to solve contradictions.

(h) Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media, verifying the data when possible.

While it is not easy to reveal what real happens in actual teaching practices, in general the practices and competences identified in this curriculum framework are consistent with IBI, when judged against the criteria of 'posing researchable questions', 'planning investigations', 'designing investigations' and 'communicating the results of investigation'. For instance, each competence listed above has an embodiment of at least one of these features of IBI. However, regarding assessment activities, the framework does not have detailed information about how subjects should be assessed.

4.1.3 The South African Case

As a recent adopter of IBI, the Republic of South Africa (RSA) represents a relevant and interesting case for the future of IBI. Along with the National Curriculum Statement (NCS), in 2006, the RSA introduced a new physical science curriculum. The new curriculum emphasises on 'science through inquiry (Dudu & Vhurumuku, 2012b: 581) as an approach that should guide the teaching and learning of physical sciences. Since then, the school curriculum in the RSA has undergone several reforms that aim to shift teaching and learning of science from transmission modes to more 'inquiry-based teaching' (Erduran & Msimanga, 2014; Lehesvuori et al., 2018: 1049). For instance, according to Lehesvuori et al. (2018), IBI has been integrated in pre-service teacher education programs. They further argue that, another achievement of the IBI curriculum is the allocation of about 40% of the time for continuous assessment on practical investigations. Additionally, as per this curriculum, students should be assessed twice on practical investigations, one for each subject (chemistry and physics). Practical investigations, the curriculum recommends, should be designed in such a way that students are "... assessed on their use of scientific inquiry skills, like planning, observing and gathering information, comprehending, synthesising, generalising,

hypothesising and communicating results and conclusions" (RSADoE, 2008: 144). Consequently, there has been a significant change in teachers' practices of IBI (Dudu & Vhurumuku, 2012b; Lehesvuori et al., 2018).

The learning program guideline analysed physical sciences (grades 10 through 12) of the new curriculum the same way other documents were done. When defining physical science, the guideline stresses that physical science will be taught "... through scientific inquiry, application of scientific models, theories, and laws in order to explain and predict events in the physical environment" (RSADoE, 2008: 3). It states the purpose of the physical sciences as:

> ...to make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena, for example, lightning and solubility. Examples of some of the skills that are relevant for the study of Physical Sciences are classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills" (ibid: 2)

Along with the purpose of the physical sciences, the curriculum identifies important skills as follows: (1) plan investigations; (2) conduct investigations; (3) interpret data and draw conclusions (4) solve problems; and (5) communicate and present information and scientific arguments. Although inquiry is mentioned only five times, there is an overall emphasis on IBI (see Table 4).

Table 4: Suggested Weightings for Assessment in RSA

Grades	Formal School-based Assessment	End-of-year Examinations
R-3	100%	n/a
4-6	75%	25%
7-9	40%	60%
10 and 11	25% including midyear examination	75%
12	25% including midyear and trial examination	External examination 75%

Source: Modified from RSADoE (2008: 144)

However, in ascending order of grade levels, the curriculum seem to overemphasise on standardised examinations as shown in Table 4. This pattern corresponds to that in Tanzania. The only difference is that the new physical science curriculum in the RSA stresses that assessment activities should focus more on higher-order thinking skills, especially for grades 10 through 12 (equivalent to high school in Tanzania).

Table 5: Recommended weighting by cognitive levels for grade 10-12

Cognitive Levels	Description	Paper 1 (Physics)	Paper 2 (Chemistry)
1	Remembering	15%	15%
2	Understanding	35%	40%
3	Applying, analysing	40%	35%
4	Evaluating, creating	10%	10%

Source: Modified from RSADoE (2008: 144)

Overall, the new physical sciences curriculum in the RSA, as compared to the Tanzanian curriculum, is more consistent to the features of IBI such as 'posing researchable questions', 'planning investigations', 'designing investigations' and 'communicating the results of investigation'.

4.2 A Guiding Framework for IBI Adoption

As stated earlier, the purpose of this study was not to advance and propose a blueprint for adopting IBI in Tanzanian science classrooms. Rather, it intends to stimulate the debate on the best practice of teaching and learning science. Thus, the study tries to suggest a framework for guiding Tanzania in case the adoption of IBI as an approach to teaching and learning of science avails. The good news is that science teachers in Tanzania can build on existing teaching practices such as those stressed in the competence-based curriculum to implement classroom inquiry. Thus, the adoption of context-specific aspects is recommended. Indeed, because of inevitable contextual differences, scholarship in comparative education warns that borrowed models may not necessarily work in other contexts as in the original contexts (Booth, 2006; Phillips, 2004; Steiner-Khamsi, 2006). According to Steiner-Khamsi (2006), such models must be carefully adapted to match the new contexts.

4.2.1 Policy Borrowing and Lending: A Guiding Framework

The education policy adoption framework by David Phillips (2004) has been extensively used to guide adoption of several policies and practices in education (Steiner-Khamsi, 2006). Moreover, although globalization has resulted to a fast diffusion of education practices across national boundaries, countries still involve in deliberate efforts to learn from each other (Arnove, 2007). Thus, as per Phillips's (2004) proposed framework, policy borrowing in education follows four stages in a circular form: cross-national attraction, decision making, implementation, and domestication.

The first stage of 'cross-national attraction, describes how countries are attracted to borrow and/or lend educational practices. During this stage, factors such as regime change, systemic collapse, negative external evaluation, and internal dissatisfaction may spark cross-national borrowing/lending. Some of the things that may be of interest for borrowing/lending include things like the guiding philosophy, goals, strategies and/or techniques, processes and 'enabling structures' (ibid: 58).

The second stage is the decision-making stage. Here the decision may be 'theoretical' (assumptions that certain ideas/practices will work in the home contexts), or 'practical' (analysis of the home context has been carefully made and implementation proved to be possible), and what the author has described as a 'quick fix' meaning that the idea/practice may not be compatible with the new context, but must be implemented to meet internal criticism or please some influential actors such as donors (ibid: 58).

Implementation constitutes the third stage, involving efforts to adapt a borrowed idea/practice to the new context where the extent of compatibility, in terms of context, will largely affect the speed of implementation. According to Phillips (2004), the speed can also be affected by resistance or support from implementers. Generally, adapting the new idea/practice to a new context is a key for successful implementation.

The last stage involves making a borrowed idea/practice part of the new system. Different terms have been used to refer to this process, for example, 'internalization' (Phillips, 2004: 59) and 'indigenization' (Steiner-Khamsi, 2000: 162). Also, during this stage evaluation is made to assess the impact of a borrowed idea/practice on existing structures and the overall performance in relation to existing systems. Results of evaluation may lead to another 'cross-national attraction", repeating the cycle repeatedly (see Fig.1).

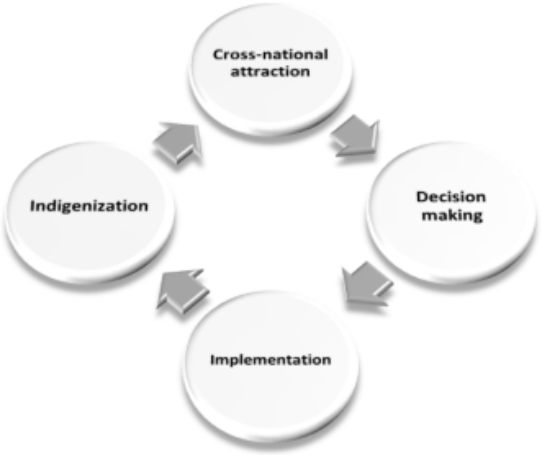


Figure 1: *Four Stages of Policy Borrowing and Lending*

This study situates IBI in a science education within the large context of educational transfer/borrowing. As shown in Fig. 1, reflection on the process of policy borrowing can guide Tanzania policymakers and curriculum developers in adopting some aspects of IBI as discussed in the previous sections. Specifically, lessons from the RSA and the US provide the foundations for constructing curriculum materials that promote IBI.

5. Discussion

Worldwide, the story of IBI is characterised by many faces both of successes and challenges. So, even Tanzania ought to expect some limitation in the implementation of IBI if it is to be adopted. Many would expect the situation in the US to be ideal. However, even in the US, considered as the champion of IBI (NRC, 1996), teachers are still struggling on how to implement IBI (Capps et al., 2012). For example, as Capps et al. (ibid.) argued, teachers in the US perceived high-stakes testing, time constraints, lack of enough professional development opportunities, and the lack of common consensus on what constitutes IBI as main barriers of implementation. Likewise, science teachers in South Africa are still facing similar challenges (Dudu & Vhurumuku, 2012b; Lehesvuori et al., 2018). That is to say, despite deliberate efforts to implement IBI, science teachers in these countries are still perceiving the barriers perceived by Tanzanian science teachers as they implement more learner-centred methods.

Nonetheless, document analysis has indicated that the two countries have formally recognised IBI as an approach to teaching science while Tanzania has not. As Capps et al. (2012) warned, many teachers confuse IBI with other student-centred techniques that do not necessarily expose students to scientific inquiry. Thus, the use of learner-centred approaches in science classrooms in Tanzania do not necessarily lead to the development of inquiry skills. To capitalise from the advantages of IBI -- such as enhancement of students interests and self-efficacy of science (Cairns & Areepattamannil, 2019; Fitzgerald et al., 2019), conceptual understanding of science concepts (Edelson et al., 1999), promoting scientific reasoning (Fang, 2020; Fitzgerald et al., 2019; Manz et al., 2020) and development of self-regulation skills (Crujeiras-Pérez & Jiménez-Aleixandre, 2019; Moote, 2019) -- it is a practice that Tanzania should think of emulating. In addition, given that IBI embodies the principles of real scientists, students will be properly groomed as future scientists by engaging in it. Apart from policy borrowing and lending framework (Phillips, 2004), and the IBI frameworks presented above as guide, the following additional tips ought to be taken into consideration if Tanzania wishes to adopt IBI as an approach to T/L science.

1. Lifting-up barriers by creating enabling structures: Lessons from the implementation of IBI identify major barriers such as time restrictions, insufficient training, and resources (Capps et al., 2012). More serious, the main challenge facing the implementation of IBI is the lack of consensus on what constitute IBI (Dudu & Vhurumuku, 2012a, 2012b; Nadelson et al., 2013; Williams et al., 2019). Thus, to succeed in the adoption of IBI, these barriers must be addressed. For instance, to address the question of time restrictions, the new curriculum in the RSA allocated specific time (40% of continuous assessment activities) for practical investigations. Overall, it is important to understand teachers' decisions within the wider implementation context.

2. Working on teacher beliefs: One of the serious barriers has to do with teacher beliefs (Dudu & Vhurumuku, 2012b; Hutchins & Friedrichsen, 2012). More revealing, teachers' beliefs tend to be persistent and resistant to change. Given that science teachers are, for a long time, used to the transmission model of teaching (Kinyota & Kavenuke, 2018), the adoption of IBI will demand serious considerations in unpacking teacher beliefs.

3. Setting educational intents that are consistent with IBI: Document analysis has shown that countries that adopted IBI started by revising the objectives of science education. Given that curriculum documents in Tanzania, as document review has indicated, overemphasise on content coverage, the adoption of IBI will surely call for revising the objective of science education into more process-oriented ones.

4. Focus on Teacher professional development: IBI is a complex approach that demand teachers to have a set of key skills to implement it (Capps et al., 2012; Dudu & Vhurumuku, 2012b). Given that teachers in Tanzania, including science teachers, rarely engage in professional development (Kinyota et al., 2019; Kitta

& Tilya, 2010), the adoption of IBI will require science teachers to engage in short-term on-job training and ongoing professional development that will equip them with attitudes and skills necessary to implementing IBI. In addition, IBI should be integrated in science teacher education programs as in the case of the RSA and the USA.

5. Reconsider the way practical experiments are carried out: One of the challenges facing the IBI implementation of the way scientific experiments are conducted. It is noted that in Tanzania most experiments are conducted in such a way that students follow the provided step-by-step procedures to test an existing theory (Mkimbili et al., 2017). This practice, according to several scholars (e.g., Dudu & Vhurumuku, 2012a, 2012b; Lehesvuori et al., 2018), does not support IBI. Instead, students should be given opportunities to design and conduct their own investigations during scientific experiments.

6. Conclusions

To conclude, the study has established that IBI can be practised in science classrooms in Tanzania. However, challenges such as time and resources allocated for investigative learning activities, and teacher beliefs will have to be considered in case Tanzania wishes to adopt IBI. However, it is important to note that the adoption of IBI does not necessarily demand an overhaul of the existing education system. Rather, it calls for experts and teachers to carefully select aspects of IBI that can be integrated into existing approaches to science teaching and learning. In other words, adoption could involve only a few missing aspects of IBI in the existing science curriculum in Tanzania.

7. Limitations

One of the major limitations worth mentioning is the reliance on documents. As a result, it is hard to make several claims. For instance, observing teachers' classrooms would have provided more information regarding teachers' practice of inquiry across all cases. Additionally, relying on documents only makes this analysis to miss important contextual realities surrounding the implementation of IBI in the three countries. Therefore, more studies are needed to investigate how science teachers in Tanzania implement some aspects of open inquiry. So far, one study (Mkimbili et al., 2017) that has done so has revealed that teachers rarely practice IBI in science classrooms. Another limitation relates to comparing of education systems that differ, for instance, in terms of education centralization, curriculum organization, and resource contexts. Thus, contextual differences should be carefully considered if IBI is to be adopted in Tanzania.

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