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The Constructivist Theory in Mathematics: The Case of Botswana Primary Schools

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Abstract

This paper is based on a large research study that compared teacher quality and student performance in Southern Africa countries of Botswana and South Africa. In this paper we explore the extent to which the primary school teachers in Botswana use the constructivist approach in the teaching and learning of mathematics. Data was collected through classroom videotaping. Sixty out of the 64 mathematics teachers teaching at least one mathematics lesson, and more than one third of the teachers were videotaped twice. A total of 83 mathematics lessons were videotaped. The results of the study indicated that a large percentage of lessons observed required learners to simply recall rules, while a very small percentage of the lessons observed required learners to investigate or explore relationships between mathematical ideas.

Keywords: Constructivism, mathematics, active learning, Botswana, passive learning.

Introduction

Constructivism is a learning theory describing the process of knowledge construction. Knowledge construction is an active, rather than a passive process. Constructivists believe that knowledge should not be just deposited into the learners' minds; instead it should be constructed by the learners through active involvement in the learning process. Hausfather (2001) noted that,

Constructivism is not a method. It is a theory of knowledge and learning that should inform practice but not prescribe practice. By its very nature, constructivism emphasizes the

importance of the teaching context, student prior knowledge, and active interaction between the learner and the content to be learned. (p. 18).

In the constructivist perspective, knowledge is constructed by the individual through his/her interactions with the environment. Unlike the traditional mode of learning whereby the teacher plays an active role in the teaching/learning environment, and learners passively receive the content, constructivists believe the learning should be centered on the learner. This has been acknowledged by Simon (1995) that "we construct our knowledge of our world from our perceptions and experiences, which are themselves mediated through our previous knowledge" (p. 115).

When teachers believe that learners are empty vessels to be filled with the information from the authority, then teacher domination will always exist in the teaching learning environment. According to Freire (1970) the domination of the teacher is referred to as the 'banking concept' education. The banking concept sees the teacher as the only source of information. It is important that teachers should actively involve learners in their teaching to enable the students to construct knowledge. According to the Educational Broadcasting Corporation (2004) " in the classroom teaching, constructivist view of learning can point towards a number of different teaching practices…it means encouraging students to use active techniques (experiments, real-world problem solving)" (p. 1). Kennedy (1997) also noted that "what students learn is greatly influenced by how they are taught" (p. 2). Mathematics by nature is a subject that requires learners to be fully engaged in order for learning to take place. Therefore, this paper explores the extent to which learners were given the opportunity to construct their own knowledge in the mathematics lessons.

Statement of the Problem

Botswana students need to learn mathematics differently than the current practices employed. Research has revealed that most teachers in Botswana tend to present mathematics knowledge to the learners to swallow and regurgitate when needed, and not with the aim of helping them to develop independent skills to construct their own mathematics knowledge (The Report on the process of learning in Botswana: An in-depth study of the quality of mathematics teaching in sixth grade classrooms and its effect on learner achievement, 2011). Teachers have also been discovered to have insufficient skills to present maths skills to learners (The Report on the process of learning in Botswana, 2011). Teachers, therefore, must change their instructional techniques for learners to be actively engaged in their own learning and not passive recipients. Learners must learn to communicate and think mathematically. For future educational growth, , Botswana needs learners who are creative, analytic, problem solvers. Such skills can be promoted at the school level through the constructivist approach.

Review of Literature
Constructivism

The constructivist theory to teaching and learning has been broadly addressed in a number of researches in mathematics education (Katic, Hmelo-Silver & Weber, 2009; Steele, 1995). According to this theory, students do not just passively receive information but constantly create new knowledge based on prior knowledge in conjunction with new experiences. As opposed to the traditional approaches where students learn by copying "word for word" what teachers say, constructivism has shifted to a more radical conception of teaching and learning whereby learners' fresh ideas are brought to class, acknowledged, and enhanced through a variety of teaching and learning techniques that actively engage them.

A number of studies have shown the effectiveness of the constructivist approach in teaching and learning in contrast to the traditional drilling and reciting approach (Hmelo-Silver, Duncan, & Chinn, 2007; Steele, 1995). A study by Steele, (1995) on "A construct visit Approach to mathematics teaching and learning….." revealed that using constructivist

learning strategies has positive gains. For example, such strategies tend to create an exciting environment for students to learn mathematics and enhance their self-esteem. According to this study, when students learn to construct their own knowledge, they tend to have control of mathematical concepts and think mathematically.

Another study by Katic, Hmelo-Silver & Weber, (2009) on Material Mediation, suggest that materials can help to motivate and mediate the participants' collaborative problem solving discussions. In this study, Katic, et al., teachers used a variety of resources to solve a mathematics problem and construct explanations about the learning process; they, then, posed questions about the problem to clarify their solutions. This is a method that is encouraged in social theories like constructivism, as it generally assists in keeping the learners on task. Although constructivist learning theory does not tell us how to teach mathematics, a teacher with a constructivist background can facilitate learners' construction of knowledge by applying different constructivist teaching approaches that are in aligned with this learning theory. This type of mathematics teaching forms the basis of this study.

Nevertheless, a number of studies in Botswana on teacher centered versus learner centered approaches have revealed that teacher centered approaches are dominant in Botswana classrooms (Prophet, Rowell, 1993; Republic of Botswana, 1993; Tabulawa, 1997, 1998). For example a study By Tabulawa, (1997), on Pedagogical Classroom Practice…… has indicated that students in the classrooms have been shown to be passive recipients of knowledge, which means that they are not given the opportunity to construct their own knowledge. The commission on Education (1977) has also highlighted this as a major concern in the education system of Botswana. According to this policy, teachers have a tendency to dominate in the classroom as most of the information transmitted to students is often too abstract and mostly requires them to memorize. This policy in a way was calling for a radical change in the classroom practices to allow for students' growth through teaching and learning that is learner driven. Tabulawa, (1998) has also indicated a concern on the perceptions that teachers have that influence their classroom practices. In addition, Tabulawa, noted that there are certain factors that influence teachers to be dominant in the classrooms such as "teachers' assumptions about the nature of knowledge and the ways it ought to be transmitted and the perceptions of students". These factors are worrisome as they tend to perpetuate teacher centered approaches as opposed to learner centered practices. The study is out to find out the extent to which teachers apply the constructivist theory of teaching and learning when teaching mathematics. This is a theory that has been proven beyond reasonable doubt to enhance students' independent learning.

Methodology

Sampling

To address the objective of the study, the researcher used data from Human Research Science Council (HRSC) -Stanford- University of Botswana Regional Education Study that was conducted in 2009/10 as a comparative study on teacher quality and student performance in Botswana and South Africa. Out of 60 sampled schools in Botswana, data was obtained from 58 schools and 64 classrooms (two math classrooms in six of the schools taught by the same teacher in each school). The sample focused on 5 districts in Botswana, namely; low-income schools in five districts within 50 kilometers of the South African border, Gaborone (18 schools, 617 students), Kgatleng (16 schools, 495 students), Lobatse (6 schools, 152 students), South East (10 schools, 305 students), and Southern (8 schools, 205 students).

Instrumentation

Data was collected through videotaping 83 standard six mathematics teachers teaching at least one mathematics lesson. More than one-third of the teachers were videotaped twice. The filming was done at the middle and towards the end of the year by trained personnel of the

Botswana team from the University of Botswana. Teachers whose classes were videotaped were informed in advance about the research team visits. They were further told that the videos will only be used for the study.

Data Analysis

The videotape analysis was also done by well trained personnel from the University of Botswana and the U.S.A. From various video analyses conducted, the levels of cognitive demand were selected based on the relevance of this paper since the focus was on the thinking process in which the learner was engaged. The 'level(s) of cognitive demand' in which learners were engaged in during the lesson were derived from a rubric in Stein et al.'s (2000) classification of higher and lower cognitive demand. These are:

Lower Level Demand

1. ***Memorization:*** Memorization recollection of facts, formulae, or definitions

- Task requires the recall of previously learned material. Or the committing of facts, formulas or definitions to memory.
- Task cannot be solved using procedures because procedures do not exist or the time frame in which task is to be completed is too short to use a procedure.
- Tasks involve exact reproduction of previously seen material and what is reproduced is clearly and directly stated.
- Task has no connection to concept or meaning that underlies the facts, rules, formula, or definition being learned or reproduced.

2. ***Processes without Connections****:* Performing algorithmic type of problems and have no connection to the underlying concept or meaning

- Task is algorithmic. Use of procedures either is specifically stated or its use is evident based on prior instruction, experience, or placement of task.
- Task leaves little ambiguity about what needs to be done and how to do it.
- No connection or explanation of the concept is needed.
- Task focuses on producing correct answers rather than developing mathematical understanding.

Higher Level Demand

3. ***Processes with Connections*****:** Use of procedures with the purpose of developing deeper levels of understanding concepts or ideas

- Task requires use of procedures to develop deeper understanding of the concept.
- Task suggests pathways to follow that are broad general procedures rather than algorithms that are opaque with respect to underlying concepts.
- Tasks are usually represented in multiple ways (e.g. visual diagrams, manipulatives, symbols, problem situations) Connections among the representations builds meaning to concept.
- Tasks require some thinking, although using a procedure it cannot be followed mindlessly. Students need to engage in conceptual ideas to successfully complete the task.

4. ***Doing Concepts and Processes*****:** Doing mathematics complex and non-algorithmic thinking, students explore and investigate the nature of the concepts and relationships

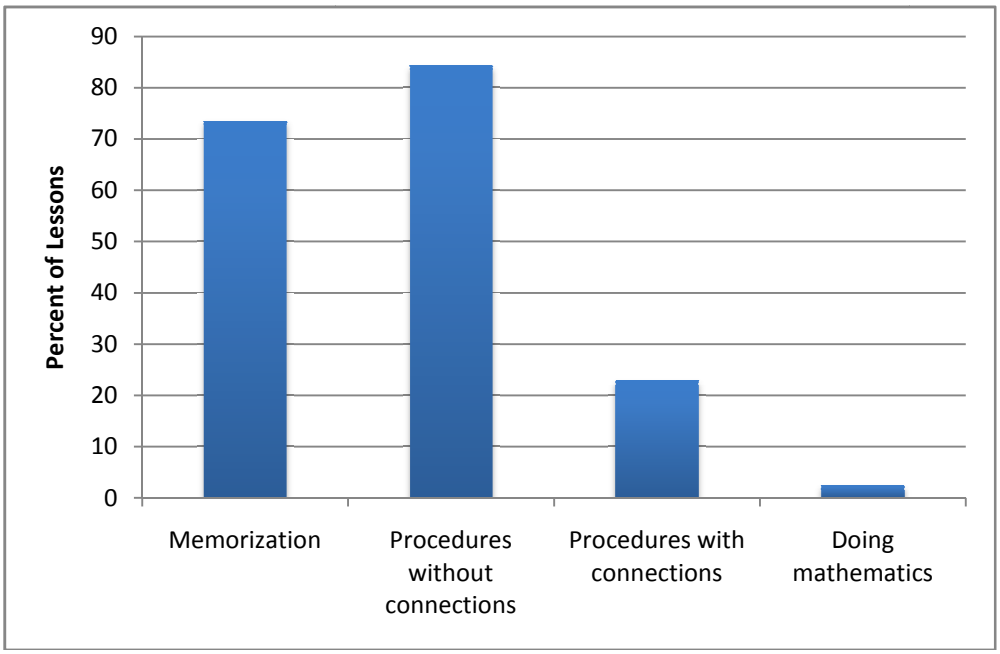
- Task requires access of relevant knowledge, self-reflection on actions, exploring concepts, processes and relationships in non-algorithmic activity.
- Task demands self-monitoring or self-regulation of thinking.

- Task requires analysis of constraints that may limit possible solution strategies and solutions.
- Task is unpredictable due to nature of solution process required.

The focus in this component (the levels of cognitive demand) is the thinking processes in which learners engage in the observed lessons. In a constructivist classroom, learners are expected to think at a very high level, - as they are actively involved in their own learning.
Apart from the analysis of the levels of cognitive demand, the data analysis members also made some observations on how students interacted with the teacher. They made notes on these observations.

Findings

Levels of cognitive demand in classroom teaching in a sample of Botswana School



The findings of the study indicated that 7.3.5% of the lessons required learners to recall a fact which in fact is memorization, 85% of the lessons do procedures without connections, and 23% do procedures with connections and only 3% students explore and investigate the nature of the concepts and relationships.
From the video note observations, the data indicates that in most lessons teachers asked the students questions and allowed the whole class to call out the answers. These findings concur with Arthur's (1998), that "I observed many teacher-dominated classroom procedures, in particular lengthy recitations of questions by teacher and answers by individual or whole class" (p. 314). When teachers are the only ones asking questions and students being the respondents, learning is no longer centered on the learner but more on the teacher.

Discussions

From the findings it is evident that teachers used the procedural teaching and students learned by memorizing facts. When learners do the rote learning they are not encouraged to think critically and to construct their own knowledge as the teacher is the one who provides the content for them. Memorization in Botswana classrooms is very common as evidenced by previous researchers such as Fuller and Snyder (1991), Arthur (1998), Tabulawa (2004, 1998,

and 1997). Arthur and Martin (2006) in their study on comparative classroom teaching and learning found that most teachers in Botswana "ask low-level factual questions, with few opportunities for pupils…learners do not exercise their reasoning powers or imaginations" (p. 195). As data has indicated that lessons were predominately recalling of facts and procedures without any application to real life situations, one may assume that learners were not constructing their own knowledge but were simply spoon-fed by teachers. The National Commission on Education of Botswana (1977) also concurs with this study that learning is mostly memorizing and recalling of facts which, in a way, does not add any value to the learning process. One of the goals of vision 2016 is for the education system of Botswana to provide quality education that would enable Batswana to adapt to the changing needs of the country as well as the global changes. This vision goal can be achieved if teachers adapt to theories such as constructivism that allow learners to explore and come up with their own solutions to the problems. Memorization and imitating teachers will not give Botswana learners sufficient wisdom to survive independently in this world of socio-political and economic unrest.

From the data, one concludes that learners were not given tasks that challenged their thinking and the construction of their own knowledge. Henningsen and Stein (1997) noted that Mathematical tasks are central to students' learning because "tasks convey messages about what mathematics is and what doing mathematics entails"(NCTM, 1 991, p. 24). The tasks in which students engage provide the contexts in which they learn to think about subject matter, and different tasks may place differing cognitive demands on students. (p. 525)

Indeed if learners are given tasks that encourage memorization of ideas, according to Stein et al.'s (2000) levels of cognitive demands, the learners are at the lowest level. In this level students are given formulas to memorize and just follow procedures without making any connections to real life situations. For example, in one of the videos the teacher was teaching the topic "area". This is how she taught the lesson; first she asked the learners the meaning of the word area. Learners could not define the word, and instead of the teacher defining it, she gave the learners the formula for solving the area of a square. She then drew some shapes on the board, solved one as an example and then asked the learners to use the formula to find areas of the rest shapes. Indeed using the formula given, most learners were able to find the areas of the shapes drawn by their teacher. But can the learners apply the idea to real life? The procedure may be correct. However, did the learners make any connections to real life? From the analysis of the data it is evident that most tasks given to the learners only concentrated on the low levels of cognitive demand. The task focused on producing correct answers rather than developing mathematical understanding.

Various reasons such as examination driven curriculum may have contributed to Botswana teachers delivering facts (giving lower level tasks) to learners rather than allowing learners to think and construct their own knowledge. The centralized curriculum as well as examinations does contribute to teacher-domination as teachers are more concerned with completion of the syllabus at a given period. Arthur and Martin (2006) acknowledged that "pupils examination success provides access to further education in Botswana" (p. 192) forcing teachers to rush through the syllabus. This has also been confirmed by Tabulawa, (1998), that teachers' perceptions of students and the goals of schooling have a direct influence in the way teachers teach because teachers see themselves as the main transmitters of knowledge, while students are passive recipients who must memorize and produce during examinations. Another reason may be the large numbers of teacher to students' ratio which then encourages delivering of facts rather than allowing learners to construct their own knowledge.

In a constructivist learning environment, learners learn best by discovering their own knowledge. Teachers encourage higher – level thinking so that students can reach beyond the simple factual response. Moreover, in a constructivist classroom, learners are encouraged to summarize concepts by analyzing, predicting, justifying, and defending their ideas. Cobb (1999) noted that "constructivist learning theory predicts that knowledge encoded from data by learners themselves will be more flexible, transferable, and useful than knowledge encoded for them by experts and transmitted to them by an instructor or other delivery agent" (p. 15).

In constructivism knowledge construction is emphasized rather than knowledge reproduction. Knowledge construction helps the learners to remember what they have learned.

The second highest level of cognitive demand encourages 'use of procedures with the purpose of developing deeper levels of understanding concepts or ideas'. For learners to master the content, constructivist believe that higher order thinking skills and deeper understanding should be emphasized in the learning environment. Learners develop into critical thinkers if they are actively involved in the learning process and are encouraged to apply the concepts to real life situation. By this, learners are making meaningful connections. Learners can use their experiences to construct new information if given the opportunity to practice in the teaching/learning environment rather than having facts poured into them by the one in authority. The role of the teacher is to serve as a facilitator.

The highest level of cognitive demand calls for doing mathematics complex and non-algorithmic thinking, students explore and investigate the nature of the concepts and relationships. Tasks that learners are supposed to be engaged in should help them explore the relationship between concepts they are learning and reality. For, example, if learners are doing 'area' as a topic of study, let them explore the idea and find out how the topic can be applied in real life situations. Teachers should provide tasks that will lead the learners to explore, discover, and apply the concepts. Richard cited by Simon (1995) noted that

It is necessary [for t he mathematics teacher] to provide a structure and a set of plans that support the development of informed exploration and reflective inquiry without taking initiative or control away from the student. The teacher must design tasks and projects that stimulate student to ask questions pose, problems, and set goals. Students will not become active learners by accident but by design through the use of the plans that we structure to guide exploration and inquiry. (118)

It is, therefore, the responsibility of every teacher to plan activities that require high level of cognitive demand.

It is important to note that high levels of cognitive demand require students to use their prior knowledge as advocated by the constructivists. Henningsen and Stein (1997) contended that "connections with what students already know and understand also play an important role in engaging students in high-level thought processes" (p. 527). For students to perform tasks that require critical thinking and applying of concepts, experience or prior knowledge used as a base is crucial.

The findings in this study indicate that teachers did not engage the learners on tasks that required them to use higher levels of cognitive demand. These findings concur with what Prophet and Rowell cited by Fuller and Snyder (1991) that teachers in Botswana classrooms "ask for factual information through sentence completion exercise with pupils individual or in chorus simply adding the missing word. Students are rarely asked to explain the process or the interrelation between two or more event" (p. 276). This is a clear indication that teachers in Botswana classroom give learners tasks that are mostly associated with the low level of cognitive demand of which the constructivist theory does not encourage.

The theory of constructivism also values the uniqueness of every learner. Students learn differently. The teacher, as the facilitator, should appreciate every learner's strengths and weaknesses. Each learner should be given the opportunity to construct knowledge from his/her own experiences.

Summary

DeVries, Zan, Hildebrandt, Edmiaston, and Sales (2002) asserted that "teacherswho have been accustomed to teaching by telling and directing children's work must shift from seeing themselves as central in producing learning to seeing thechild as central"(p. 36). From the study one concluded that there was a lot of spoon-feeding in most classes. Students were not given tasks that encouraged them to be doers and thinkers of mathematics, but rather to be consumers of mathematics concepts. Knowledge construction was very limited in most classes making learning more teacher-centered.

The continued teacher domination in the Botswana teaching/learning environment will result in learners who cannot think deeply and critically. Knowledge is not passively received, but actively built up by the learners. Constructivism, therefore, encourages learners to be given the opportunity to construct their own knowledge from the previous experiences so at to be able to apply theory to practice and to make meaningful connections to what they learn to the real world.

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