Using Cognitive Activation to Support Constructivism in Teaching Mathematics in the Colleges of Education

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ABSTRACT
This study considered cognitive activation to confirm whether constructivism is used by the tutors to teach mathematics in the colleges of education. A cross-sectional quantitative data was collected conveniently from 621 third-year teacher-trainees of the 2019/2020 academic year in three colleges of education in the Volta Region of Ghana using a questionnaire whose variables were measured along a 5-point Likert scale to determine tutors' use of cognitive activation in mathematics lessons. The instrument was internally consistent with Cronbach's Alpha coefficient of 0.932 and externally consistent with Cohen's Kappa's interrater technique value of 0.924 for the 14 items that explained cognitive activation. The face, construct and content validity tests were conducted to ensure instrument validity. The mean Likert-scale response of 3.811 was corroborated by the composite score of 3.810 to indicate that tutors in the colleges of education largely teach mathematics using cognitive activation to emphasize constructivism. In addition, with a mean standard error of 0.044 and mean standard deviation of 1.096 which were significant at a 95% confidence interval, 69% of the respondents agreed that college tutors use cognitive activation strategy to deliver mathematics lessons. The study, consequently, revealed that tutors in the colleges of education use cognitive activation to effect constructivism in mathematics lessons. This conclusion should impact the teacher-trainees, to deliver effective mathematics lessons to basic school learners.

Keywords: constructivism, cognitive activation, instructional strategies.

1. Introduction

While education is the means to the political, social and economic growth of a nation [1], mathematics is the queen of science and technology and the bedrock of national development [2]. According to the Ministry of Environment Science, Technology and Innovation, science, technology and engineering education opportunities are adjusted by a strong mathematics background, such that, its effectiveness hinges on teacher quality. So, to build an industrial economy, there is a need for a strong mathematics culture [3]. In this regard, the 2014 Chief Examiners of the West African Examinations Council emphasised the strong mathematics culture for instructors to adopt effective instructional strategies preferably, constructivism, to teach mathematics. Learning theories of mathematics, accordingly, describe the process of learning that provides frameworks for instructional design for educators to create learning environments that empower learners to get the most from instructional experiences [4, 5].

Quality teacher education is a priority as teacher performance is of the highest interest in achieving excellent mathematics competence [6, 7].

Teachers are a powerful influence on students' success [8] such that, the use of effective instructional strategies and methods results in a good academic achievement rate which is seen in teacher competency in education with appropriate motivation and concentration in learning [9]. These learners are, subsequently, expected to use their existing knowledge and experiences, stimulated by asking questions to excite the learning process to understand new concepts [10]. Highly motivated students, who take studies seriously, accept challenges, participate in classroom activities and consider teachers' recommendations, have high academic achievement [11, 12]. These actions enable them to display their real mathematics potential as Praetorius, et al., (2017) buttress the point of using cognitive activation that focuses on "challenge" as a source of motivation in mathematics lessons. This action goes with the argument that the combination of challenging instructions with positive affection and support from the teacher is necessary to cultivate motivation among students during lessons [14].

Stimulating the interest of mathematics teaching and learning in teacher-trainees is critical in this current dispensation because of the significant role that mathematics plays in real life for everyone. While the traditional lecture method of reading the texts and giving exercises and drills helps students memorise facts and formulas to solve mathematics problems [15], it does not help them to learn and attain an in-depth understanding of what is required in the new knowledge settings [16]. To this end, cognitive activation supports the notion that when one understands a subject matter, the individual can transform the information into usable knowledge [17] thereby putting the theoretical concept into practice. Furthermore, knowledge transfer occurs when the learner understands the underlying concepts and principles that can be applied to problem-solving in new contexts [18]. On the other hand, when knowledge is obtained by rote, it is rarely transferred because the acquired knowledge is discrete and fragmented.

Research suggests that pre-service basic schoolteachers often do not have a fundamental understanding of school mathematics [19], particularly where, the research states that primary school teachers are incompetent in mathematics and pedagogy mainly due to the short pre-service teacher training periods [20]. In addition, teachers' insufficient subject-content knowledge is not surprising since they are products of primary and secondary schools, where research has shown that they rarely developed a deep understanding of mathematical concepts when they were in school ([21, 22]. Teachers' adequacy in mathematical content knowledge is more than simply ensuring that they acquire satisfactory subject matter, it also depends on improving instructional strategies to maximise student learning [23].

Scanning through the 2019 mathematics syllabuses for basic and secondary schools of the Ghana Education Service, the constructivist theory has been explicitly prescribed to mathematics teachers with the concept of scaffolding, inclusion and differentiated learning models. Constructivism, therefore, emphasises that knowledge is a product of one's cognitive act, which is built on previous knowledge to support effective teaching, and allows one to move to new knowledge [24]. Research conducted by [6] indicated that teachers do not have sufficient knowledge about the concept of constructivism such that, out of 138 teachers interviewed, only 35 responded that they understood the term, constructivism. However, 75.3% of the 35 participants of this number could not explain the term "constructivism" correctly. This means that most teachers at the pre-tertiary levels do not know about constructivist theory, let alone understand it. This decision was later extrapolated to the colleges of education to confirm that teacher-trainees do not understand the concept of constructivism, which is explained by cognitive activation. In their research, [9] Saritas and Akdemir (2009) state that poor academic achievement rates at all levels are due to ineffective instructional strategies and methods, teacher incompetency in education, and lack of motivation and concentration in learning. Consequently, the researcher wished to investigate the use of cognitive activation to establish constructivism as a teaching strategy in the Colleges of Education.

Though mathematics teaching strategies in the Colleges of Education prioritise student-focused, problem-solving, and critical and reflective thinking techniques, emphasising practical sessions, these do not reflect learners' performance at the pre-tertiary levels, where college graduates teach them. This revelation is emphasized by the West African Examination Council in 2023 stated that 61.53% of the candidates in the West African Senior Secondary Certificate Examination (WASSCE) in mathematics at the pre-tertiary levels for the past five years ending 2022/2023 academic year, passed mathematics with grades 1-6 in Ghanaian schools. In addition, less than 30% of WASSCE candidates scored above 50% marks in Elective Mathematics in a survey conducted by the author in 2018. In 2017, the mathematics pass rate of teacher-trainees at WASSCE showed that 50% of the respondents had a grade of D, 36% had a grade of C, 9% had a grade of B and 5% had a grade of A at the time they got admission into the colleges of education [6]. The results established that mathematics teaching and learning as a problem permeated to tertiary institutions including the colleges of education. According to the Ministry of Education, admissions to tertiary institutions must be proportional to 60% for the sciences including mathematics and 40% to the humanities. However, Ghanaian tertiary institutions have never achieved this standard such that, in the 2007/2008 academic year, only 35% of prospective students qualified to pursue STEM-related programmes. The Educational Strategic Programme in 2019, indicated that in the 2012/2013 academic year, 32% of the candidates offered STEM-related programmes and in the 2017/2018 academic year, 39% enrolled in STEM programmes in tertiary institutions. According to the Ghana Statistical Service in 2013, this situation led to low STEM industries and organisations in Ghana. Furthermore, the performances of JHS 2 pupils in TIMSS in 2003, indicated that the Ghanaian pupils' average score of 276 points in mathematics and science was below the average score of 467 points and the international benchmark of 400 points [25]. Similarly, in 2007 Ghana's average score of 316 points was below the overall average score of 500 points and the lowest international benchmark score of 400 points [26]. Additionally, Ghana had the last position when 46 countries participated in TIMSS 2011. Conversely, in the second review about how Ghana prepares her teachers for the 2011 TIMSS assessment, it was discovered that there was a mismatch in teacher preparation and student achievement where the teachers scored relatively high on most of the constructs. So, it is against this background that the researcher wishes to investigate the use of cognitive activation in mathematics instruction at the colleges of education.

Cognitive Activation (CA) as an effective instructional strategy, emphasises constructivist theory where knowledge is better acquired when the learners construct their understanding of mathematical concepts [27]. The Programme for International Student Assessment (PISA) identifies cognitive activation as one of several instructional strategies that supports the development of mathematical literacy which exposes learners to activities in mathematics lessons to solve real-life problems [28]. This strategy supports teachers' ability to give challenging tasks to students during instructional processes. According to [29] Dennick, (2014), mathematics teaching considers several learning theories of Piaget (1978), Ausubel (1968) and Vygotsky (1986), and operationalised by cognitive activation [30], making it possible to construct a stable foundational mathematics model that can be implemented flexibly [31].

Cognitive Activation is one type of learning strategy that a teacher introduces to his students to encourage them to think more deeply in finding solutions to problems, as they focus on the method rather than the answer. Constructivist theory is explicitly prescribed in mathematics syllabi as an instructional strategy at the pre-tertiary and college levels, prioritising student-focused, problem-solving, and critical and reflective thinking techniques, to emphasise practical sessions. As an instructional strategy in constructivism, cognitive activation promotes mathematics achievement among learners, where teachers are required to stimulate students in the learning processes through guidance and challenging tasks, as students use their existing knowledge to think extensively to solve problems [27]. Giving problems to learners with no immediately obvious method to find solutions encourages them to reflect on the difficulties of searching for the way that requires thinking for an extended time. This strategy demands that learners use their procedures for solving complex problems, explaining how the problems are solved and why they chose that method becomes crucial in cognitive activation. With this, learners apply their method in practical situations to construct ideas as the teachers use the students' suggestions as a source to plan subsequent lessons.

Creating a learning community where learners can learn from their mistakes, encourages them to identify how mathematics concepts can be applied in practical situations [32]. There is, therefore, the need to encourage a culture of exploratory talk in the classroom, where learners consider a series of possible solutions to problems and identify and analyse what they need to learn has become a panacea to critical thinking. Further support for these findings comes from the OECD's International Survey of Teaching and Learning (TALIS) which notes that in fostering cognitive activation, teachers need to use deep and challenging content [33, 34]. These prominent influences guide students' activities in the classroom, as the teacher helps them to engage in higher-level thinking to solve problems. Subsequently, it is deduced that argumentation and non-routine problem-solving strategies develop learners' ability to make connections between and among mathematical concepts, procedures, ideas and representations [35, 36]. This development stresses the instructional process for comprehension through the provision of challenging tasks using students' existing knowledge, ideas, and experiences to explore new concepts as they ask stimulating questions to excite the learning process [37, 38]. Cognitive activation is, therefore, composed of specific aspects of the teacher-student relationship that solicit positive and constructive teacher feedback; a positive approach to correcting students' errors and misconceptions by a caring teacher [39] which subsequently promotes students' motivation in a mathematics classroom.

Cognitive activation as a mathematical instruction has a direct effect on students' performance [40], however, not all students benefit to the same degree from cognitive activation because the process subsequently has greater potential for those who are more interested in mathematics [41]. Thus, a serious student, desirous of making strides in understanding mathematics concepts will employ all the available resources and connect them appropriately to understand concepts for excellence. This means that students, who are not interested in mathematics will be limited in expanding their horizons. Therefore, assumptions in cognitive activation are that students are at equal ability levels, have an equal measure of economic background, and come from similar social and cultural statuses. Thus, cognitive activation mentally stimulates learners to engage in deeper investigations through challenges that enable them to think critically, creatively and reflectively about the subject matter as they apply the new knowledge to non-routine situations.

Cognitive activation can also be triggered by various factors such as classroom climate and management of student achievement [42]. For instance, research findings suggest that students' high academic achievement is linked to a safe and orderly climate, normal temperatures, good school setting and standard school buildings [43, 44, 45]. So, cognitive activation instruction with a more supportive classroom climate stimulates students' interest and transforms their existing interest towards mathematics learning [46]. Consequently, cognitive activation is effective in understanding mathematical concepts, when students make good use of the environment available to them.

In summary, cognitive activation is about exposing learners to instructional strategies that encourage them to think more deeply to find solutions to problems and to focus on the method they use to get the answer rather than simply focusing on the answer itself. This includes summarising, questioning and predicting possible ideas that link new information to those they already have.

2. Methodology

A cross-sectional quantitative data was collected conveniently from 621 out of 842 third-year teacher-trainees in three colleges in the Volta Region of Ghana, using a self-administered questionnaire whose variables were measured along a 5-point Likert scale for tutors' use of cognitive activation as an instructional strategy to ascertain constructivism in mathematics lessons. However, a purposive sampling technique was adopted in selecting these three colleges due to the variations in the programmes the teacher-trainees offer. Respondents were teacher-trainees who studied mathematics in the first and second years and were present during an orientation programme for an off-campus teaching practice. These respondents, who had adequate knowledge in the teaching and learning of mathematics processes were each given a questionnaire for their responses as the items were read out to them to reduce social response bias. Most tutors were present in the halls when the instrument was being administered. The presence of their tutors motivated them as they took the exercise seriously. To ensure the confidentiality of their responses, permission was obtained from the colleges' principals, and the teacher-trainees' consent was also sought before the start of the exercise. In this instance, respondents were advised of their right to terminate the response process at any time. The instrument was internally consistent with Cronbach's Alpha coefficient of 0.932 and externally consistent with Cohen's Kappa's interrater technique value of 0.924 for the 14 items that explained cognitive activation. The instrument was validated using face, construct and content validity to reduce the original number of items from 28 to 14 as indicated in the questionnaire in Appendix 1.

3. Analysis and Results

Construct validity measured the meaning of the construct of the questionnaire as administered to the participants [47]. The construct validity of the questionnaire was tested when all items together with their responses were entered into SPSS version 2.0 represented by the underlying construct [48]. This is to reduce the number of items using Principal Component Analysis and still explain cognitive activation. Thus, exploratory factor analysis detected the factors beneath the dataset based on the correlations of the items [49]. The trustworthiness of factor analysis depended on the sample size and the factor loadings such that the coefficient of determination of the variable was above the acceptable level of 0.6 [50] cited in [51]. For cognitive activation, the determinant of the R-matrices was greater than 0.00001, the KMO value was higher than 0.7, the Cumulative Rotation Sums of Squared Loading (CRSSL) explained more than 50% of the variance and the factor loading was more than 0.6 as shown in the table below:

Table 1: Indexes for Cognitive Activation

Instructional Strategies	Amedzofe				Holy Spirit			
	DRM	KMO	CRSSL (%)	FL	DRM	KMO	CRSSL (%)	FL
CA	0.037	0.877	59.0	0.711	0.003	0.884	57.1	0.666

The data were analysed using the binomial test with 0.5 p-values, the descriptive statistic and composite score analysis of the Likert-scale responses at 95% confidence interval. Responses were categorised on a scale of 1, 2 and 3 as disagree, and 4 and 5 as agree when the reactions were partitioned into two groups [51]. Conducting bootstrapping of the descriptive statistics indicates that the results were statistically significant at 95%. The composite score of 3.810 confirmed the descriptive statistics, as shown in Table II. All these indices were calculated using SPSS version 2.0.

Table 2: Analysis of Results

s/n	Items	Binomial Test		Descriptive Statistics Test						
		Proportion		Bootstrap						
				MLSR	Confidence Interval (%)		S. D.	Confidence Interval (%)		SE
		<= 3	> 3		2.5	97.5		2.5	97.5	
1	CA1	0.24	0.76	3.89	3.79	3.97	1.087	1.011	1.157	0.043
2	CA2	0.33	0.67	3.66	3.56	3.73	1.047	0.983	1.114	0.042
3	CA3	0.26	0.74	3.86	3.76	3.94	1.082	1.023	1.159	0.043
4	CA5	0.31	0.69	3.74	3.68	3.86	1.107	1.010	1.145	0.044
5	CA7	0.28	0.72	3.86	3.79	3.96	1.053	0.964	1.098	0.042
6	CA8	0.35	0.65	3.65	3.59	3.77	1.111	1.014	1.141	0.045
7	CA12	0.31	0.69	3.80	3.72	3.88	0.999	0.917	1.049	0.040
8	CA15	0.27	0.73	3.83	3.74	3.91	1.068	0.988	1.130	0.043
9	CA17	0.24	0.76	3.98	3.89	4.06	0.979	0.917	1.050	0.039
10	CA19	0.28	0.72	3.81	3.71	3.89	1.063	1.005	1.133	0.043
11	CA20	0.28	0.72	3.83	3.77	3.94	1.076	0.980	1.114	0.043
12	CA21	0.31	0.69	3.74	3.65	3.82	1.065	0.996	1.136	0.043
13	CA22	0.27	0.73	3.91	3.79	4.06	1.543	0.954	2.345	0.062
14	CA23	0.31	0.69	3.80	3.69	3.87	1.062	0.996	1.126	0.043
Mean		**0.29**	**0.69**	**3.81**	**3.72**	**3.904**	**1.096**	**0.983**	**1.207**	**0.044**
3.810										

MLSR- Mean Likert-Scale Response; SD - Standard Deviation; SE - Standard Error

Average Sample Response No.- 619

4. Discussion

On average, 69% of the mean respondents of the 621 respondents agreed to the 14 items that college tutors use cognitive activation strategy to deliver mathematics lessons as indicated by the binomial test in Table 1. This conclusion was supported by the mean Likert scale response of 3.11 with a mean standard error of 0.044 and mean standard deviation of 1.096 which were significant at a 95% confidence interval. This response was also collaborated by the composite score of 3.810. By these statistics, it was accepted among the teacher-trainees that college tutors use cognitive activation strategy to teach mathematics.

5. Conclusion

Cognitive activation as a product of constructivism, established the teacher-trainees' agreement that college tutors use cognitive activation to teach mathematics. Therefore, graduates from the Colleges of Education have the teaching skills to teach mathematics to pupils in basic schools to understand as they are introduced to cognitive activation. Accordingly, this helps teacher-trainees espouse their learning theory to solve problems through tutors' support and encouragement. Tutors in colleges of education must explicitly make teacher-trainees aware of the constructivist theory during mathematics lessons using a cognitive activation instructional strategy. This is because constructivism enables teacher-trainees to construct knowledge especially when that knowledge is applied to everyday life which consequently helps increase teacher-trainees' understanding of mathematics concepts [52, 53]. Mathematics teachers must also be trained on, how to set questions to encourage mathematical thinking and reasoning rather than those that require recalling facts through copying theoretical questions from textbooks. This will help students to demonstrate their understanding of mathematical concepts with the application to real-life problems, such that those with difficulties can easily be identified and assisted. Cognitive activation will help to eradicate the conventional way of de-contextualizing the teaching of mathematics in Ghana as observed by [54]. Finally, teachers must ensure that learners are well motivated, both internally and externally to undertake mathematics activities.

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