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Problem Based Learning in the Teaching and Learning of Mathematics for Pre-Service Teachers in Ghana: A Literature Review

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Abstract

Problem based learning (PBL) was first introduced in medical education and its success stories have led to its implementation in other disciplines. However, literature has not revealed its implementation and subsequent effectiveness in teacher education in Ghana. This paper reviewed past studies into PBL implementation in teacher education and Mathematics education relative to the traditional methods of teaching Mathematics at the Colleges of Education (COE) in Ghana. Through this literature review, it is largely noticed that PBL pedagogical strategy has proven to be more effective compared to the traditional methods of teaching. This implies that the strategy could contribute to effective Mathematics delivery at the Colleges of Education for pre-service teachers. Consequently, it is expected that learners will develop critical thinking and problem-solving skills in Mathematics at the basic schools where these pre-service teachers will be deployed to teach. The review has identified three research gaps that require further investigations.

Keywords*: Problem Based Learning, Mathematics, Pre-service teachers, Traditional teaching method*

Introduction

Effective teachers of Mathematics acknowledge pedagogy that inspires their learners and motivates them to successfully learn. Such teachers appreciate that for learners to effectively apply mathematics in real-life situations, they need to understand the concepts and become fluent with the skill taught. The paper will review PBL, an instructional pedagogy whose impact in Mathematics education for pre-service teachers in Ghana is yet to be established. A review of related literature is an important component of research. In addition to identifying gaps in the study, this aspect of the research process helps the researcher to gather relevant information and current developments about what has been done in a particular area. This paper is aimed at reviewing past studies into PBL implementation in teacher education and Mathematics education relative to the traditional methods of teaching Mathematics at the Colleges of Education (COE) in Ghana. The review will cover the theories underpinning the topic and a proposed conceptual framework. It will also look at PBL and teacher education, the traditional method of teaching, problem solving and PBL. Under PBL, the sub-sections shall cover a brief background and criticisms of PBL. Finally, the paper will examine previous studies into the effectiveness of the PBL strategy after which some research gaps will be revealed.

Theories underpinning PBL in mathematics education

The traditional method of teaching has been criticized as teacher-centred and learner passive (Freiberg, 1999). Some theories that can help resolve this phenomenon are Lev Vygotsky's theory of social constructivism, Piaget's theory and the theory of Constructivism. The theory of constructivism would serve as the overarching theory in this review. The application of Vygotsky's theory in education promotes interaction and discussion between a facilitator and a small group of learners. Additionally, peer collaboration is another educational application of the theory. In the PBL classroom, learners engage in social interaction, discourse, and Mathematics as an object of learning is made more meaningful when learners are given a minimum level of support and guidance. Zone of Proximal Development (ZPD) is Vygotsky's term for the range of tasks that are too difficult for the child to master alone but that can be learnt with guidance and assistance of adults or more children that are skilled (Vygotsky, 1978).This social constructivist theory and the zone of proximal development concept of Vygotsky relate PBL and these advocate for teaching and learning in small

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groups with learners playing active roles and teachers serving as facilitators. Again, Vygotsky further argues that interaction with peers is an effective way of increasing skills and strategies. He suggests that teachers use cooperative learning means where low learners develop with help from more skillful peers within the zone of proximal development. This is a teaching and learning strategy pre-service teachers are required to know and implement in PBL Mathematics classroom to improve understanding and performance. Education in Piaget's view simply defines the child's cognitive skills that have already emerged. Piaget also views the teacher as a guide, not a boss who provides support for children to discover their world and explore knowledge (Santrock, 2005).

The educational implication from Piaget's work and its use in the PBL classroom is that children learn but from concrete activities. If implemented in schools, the use of concrete objects significantly alters the role of the teacher and the nature of the learning environment. Piaget's view about PBL Mathematics classroom is that learners learn best by making discoveries, reflecting on them, and discussing them rather than blindly imitating the Mathematics teacher or doing things by rote, which impedes meaningful learning. The theory of constructivism is an integration of Vygotsky's theory and Piaget's theory. Constructivism is a theory about how to learn. Here, learners are active participants in the development of their understanding. In the PBL classroom, learners are allowed to construct their knowledge of Mathematics through schematization of the learning process in which previously learnt knowledge serves as the forerunner and anchor to the new knowledge.

Constructivism transforms the learner from a passive recipient of information to an active participant in the learning process in a collaborative environment. In constructivism, group discussions/group activities are emphasised and this forms the basis of PBL Mathematics classroom which pre-service teachers must be exposed to. The researcher argues that the tenets of constructivism must be the basis for the teaching of Mathematics from the known to unknown and this should characterise Mathematics classrooms. The views of Piaget and Vygotsky are somewhat intersecting and a collaborative effort in ensuring meaningfulness and schematization in the teaching and learning of Mathematics for pre-service teachers. There is therefore, the need for college tutors and pre-service teachers to identify a suitable educational theory and conceptualise it for effective Mathematics teaching.

Proposed conceptual framework

The proposed framework in figure 1 is underpinned by the above theories with the theory of constructivism being overarching. Vygotsky's and Piaget's theories are subsets of the constructivism theory and they culminate into a PBL. These tenets of PBL would be operationalized, defined contextually and measured in a PBL lesson. This further implies that any PBL lesson that is designed must measure these 5 tenets (learner-centred, cooperative, interactivity, small group work, and communicative skills) and this is expected to improve learning outcome.

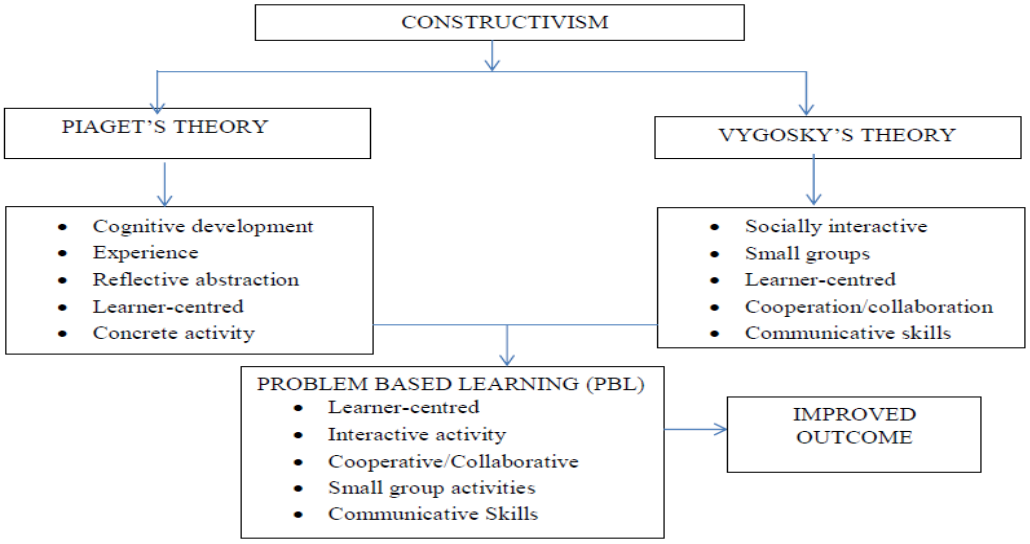

Figure1. Proposed conceptual framework

PBL and teacher education

Generally, the roles of teachers in schools are now changing from merely imparting knowledge to inculcating creativity, intellectuality, problem solving ability and critical thinking skills among learners. PBL requires pre-service teachers to work in groups to research on best practises and strategies that could be used to address real-world situations as beginning teachers. It is presented as a practical means to help pre-service teachers develop skills; they will need in teaching Mathematics before entering the teaching profession. In recent times, PBL has called for attention in the teacher education literature. Levin (2001) argues for the need and inclusion of PBL application in a teacher education course. Similarly, Dean (1999) viewed PBL as an important vehicle to convey the pre-service teacher to the situation that they are likely to encounter as professional educators. He asserted that employing a teaching and learning approach that captures the central tenets of constructivist and social constructivist learning theory should guide lesson delivery. Past studies into the use of PBL in teacher education programmes have shown that the approach supports pre-service teachers to acquire theoretical concepts related to practice.

The Traditional teaching method in teacher education grounded on the technical-rational model of development and knowledge have met serious scrutiny as an unsuitable means of supporting pre-service teachers to comprehend and relate theory to practical works (Korthagen, 2001). A more effective approach to teacher education will require the provision of pre-service teachers with opportunities to construct understandings of practice which draw on relevant theory to inform understandings of the teaching and learning process.

The researcher associates with the argument advanced by Dean and support the idea that pre-service teacher education must be backed by the theory of constructivism particularly in designing a Mathematics lesson. Besides, the course packages for pre-service teacher education must be redesigned to make learning more relevant and thought-provoking with PBL. This will help pre-service teachers perceive their profession as true profession worthy of their intelligence and passion. Existing pieces of literature on PBL have not specifically revealed its implementation in the teaching and learning of Mathematics at the pre-service teacher education level. Literature has it that in Ghana, PBL approach has been introduced in the medical schools at the University of Cape Coast and the University for Development Studies (Amoako-Sakye and Amonoo-Kuofi, 2015). Literature also points to PBL implementation at the Kwame Nkrumah University of Science and Technology, Ghana (myjoyonline.com). The approach could also serve as a catalyst to speed up the gradual shift from the traditional teaching method (teacher-centred) to PBL (learner-centred) approach in Mathematics education at the COE. The next section will review the traditional method, problem solving and PBL approach in teaching.

Traditional methods of teaching, problem solving and PBL

Different learning theories and teaching methods have dominated the educational system worldwide. The teaching methods are to a large extent determined by the characteristics of the learner, the facilitator (teacher) and the teaching and learning environment. This section of the paper will look at a review of the traditional method, problem solving and an overview of PBL in line with theories such as behaviourism, cognitivism and constructivism.

Traditional method

The traditional method is focused on the behaviourism learning theory. Ormond (1995) indicated that behaviourist teaching theories emphasises changing behaviours which results from learners' association with stimulus-response. The researcher added that, learning is a change in behaviour due to experience. This method is teacher-centred and teaching by telling is the dominant situation commonly used in Mathematics classrooms. This pedagogical approach of placing the primary focus on the teacher as a repertoire and transmitter of knowledge leading to some form of imitation by the learner portrays behaviourist theory.

Some previous studies have advocated for the use of learner-centered methods of teaching against the teacher-centered method. The researcher argues that since this method is based on stimulus-response association, little or no attention is giving to the cognition of the learner (learner becomes

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dogmatic) which does not encourage critical thinking in solving real-life problems. The ability of the learner to learn by rote and be able to poor and pass at the expense of meaningful learning is what this method seeks to achieve. Problem solving skills must be developed by both the learner and the facilitator.

Problem solving

Mathematics education predominantly seeks to teach how mathematical problems could be solved with ease. This calls for "Problem Solving", an important element of Mathematics education to be examined in relation to PBL. Problem solving which is a cognitivist learning theory helps students to develop a wide range of complex mathematical structures and gain the capability of solving a variety of real- life problems (Tarmizi and Bayat, 2012). Moreover, the Ministry of Education (MOE) and the National Council for Tertiary Education (NCTE) of Ghana have revised the course package for pre-service teachers to enhance their instructional competence and problem-solving skills (MOE, 2019).

Polya (1957) postulated a four-step approach to problem solving. These are stated as follows:

1. Understand the problem: it is impossible to solve a problem if you do not know what the problem is. What is known or unknown? What do the terms mean? This buttresses that assertion that understanding the question is part of the solution.
2. Devise a plan: this way helps to solve the problem using strategies as (a) Draw pictures (b) Use a variable and choose helpful names for variables or unknowns. (c) Be systematic. (d)Solve a simpler version of the problem. (e) Guess and check. (f) Look for a pattern or patterns. (g) Make a list. This helps to conceptualise and easy to recall.
3. Carry out the plan: If the plan does not seem to be working, then start over and try another way. Often the first approach does not work. No worries because an approach did not work. It does not mean you did it wrong. Impliedly, lack of an in-depth understanding and poor grasp of mathematical content worsen the situation; more time would be wasted just to find the way forward.
4. Look back: Did you answer the question? Is your result reasonable? Is there another way of doing the problem which may be easier? This approach is important as it can lead problem solvers to the path of success.

The researcher asserts that because problem solving is linked to the cognitivist theory, a shift from teacher-centred teaching to learner-centred teaching characterises this method of teaching. This contributes to a progressive attempt to make pre-service teachers understand the concepts of PBL in Mathematics education. There is therefore, the need for problem solving to be emphasised as part of PBL at the COE in Ghana. Problem solving is not the same as PBL and the latter is discussed in the next section.

Problem based learning

The Problem Based Learning teaching strategy was implemented for the first time in medical education at the University of McMaster, Canada, in the 1960s. The concept has since been embraced by other universities like the University of Maastricht, in the Netherlands; Newcastle University, in Australia and the University of New Mexico, USA. The University of Cape Coast School of Medical Sciences (UCCSMS) and the University for Development Studies School of Medicine and Health Sciences in Ghana have also adopted the use of PBL in their curricula (Amoako-Sakyi et al. 2015).

In PBL, learners have to build their understanding of every concept of mathematics in Mathematics education, so that teaching will not be viewed purely as explaining, lecturing, or attempting to convey mathematical knowledge, but creating situations for learners to promote their mental structures. Therefore, learning reflects a social process in which students would be required to engage in dialogue and discussion with themselves as well as others as they develop intellectually (Hanley, 1994). This method is the best method to move away from the traditional method or teacher-centre practices. The method empowers teachers and students both for better critical thinking and creating changes in old teaching methods (Sawada, et al., 2002). A key element in the PBL approach is the level of cooperation in small groups. Groups usually consist of 6-10 learners who meet 2 to 3 hours per session and mostly twice a week (Schmidt et al, 2007).

Small group discussions in Problem Based Learning enhance interaction among peers. Students answer a series of questions and give explanations and discuss the differences in opinions and understanding the concepts. These processes stimulate a deep knowledge of the subject. The cooperative work in small groups also increases the capacity to work in teams, an essential skill in professional practice (Norman and Schmidt, 1992).

This method is based on the constructivist approach which is learner-centred. In this approach, learners actively construct their knowledge and understanding by the guidance of their facilitators. Literature highlights that the likes of Jean Piaget and Lev Vygotsky glorified constructivism and its implementation in PBL and discovery learning in Mathematics education.

The researcher views this method as synonymous with discovery learning that is highly encouraged to help learners to understand the "how, why and what" of teaching and learning Mathematics. The ability of pre-service teachers to relate PBL and discovery learning sets the tone for constructivism in Mathematics education. Even though PBL has found its way in the Ghanaian curricula, its impact has not been felt in pre-service teacher education and Mathematics education. There is therefore, the need for teachers to embrace the tenets of the theory of constructivism and make lesson delivery self-directed and learner-centred. The much-trumpeted PBL has also faced criticism in one way or the other. This however, serves as an eye-opener and a guide in planning and implementing PBL in the teacher education curriculum. Some criticisms of PBL approach are discussed.

Criticisms of problem-based learning

Literature compiled by Zieber (2006) outlines some criticisms of PBL which are not intended to oppose the methodology in principle or practice but instead highlight the need for acknowledgment and further research. Criticisms of PBL centre on four areas: resources, the student experience, adulterated forms of PBL, and the question of efficacy.

Firstly, PBL is resource-intensive in terms of faculty time, space (tutorial rooms), teaching materials, and library resources (Azer, 2001; Johnson and Finucane, 2000; Morrison, 2004; Moust, van Berkel and Schmidt, 2005; Walsh, 2005; Wood, 2003). The development of suitable cases is time- consuming and requires staff development, current clinical practice and partnerships between education and health care institutions (Johnson & Finucane, 2000; Tan, 2004). Some colleges have found that due to fiscal and other resource limitations PBL is not sustainable. For instance, in medical education, if a PBL program is fiscally unable to maintain the high staffing ratios required the nursing program may decide to revert to a more traditional curricular approach which is more sustainable. There is therefore the need for PBL planners to do resource appraisal before its implementation.

Secondly, students experience stress and feel overloaded until they are familiar with the PBL process (Azer, 2001b; Johnson and Finucane, 2000; Tan, 2004; Wood, 2003). Other criticisms include the noticeable lack of a classroom role model as seen in traditional lecture-based programmes; Wood (2003) suggests such role models can be very inspirational for students. Also, the quality of learning in a PBL context is somewhat dependent on having a high functioning group (Azer, 2001; Walsh, 2005). I argue that the presence of the classroom teacher may not matter but the role in the facilitation process is what matters.

Thirdly, criticism centres on the numerous adulterated forms of PBL. Several years after the inception of PBL, it has been noticed that there exists a wide understanding of the nature of PBL in its pure form and that a range of adulterated forms of PBL exists (Baker, 2000; Butler et al, 2005; Camp, 1996; Tanner, 1999). Again, the implementation of PBL is influenced by pedagogies that underpin both curricula and the staff that implements it, which also contributes to modifying its essence (Savin-Baden, 2000). There is also the perception that PBL constitutes a relatively inefficient way to learn and that not as much content is covered as in traditional curricula, which also leads individual instructors to significantly modify the PBL process (Azer, 2001b; Johnson & Finucane, 2000; Moust et al., 2005). This third point informs the need for a PBL lesson to be backed by a framework. By this, the concept can be operationalized and be measured. This would help check the adulteration of the concept.

Fourthly, criticism about the efficacy of PBL as an instructional and curricular methodology has been addressed. High-quality evidence from existing literature regarding the effectiveness of PBL as

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an educational method is simply lacking (Newman, 2003). Besides, variables are often confounded because PBL is accompanied by other major curriculum revisions, such as staff development, and it cannot be determined if the results can be attributed to the use of PBL (Johnson & Finucane, 2000). Kirschner et al. (2006) criticised PBL as a minimally guided instructional approach and presents some negative findings related to its effects on content knowledge acquisition. However, Hmelo-Silver et al. (2007) had an objection to Kirschner et al criticism.

The researcher aligns with the above review and asserts that the criticisms enumerated above are a genuine basis for careful planning and effective execution of a PBL lesson. The views expressed on resource constraints, to some extent, defeat the purpose of constructivism but the feeling of stress and work overload characterises practicality which ensures meaningfulness in learning. On the issue of efficacy, literature has largely pointed to the fact that PBL is effective and this is explored next.

Previous studies into the effectiveness of PBL

In the late 1960s, PBL was added to the literature following a research study undertaken at McMaster University in Canada (Rhem, 1998). PBL is consistent with the constructivist theory by challenging the learners to take responsibility for learning (Coombs and Elden, 2004). PBL is an approach in which the process of constructing knowledge activates learners' prior knowledge and problem –solving strategy of ill-structured problems acquired through small in-group discussions and research (Koca-Koglu, 2010). Using a problem scenario in education differentiates PBL from other teaching approaches (Tan, 2010).

Van Loggerenberg-Hattingh (2003) discovered that the use of PBL is more effective in learning Science than the traditional method. Learners taught through PBL scored significantly higher than those taught with the traditional method. Selected questions were used for the post-test that were classified on Bloom's taxonomy as higher-order questions.

According to Lombard and Grosser (2008), it is clear that critical thinking skills and understanding of how to teach these skills are lacking among pre-service and in-service teachers. The results showing that PBL has a positive effect on critical thinking skills emanates mainly from medical literature (Tiwari et al, 2006). This makes this research remarkable in education, especially in Mathematics education.

Literature collated by Temel (2014) explored the effect of PBL on pre-service teachers' critical thinking disposition and perception of problem-solving ability was reviewed. The aim of the study was to determine the levels of critical thinking disposition and perception of problem-solving ability of pre-service teachers in the teaching of the acid-base topic. It was largely observed that pre-service teachers display a low level of critical thinking disposition and a medium level of perception of problem-solving ability. PBL and traditional method did not have different effects on the critical thinking disposition of pre-service teachers however; they had different effects on their perception of problem-solving ability. This showed that PBL was more influential in increasing the perception and problem-solving abilities of the pre-service teachers than the traditional method.

Furthermore, Baysal (2017) investigated the topic "The Problem-based learning process: Reflection of pre-service elementary school teachers". The aim was in two folds. The first was to identify the benefits acquired by third-year pre-service elementary school teachers participating in a PBL process in Social Studies education. The second aim was to identify the issue they encountered in the process and those they are likely to encounter in the process. The results showed that PBL reflections/benefits were positive to pre-service elementary school teachers in the areas of learning and skills acquisition in Social Studies classes.

Padmavathy and Mareesh (2013) conducted a study on the effectiveness of PBL in Mathematics. The findings of the study revealed that PBL had an effect in teaching Mathematics and improve students' understanding, ability to use concepts in real life.

In Ghana, literature reveals that PBL has been implemented as part of the curriculum at the University of Cape Coast School of Medical Sciences (UCCSMS), the University for Development Studies School of Medicine and Health Sciences and the Kwame Nkrumah University of Science and Technology. Amoako-Sakyi & Amonoo-Kuofi (2015) researched on the topic "Problem based learning in a resource-poor setting: Lesson from a medical school in Ghana". The authors assert that

the University of Cape Coast is located in a resource-poor setting, however, its medical school has used PBL curriculum since 2007. The author further argues that in spite of its cost implication, a PBL curriculum can be successfully implemented in resource-constrained settings.

Analysing from the forgoing literature on the effectiveness of PBL, the researcher is of the view that largely the effects of PBL are positive relative to other methods of teaching. The fields of medical education, Chemistry and Social Studies have had their fair share of PBL and have also added to the literature. In the field of Mathematics which is the area of interest in this review, Padmavathy and Mareesh (2013) revealed that PBL increases critical thinking.

In spite of the above literature and others gathered from other sources, no extensive literature has been found on PBL implementation in Mathematics education for pre-service teachers even though some literature points to Social Studies and Chemistry.

Research gaps for further studies

The literature reviewed in this paper identified three issues that have called for the need for further research in line with the subject under review. This will contribute to enhancing critical and problem-solving ability of pre-service teachers as they strive to grasp an in-depth understanding of Mathematics contents and methods at the COE in Ghana. Firstly, the literature review shows that the government of the Republic of Ghana does appreciate the importance of using learner-centred teaching method. Unfortunately, however, no mention was made of PBL implementation for pre-service teachers in Ghana. The importance of this PBL teaching method at the Colleges is the prevention of 'spoon-feeding' pattern of teaching that demotivates learners to think constructively when faced with Mathematics problems.

Secondly, the literature revealed that lack of resources could inhibit the implementation of PBL in the Ghanaian curricula. A case in point was the mention of PBL in poor resource settings at the University of Cape Coast, Ghana. Even though the literature did not reveal its adverse effect on PBL implementation, there would be a need for further research to be conducted into resource assessment and evaluation before its implementation for COE in Ghana.

Thirdly, total affection and affinity for traditional teaching methods has characterised the COE in Ghana. Interestingly, the call for a shift to a more learner-centred approach has not received the much-needed attention. Even though the literature mentioned three universities in Ghana that have bought into the idea, no mention was made of its implementation on pre-service teachers in Ghana. There is therefore, the need for further research to discover the motivation for its implementation and acceptance by COE. This will trigger a review of the entire curriculum to include PBL especially if teaching Mathematics since the subject appears difficult for a large number of pre-service teachers.

Conclusion

A brief literature review on PBL for the teaching and learning of Mathematics for pre-service teachers in Ghana has been discussed. The theoretical underpinnings and the conceptual framework for the study set the tone for the discussion. The review focused on some past studies on how PBL had dominated various fields of study including its impact on pre-service teachers and the teaching of Mathematics.

A brief review of PBL and teacher education was done and some criticisms of PBL were also shared to guide curriculum developers and implementers in the design and implementation of this strategy in the future. Again, clarity was attached to other teaching methods (traditional and problem solving) to make it distinguishable from the concept of PBL. Furthermore, a few success stories were reviewed on past PBL implementations across various fields of study. The literature also revealed three gaps that would require further studies. Firstly, it revealed that no mention was made of PBL implementation for pre-service teachers in Ghana even though the government of the Republic of Ghana appreciates a learner-centred approach to teaching. Secondly, it called for further research on the need for resource assessment and evaluation prior to the implementation of PBL at the COE in Ghana.

Finally, the high affection for traditional teaching method and the difficulty in embracing new method of teaching like in the case of PBL continue to baffle educational researchers. It is hoped that

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the government of the Republic of Ghana would embrace this learner-centred, cooperative, interactive, small group and communicative skills enhancing teaching strategy in the various COE for pre-service teachers.

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