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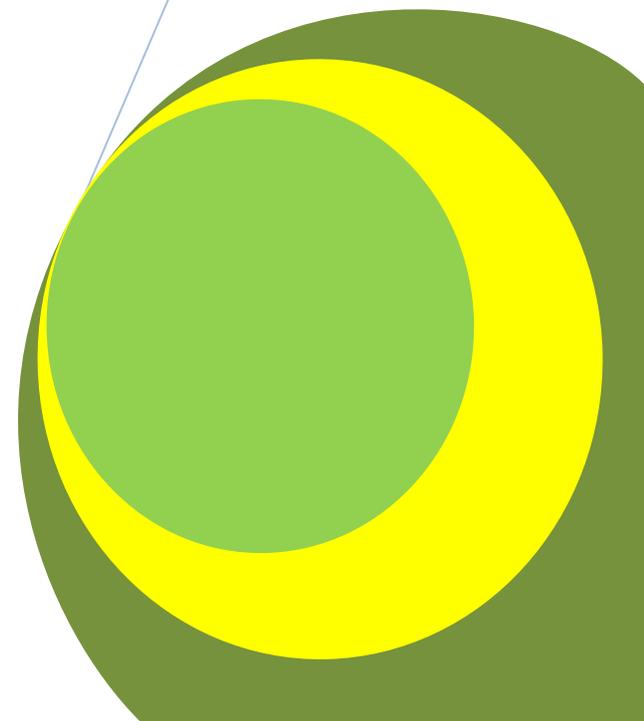
Research Article

Vygotsky's Zone of Proximal Development Theory: What are its Implications for Mathematical Teaching?

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ABSTRACT

This article focused on Vygotskian Zone of Proximal Development and its implications to the teaching of Mathematics in the schools. Literature has shown that underachievement and poor performance characterise the learning of Mathematics. Teaching Mathematics in the child's zone of proximal development is viewed as one way of improving performance in Mathematics. Literature argues that teaching in the Zone of Proximal Development where the child's learning is mediated and scaffolded by the teacher or expert adult or knowledgeable peer makes learning more meaningful, easier, manageable, effective and efficient. The major challenge that the theory presents to teachers is that it is difficult to identify every learner's zone of proximal development. Despite this limitation, the ZPD if appropriately applied could improve Mathematics teaching and learning in the schools.

Keywords: Zone of proximal development, scaffolding, mediation, interaction and socio-cultural.

INTRODUCTION

Worldwide, performance in Mathematics by students has persistently been poor (Mbugua, Kibet, Muthaaa & Nkonke, 2012). Research suggests that the application of Vygotsky's theory of the Zone of Proximal Development (ZPD) could improve mathematical achievement (Roosevelt, 2008). It is argued that the theoretical significance of the ZPD is that it enables penetration into the causal-dynamic and genetic connections determining the process of mental development (Chaiklin 2003; Cole 2000; Obukhova, & Korepanova, 2009). The article discusses the relevance and implications of the ZPD theory to the teaching of Mathematics.

THE ZONE OF PROXIMAL DEVELOPMENT (ZPD)

Vygotsky conceives of the zone of proximal development as central to instructional enhancement and classroom change in Mathematics. According to Vygotsky, the zone of proximal development is the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or collaboration of more capable peers (Murray, & Arroyo, 2002). Vygotsky (1978) opined that the ZPD is the current or actual level of development of the learner and the next level attainable through the use of mediating semiotic and environmental tools and capable adult or peer facilitation. In other words, it is what a child can do alone at a particular point in time. The second, "potential development" is defined as that which a child can achieve if given the benefit of support during the task. It is the ability to solve problems "under adult guidance or in collaboration with more capable peers."

Figure 1: A Model of the Zone of Proximal Development.
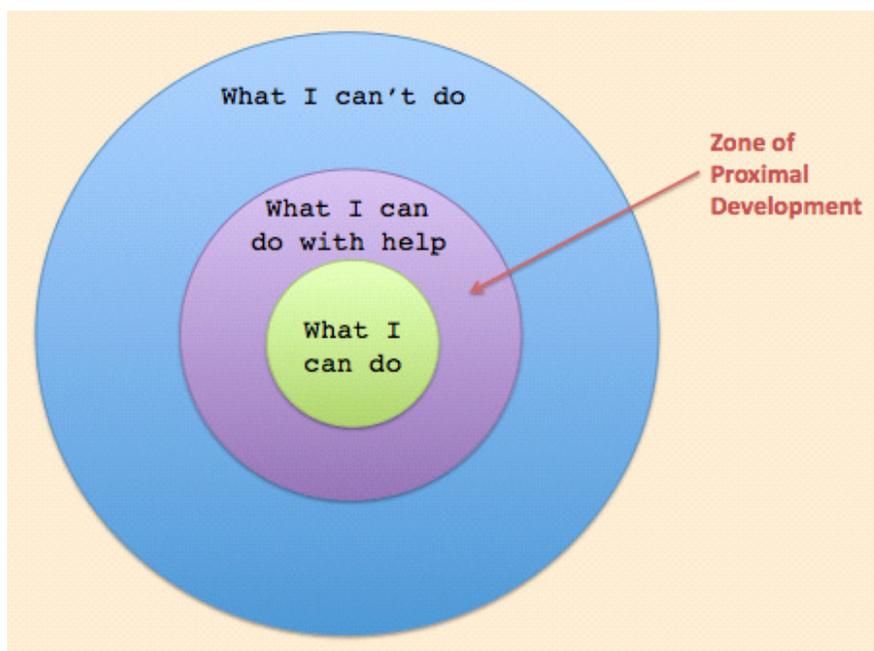
Adapted from (InnovativeLearning.com)

Explanation of the diagram:

- The yellow colour is the zone of achieved development (ZAD). The ZAD indicates that the child has mastered the mathematical concepts and can independently perform them without assistance.
- The purple area is referred to as the ZPD where learning can proceed with the assistance of an expert. This is an active learning zone.
- The blue colour denotes the area in which even with the assistance of an expert, the child will not learn.

The Zone of Proximal Development (ZPD) indicates the functions that have not yet matured but are in the process of maturation. Rogoff (1990) points out that the ZPD is a dynamic region of sensitivity to learning the skills of culture, in which children develop through participation in problem solving with more experienced members of a group. Cole (2001) in turn argues that within the ZPD, culture and cognition create each other. The ZPD is critical for Mathematics learning and instruction because it determines the level of work to be taught which is desirable to the child. Vygotsky suggested that teaching geared to developmental levels that have already been achieved will be ineffective, and that "the only 'good learning' is that in advance of development (Kearsley, 2005; Scherba de Valenzuela, 2002).

The "effective ZPD" is defined by the difficulty of mathematical tasks possible if the student is given the available help. This zone will also differ according to each student's tolerance for boredom and confusion. The student or learning is said to be "in the ZPD" when the learner demonstrates efficient and effective learning. The learners are clearly not in the ZPD if their behaviour indicates that they are bored or unable to solve problems (Beal, & Arroyo, 2002). If a learner is unable to solve a problem using the available means of assistance (have reached a non-constructive impasse), then we can infer that they are in the confused-zone.

Mediation

Mediation is central to Vygotsky socio-cultural theory (Williams and Burden 1997). Mediation according to Vygotsky refers to the part played by other significant people in the learners' lives, people who enhance their learning by selecting and shaping the learning experiences presented to them. Vygotsky (1978) (as cited in O'Neil, 2011) claims that the secret of effective learning lies in the nature of the social interaction between two or more people with different levels of skills and knowledge. This involves helping the learner to move into and through the next layer of knowledge or understanding. Vygotsky also regards tools as mediators and one of the important tools is language. The use of language to help learners move into and through their ZPD is of great significance to socio-cultural theory.

According to Kozulin (2002), human mediation usually tries to answer the question concerning what kind of involvement on the part of the adult is effective in enhancing the child's performance, while symbolic mediation deals with what changes in the child's performance can be brought about by the introduction of the child to symbolic tools-mediators such as language and learning media.

Scaffolding in the zone of proximal development

Scaffolding is another fundamental concept of the ZPD theory. The term scaffolding was introduced by Wood, Bruner and Ross (2001) in an attempt to operationalize the concept of teaching in the ZPD (Wells, 2000). In the context of the ZPD, scaffolding is used to explain the social and participatory nature of teaching and learning which occurs in the ZPD. Educators and researchers have used the concept of scaffolding as a metaphor to describe and explain the role of adults or more knowledgeable peers in guiding children's learning and development (Hammond, 2002; Daniels, 2001). Educators find the metaphor useful as it "resonates with their own intuitive conceptions of what it means to intervene successfully in students learning" and "offers what is lacking in much literature on education - an effective conceptual metaphor for the quality of teacher intervention in learning" (Mercer, 1994, in Hammond, 2002). According to Vygotsky, in a social interaction, a knowledgeable participant can create by means of speech and supportive conditions in which the student (novice) can participate in and extend current skills and knowledge to a high level of competence (Donato (1994). Educationally, scaffolding is an instructional structure whereby the teacher models the desired learning strategy or task, then gradually shifts responsibility to the students.

According to Rogoff (1990) in Donato, (1994), scaffolding implies the expert's active stance towards continual revisions of the scaffolding in response to the emerging capabilities of the learner and a learner's error or limited capabilities can be a signal for the adult to upgrade the scaffolding. As the learner begins to take on more responsibility for the task, the adult dismantles the scaffold indicating that the child has benefited from the assisted performance and internalised the problem-solving processes provided by the previous scaffolded episode.

The Educational Implications of ZPD

Researchers suggest that the ZPD Theory has significant implications for Mathematics teaching and learning in the schools. The idea of ZPD is to direct attention to the view that instruction/teaching (obuchenie) should be focused on maturing psychological functions, rather than the already functions, that are relevant for the general intellectual development to the next age period. Vygotsky recommends the use of assisted instruction. It is quite common for teachers to give students a lot of mathematical tasks as homework, without considering the sort of assistance that is available to the learner. According to Vygotsky (1999), problem solving should be under the guidance of a competent adult or capable peer. Mathematics could be an enjoyable subject if there is expert intervention and is timorously rendered. We believe that this practice is attributable to poor mathematical performance.

Another aspect that Vygotsky considers crucial is collaboration. Teachers should identify capable students in the class. Those who have low capacity for mathematical mastery should be assisted by the capable peers. Teachers should be convinced that the capable peers possess the Mathematics ability before they are allowed to assist others. If they are not really capable, chances are that they may teach the less capable wrongly. Teachers are the experts who should be able to organise challenging mathematical tasks that do not cause frustration or less motivation (Kufakunesu, Chinyoka and Ganga, 2012). The more expert partner should provide support at the moments where maturing functions are inadequate. With collaboration, direction or some kind of help, the learner is able to accomplish more mathematical tasks independently (Vygotsky, 1987). It is important to understand that a learner is able to perform a certain task alone, while in collaboration, is able to perform a greater number of tasks. The high rate of mathematical failure may be an indication that not sufficient collaboration is done to assist the learners' mathematical understanding. Teachers have the propensity of giving students voluminous homework, without ascertaining whether the learner will be able to get instructional assistance from adults at home. In most cases students just work on their own and that does not raise their individual performance.

Learners have individual zones of proximal development. Mathematical teaching should consider this (Davydov, 1998). Teaching each learner Mathematics according to his/her ZPD, has two major advantages: the tasks are made simpler for the learner and the learner's intellectual ability to deal with the task is considered. Teaching therefore, seizes to be a perfunctory practice where it is ostensibly for the purpose of covering the syllabus or teaching for examination at the expense of understanding. Conversely, it may be somewhat difficult for teachers to identify every learner's zone of proximal development especially where teachers deal with large numbers of students.

Teaching within the ZPD implies providing mathematical activities that are of appropriate difficulty as measured by the mistakes that students make while trying to come through in a process that should be higher than zero for a student to learn. However, the tasks assigned to the learners in Mathematics, sometimes fall outside the ZPD that the learner can already do, or tasks that the learner would not be able to do even with help , for example ,

trying to teach the average 10 year old to solve quadratic equations. Thus the focus of teaching in Mathematics is on tasks inside the ZPD which the learner cannot do by himself or herself but has the potential to accomplish with the guidance of others.

The theory implies that the challenge for all teachers is to pose problems that most students would perform with some assistance. One way to support this development is through scaffolding, which involves structuring the ideas to be understood in an order that is likely to lead children to develop further and faster than they would on their own (Bruner, 1996). In Mathematics learning for example, a student may know a formula but may fail to apply it. With the assistance of the knowledgeable teacher or capable peers, the student learns to apply the formula.

Roosevelt (2008) posit that the main goal of education from Vygotskian perspective is to keep learners in their own ZPDs as often as possible by giving them interesting and culturally meaningful learning and problem-solving tasks that are slightly more difficult than what they do alone, such that they will need to work together either with another, more competent peer or with a teacher or adult to finish the task. In Mathematics teaching, the teacher should avoid exposing students to tantalisers that lead students to mental cul-de-sac. The tasks given should be challenging to such an extent that mediation by the knowledgeable teacher or peer is needed. After the student had attained mastery of concept with the assistance from others, he/she should be able to do the task independently. If the student accomplishes the task individually through that process, then the learner's ZPD for that particular task will have been raised. This process is then repeated at the higher level of task difficulty that the learner's new ZPD requires.

A child's actual developmental level indicates a child's level of mental development at a particular time. It indicates the functions that have already matured in the child. This implies that the teaching of new concepts should consider the learner's readiness (Gullen, 2000) and prior mathematical understanding. The learner's internalisation of mathematical concepts can be facilitated or accelerated if the learner's mathematical milieu is within the ZPD. The learner must be assisted by a more competent teacher or peer to see relationships between concepts. The mathematical concepts must be sequentially presented to the learner to enhance profound mathematical understanding.

The main reason for teaching Mathematics in the ZPD is to enable students to be actively engaged in their learning with the future prospect of becoming self-directed, lifelong learners. The ZPD theory perceives mathematical learning as a as co-construction of knowledge between the teacher and the learner and further transformation of that knowledge into individual knowledge of the learner. The teacher-learner interaction becomes that of collaboration and co-learning. High premium is therefore placed on the active position of the learner, which is essential for becoming a self-regulated learner. According to Vygotsky (1986), the learning process should be based on the student's engagement in an activity where the teacher is the director of the social environment in the classroom, the governor and guide of the interactions between the educational process and the student (Vygotsky 1997). The teacher does not influence children directly, but through shaping and fashioning their social environment. The way that teachers interact with the child in Mathematics within the ZPD is essential in supporting children to be active as well as self-regulated learners (Diaz, Neal & Amaya-Williams, 1992).

In regard to readiness for a given task, Vygotsky (1986) proposed that an individual learns in his or her "zone of proximal development". This term refers to a point of required mastery where a child cannot successfully function alone, but can succeed with scaffolding or support. In that range, new learning will take place. The teacher's job in teaching Mathematics is therefore to push the child into his or her zone of proximal development, coach for success with a task slightly more complex than the child can manage alone, and thus, push forward the area of independence. It is through repetition of such cycles that learners grasp new ideas, master new skills and become increasingly independent thinkers and problem solvers in Mathematics (Daniels, 2001).

Vygotsky (1998) emphasizes concept formation as a major issue in the cognitive development of a child. The process of concept formation should be studied by referring to the means by which the operation is accomplished, including the use of tools, the mobilisation of the appropriate means, and the means by which people learn to organise and direct their behaviour. The internalisation of mathematical concepts involves collaborating with competent others as mediators. Hence the cognitive development in a child is social, which involves another person and the society as a whole or the class as whole. Teachers should encourage collaborative rather than individual effort. In other words, social interaction taking the form of dialogue or exchange of cues or gestures plays an important role in concept formation.

The teacher's role within the ZPD in teaching Mathematics

The teacher's role in teaching Mathematics in the ZPD becomes one of purposeful instruction, a mediator of activities and substantial experiences allowing the learner to attain his or zone of proximal development (Blanton, 1998; Rueda et al., 1992). The implications are that the teacher's task is to push the student's ZPD toward higher and higher levels of competence and complexity. To add to what teachers do , teachers provide a model to show the learner how

something is done, or they can demonstrate a process or skill both physically and by talking aloud about how an expert thinks then the learners are given the opportunity to imitate the process. Lastly, teachers are expected to simplify complex matter. Perhaps the most important form of assistance is well-timed questioning, which can guide and scaffold the learning process. Questions can also serve to extend students' thinking further and provide opportunities for them to articulate and reflect on their thoughts. They can also serve as "scaffolds" by guiding the student through a logical thinking process or by prompting the learner to think about a problem in a new way.

In a Mathematics class, for example, the teacher may scaffold a multiplication problem by relating the problem to an activity that is familiar to the students, by reviewing skills needed to solve the problem, by providing tools for students to work with and by offering support while allowing the students to find their own solutions (Brown, Collins, & Duguid, 1989). Scaffolding is an interactive process of assessing and assisting and being sensitive to the needs and the readiness of the learner. Students who have had less experience with an area, a field, or a domain will need more scaffolding than those students who have had more experience with that field or domain. They may need more sequenced supports, more attempts and more opportunities to revise to develop expertise. Assistance can also be provided by more capable peers, through resources in the classroom as well as through the internet, software, and books. The teacher's role is to make sure that the student has access to a variety of resources appropriate to the student's needs and an understanding of how to use them.

Assessing the ZPD in the Teaching of Mathematics

Vygotsky (1978) submits that independent performance to determine a person's actual level of development does not cover the whole picture of development. Instead, he stressed the importance of responsiveness to mediation, which, because it provides insight into an individual's future development, is essential to understanding mathematical problems.

The assessment results would characterize the region of tasks between what the learner could accomplish alone and what could be accomplished and ultimately mastered with assistance. With this knowledge, teachers would have clear understanding of where to match instruction to extend learning. Again, this information would provide the focus for assisting the next step in learning.

Challenges in utilising the ZPD in the teaching of Mathematics

A big challenge for a classroom teacher is that they teach learners who all have different zones of proximal development. Scaffolding should be flexibly designed to meet the needs of diverse students. It should provide that extra support learners need to successfully complete a just out of- reach task in Mathematics (Savery, 1998).

Despite the importance of scaffolding within the ZPD, research indicates that it is a concept which is difficult to master (Bliss, 1996). For example, Askew and Macrae (1996), in their study of teaching Mathematics, demonstrated that school teachers experience difficulties in using scaffolding in their teaching. They reported a relative absence of scaffolding in most lessons. According to Bliss (1996), teachers were unable to effectively engage in scaffolded interaction with their pupils: they either tended to use directive teaching strategy, keeping their initiative in the episode, or gave full initiative to the pupils, leaving them to do the task by themselves, without much help from the teacher.

Stone (1998) analysed a number of limitations of the scaffolding metaphor in relation to the interaction which should take place in the ZPD. Vygotsky (1997) viewed children and adults as active agents in the process of child's development. In this case, the quality of interaction between the child and the adult which are dialogical in nature and based in the respect of children's interests and needs, become essential (Bodrova & Leong 1996; Fleer 1992, 1995; Tharp & Gallimore 1988). The metaphor of scaffolding, however, does not capture the two-way relationship between the teacher and a student, but rather implies a one-sided view of this relationship where a teacher provides a support for the learner.

Stone (1998) doubts the theoretical and practical value of the metaphor. However, he concludes that the metaphor should not be abandoned. Indeed, the scaffolding metaphor could not be abandoned just by a decision of a theorist or a group of theorists: it has been widely accepted and used by an increasing number of educational researchers and practitioners. It is essential, however, to keep in mind that a literal interpretation of the scaffolding metaphor might lead to a narrow view of child-teacher interaction and an image of the child as a passive recipient of a teacher's direct instruction.

In spite of the obvious limitations of scaffolding within the notion of the ZPD, scaffolding remains increasingly popular among educators, researchers and practitioners. The ZPD plays a critical role in mathematical instruction, because it allows the teacher to find an entry point for each student's learning needs, so that his or her learning potential can be developed in Mathematics.

CONCLUSION

We have argued that effective use of the ZPD can improve Mathematics achievement in the schools. Critical to this theoretical concept is the assistance which is given to operationalize the idea and this is simply defined as scaffolding. In essence, the ZPD represents a phase in development in which a child is unable to perform a task alone but can eventually accomplish and internalise it with the help and supervision of someone more experienced. The teacher takes a major responsibility for structuring the interaction leading the other through the steps of a mathematical task and providing the necessary support until the learner is able to do the task independently. Research has shown that more often than not teachers do not offer the support required in Mathematics and as a result, children fail despite having the potential to perform such tasks. In light of all this, we conclude that the ZPD theory if well applied, can lead to higher mathematical achievement.

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