A REVIEW OF RESEARCH ON THE EFFECT OF USING A GROUP LEARNING APPROACH IN MATHEMATICS CLASSROOMS

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Educational research is in the forefront of investigating and evaluating the influence of a group learning approach on the scholastic performance of learners. In this paper a group learning approach refers to an arrangement in which two or more learners work together to achieve a common educational goal. The aim of this paper is to present a review of research comparing the effectiveness of using a group learning approach on the performance of learners in mathematics. The results of the review suggest that a group learning approach is mostly favoured for constructing powerful learning environments that impact positively to learning. The paper also discusses some aspects considered to account for the beneficial influence of group work in academic environments. A cognitive load theory is briefly explored to provide insights on how group learning activities have a potential to influence cognitive processes that are perceived to be at play during a problem-solving activity. In conclusion, the author emphasizes a need to place learners in powerful learning environments, such as those generated by group learning approach, to engage learners in effortful interactions that promote shared knowledge and understanding.

Key words: Group learning approach; collaborative learning; cognitive load theory; mathematics performance

INTRODUCTION

In almost every education system efforts are being made to find reformed ways to provide support to individual learners, and also find ways for effective collaboration. Recently, collaborative or group approach presents itself as the most explored channel of delivery to enhance and facilitate learning activities. In this paper the term *group learning approach* is used to refer to the learning environments in which learners work as a collective. In fact, a group learning approach is a general term that could be used to describe a teaching format in which learners are grouped heterogeneously within a school arrangement. In Dhlamini and Mogari (2013) the terms *collaborative group learning* and *a group approach* are used interchangeably to simply refer to "an arrangement in which two or more people work together to achieve a common goal" (p. 1). This, in turn, is expected to allow for rich problem analysis and quick arrival at the solution stage. Usually, within a group learning arrangement learners get an opportunity to work in groups of two or more members who mutually search for understanding, solutions, meaning and creative strategies to solve problems.

A stronger argument for employing a group learning approach is that of increasing learners' opportunities for effective interaction and meaningful sharing of ideas, thus increasing opportunities for an active mind in multiple contexts (Sanna Järvelä, Piia Näykki, Jari Laru & Tiina Luokkanen, 2007).

In a group learning setting the role of a teacher as a sole expert transmitter of knowledge is defused as learners engage in the exploration of the learning material on their own. However, the word '*difused*' as used in this context should not, by any means, be construed as implying the supportive role and the presence of the teacher in group learning environment disappear entirely. In the right way a good teacher can play a role of a facilitator or that of a motivator. For example, Slavin (1991) noted that it is not enough to simply tell learners to work together, and that learners should be made to have a reason to take one another's achievement seriously. In addition, Slavin (1991) developed a model that focuses on external motivators, which reside outside the group, such as rewards and individual accountability that are established by the teacher. His meta-analysis found that group tasks with structures promoting individual accountability produce stronger learning outcomes (Slavin, 1996). Therefore a teacher continues to remain a key component of any teaching experience, irrespective of the teaching approach that characterizes those interactions. In a group learning environment learners are guided by the teacher to take charge of their education. It is thus fitting to describe group learning environments as a significant shift away from the conventional teacher-dominated instruction (pedagogy) to that which is learner-centred. In the conventional teacher-dominated classrooms a teacher always tells learners information, which they are later expected to remember. However, in group learning environments learners construct their own knowledge (Cobb, Wood & Yackel, 1990).

In this vain a group learning approach could also be seen as a teaching arrangement that promotes active learning. In Carlson and Winquist (2011) the phrase 'active learning' is used to refer to an act of asking learners to "do something" (p. 3). This explanation seems well in line with the goals of implementing a group learning approach, where learners could be given a mathematical problem to do and solve collectively. A group learning approach brings up an important feature to the role of classroom atmosphere and culture by opening up opportunities for group members to do something that contributes to their effective learning and specifically to the development of their intellectual autonomy as they are tasked to evaluate the worth of solution methods and provide justifications in collaborative discussion. In that way a group learning environment may provide learners with "effective tools to reinforce their problem-solving system" (Dhlamini, 2012, p. 241) that create a useful space for expanding their problem knowledge, social interaction and abilities to present and defend their views.

This is possible because the processes that occur during group discussions include verbalising explanations, justifications and reflections (Beers, Boshuizen & Kirschner, 2007; Kirschner, Beers, Boshuizen & Gijselaers, 2008), giving mutual support (Van Boxtel, Van der Linden & Kanselaar, 2000) and developing arguments about complex problems (Munneke, Andriessen, Kanselaar & Kirschner, 2007). Dhlamini (2012) emphasises three elements of group learning activities: discussion, argumentation and reflection. As a characteristic feature, learners in a group setting get opportunities to argue out problem steps and solutions using their varied learning perspectives. The role of argumentation and the dynamics of social interactions in learning group settings have been widely discussed in literature (for examples, see, Dhlamini & Mogari, 2013; Hershkowitz & Schwarz, 1999; Whitenack &Yackel, 2002; Yackel & Cobb, 1996; Yackel, Wood & Cobb, 1993).

Given this background, this paper aims to provide a review of the literature of studies that focussed on the role of collaborative group work in the teaching and learning environments, as well as its influence on the learning outcomes. In most of the reviewed studies the pedagogical activities are grounded on the notion of group learning, which largely embraces the idea that "knowledge is constructed by learners based on their social (i.e., collaboration) and cognitive (i.e. problem-solving; self-regulation) activities" (Kester & Paas, 2005, p. 690). Based on this review, this paper goes further to provide a discussion covering some of the aspects of group work that are considered to account for its beneficial influence in learning environments. Also, a cognitive load theory (CLT) is used in this paper to provide insights on the workings of a human cognitive system, and how this system may be influenced when learning takes place within a group learning environment.

RESEARCH ON THE ROLE OF GROUP LEARNING APPROACH ON LEARNERS' PERMANCE IN MATHEMATICS

In almost every country around the world a need to design powerful teaching strategies and methods to elevate learners' performance in mathematics has been identified. This need emanates from the realization and acknowledgement of challenges and demands of life and circular work in the twenty-first century. Multidisciplinary teams are used in industry, government and in education to solve complex problems to allow different perspectives to enrich the problem space. As such employees are constantly expected to: demonstrate effective communication skills; to collaborate; to negotiate and argue critically. How do we prepare our learners for these higher-order skills in order to expand meaningful labour participation in future? One way could be to encourage schools to construct learning environments that promote sustained learner engagement to develop effective collaborative skills (Dhlamini & Mogari, 2013). Given this background, there is a need to look into studies that were conducted to determine the academic influence of group work in teaching and learning environments.

Dhlamini (2012) conducted a quasi-experimental study in which 783 Grade 10 mathematics learners participated. All participants performed poorly in mathematics problem-solving. To demarcate the influence of different instructional approaches on learners' performance two teaching environments were constructed. In experimental schools (n=413) the researcher constructed learning environments that largely embraced aspects of group work by learners, while in control schools (n=370) teachers preserved conventional teaching conditions which were mainly teacher-dominated (Dhlamini & Mogari, 2013). Given the design of the study the mathematics performance of learners in both conditions was compared at pre- and post-stages on the experiment. The study found that the group approach, which was mainly implemented in experimental schools, appeared to be superior to the conventional teaching approaches implemented in the control schools in substantially improving learners' performance in certain topics in Grade 10 financial mathematics (see, Dhlamini & Mogari, 2013).

A study by Kirschner, Paas, and Kirschner (2009) explored the relationship between effort and performance when solving mathematics problems. The study involved high school learners who were learning from solving high-complexity mathematics tasks. The learners were organised in a group learning environment and an individual learning environment. The Kirschner, Paas, and Kirschner (2009) found a more favourable relationship between effort and performance in the learning phase for high school learners who worked in a group environment than for learners who worked individually. Invariably, there are several research studies which were conducted to examine group learning activities in elementary and secondary schools, which focussed on mathematics classrooms. The implication of these studies is that the use of group learning approach leads to better group productivity, improved attitudes, and increased performance in mathematics (Garfield, 1993).

In his study, Shaughnessy (1977) found that the use of group work approach appeared to help learners to overcome some misconceptions about probability, and in addition, group interactions enhanced the learning of statistical concepts. In another study Jones (1991) introduced group learning activities in several sections of statistics and later observed dramatic increases in attendance, class participation, office visits by learners, and improved learner attitude, which are all variables linked to performance. There are many other studies that have shown a positive impact on learning when learners participate in mathematics lessons that embrace elements of group and collaborative work (for examples, see, Dhlamini & Mogari, 2013; Newmann, 1996). For instance, Newmann (1996) found that learners in group learning environments learn better than those in individual learning environments. Barron (2000a, 200b; 2003) conducted a series of quasi-experimental studies that compared the mathematics problem-solving performance of Grade 6 learners in group and individual environments.

Almost all studies found that learners in group learning environments significantly outperformed those in individual learning environments. In accounting for the observed performance difference, the studies noted that when learners were given a new analogous problem task to solve, those who had earlier solved the problem in group environments performed at a significantly higher level.

Complex Instruction (CI) is one of the best known and widely researched instructional approaches that are common in collaborative and group learning environments. As a teaching approach CI could be built on a set of carefully designed learning activities that require diverse talents and interdependence among group members (Cohen & Lotan, 1997). According to Cohen and Lotan (1997), within a CI approach teachers are encouraged to pay attention to unequal participation among group members, which often results from status differences among peers, and are given strategies that allow them to bolster the status of infrequent contributors. Within this teaching environment different roles, such as recorder, reporter, materials manager, resource manager, communication facilitator and harmonizer, are assigned to learners to promote and support equal participation. There is a strong body of research evidence supporting the success of CI generated instructions in promoting learners' academic performance in mathematics (for examples, see, Abram, Scarloss, Holthuis, Cohen, Lotan & Schultz, 2001; Cohen, 1994a, 1994b; Cohen & Lotan, 1995; Cohen et al., 1999, 2002).

One of the key elements in group learning environments is the role played by the teacher. In group learning environments a good teacher can play a role of a facilitator or that of a motivator. For example, Slavin (1991) noted that it is not enough to simply tell learners to work together, and that learners should be made to have a reason to take one another's achievement seriously. In addition, Slavin (1991) developed a model that focuses on external motivators that are established by the teacher, which reside outside the group learning environment, such as rewards and individual accountability. Consequently, the meta-analysis conducted in Slavin (1996) found that group tasks with structures promoting individual accountability produce stronger learning outcomes. Therefore a group learning approach becomes more efficient when a teacher allocate roles accordingly.

ASPECTS OF A GROUP LEARNING APPROACH THAT ACCOUNT FOR ITS BENEFICIAL LEARNING EFFECT

Research has gone beyond just reporting merely the beneficial influence of group and collaborative approach in learning environments, it has however also reported on the aspects of this approach that are responsible for learning gains. For instance, a number of socially-oriented processes that play themselves out during group learning interactions have been identified as explaining why group work promotes individual learning. The social interactions that promote effective learning in group environments include: (1) the sharing of original insights and understanding (Bos, 1937); (2) resolving differing and opposing perspectives through argument (Amigues, 1988; Phelps & Damon, 1989); (3) explaining one's thinking about a particular phenomenon (King, 1990; Webb, Troper & Fall, 1995); (4) providing a useful and helpful critique (Bos, 1937); (5) observing other learners' strategies; (6) listen in order to provide an explanation later (Coleman, 1998; Hatano & Iganaki, 1991; Webb, 1985; Webb, 1985; Shirouzu, Miyake & Masukawa, 2002).

A series of experimental studies by Barron (2000a, 200b; 2003), which were reported earlier in this paper, reported more learning gains in group learning environments as opposed to learning environments that are exclusively individual-oriented. Further analysis in this studies also showed that the quality of the collaboration, that is, how learners talked and interacted with one another in group learning environments, was directly related their group score and later to their individual scores. Richards (2003) acknowledged that a group member's knowledge and expertise is not enough for the group to obtain the desired results; individual approaches should also be considered. Richards (2003) believed that effective groups require individuals who use and value different approaches when solving problems. According to McClough and Rogelberg (2003), group members that approach problems in a similar manner have relatively small amounts of tension, but may not produce the best solution. Therefore the type of approach that a group chooses to employ has a potential to determine the success rate in terms of how the problem solution is achieved.

In their summary of studies which were conducted over 40years on cooperative or group learning, Johnson and Johnson (1999) identified five basic elements of successful group learning. These are: positive interdependence, individual accountability, structures that promote face-to-face interaction, social skills, and group processing (Johnson and Johnson, 1999). In the same vain, Graves and Graves (1990) cite the following as the basic indicators of successful group learning: face-to face heterogeneous learning teams, positive interdependence, individual accountability, explicit training in interpersonal skills and reflection. Social interactions that are normally encouraged in group learning environments provide opportunities for expression and debate by learners.

THEORETICAL FOUNDATIONS OF THE PAPER

In Dhlamini and Mogari (2013) a cognitive load theory is used to inform the design of efficient group-based learning environments. Cognitive load refers to the mental burden and effort that an individual endures whilst executing a problem-solving task (Chen, 2003), and is largely linked to a *working memory*, which is considered to be critical in determining the success of learning. Working memory or the 'short-term memory' is the part of the memory, or human cognitive architecture that is needed to process incoming information (Kirschner, 2002). However, the limitations of the working memory in processing ability and duration are well documented and widely accepted within cognitive science research (Dhlamini & Mogari, 2011). Concerning its processing duration, researchers such as Paas, Van Gog and Sweller (2010) argue that almost all information stored in working memory and not rehearsed is lost within 30 seconds. Also, the working memory's capacity cannot deal with more than about seven elements of information simultaneously (Engle, 2010). Hence, if the working memory capacity is exceeded whilst processing information then some or all information may be lost. When the working memory is unable to deal with or process information, the cognitive load may be said to be too high.

Although cognitive load theory generated lessons are meant to manage individual working memory load (cognitive load) of individuals (Kirschner, Paas, Kirschner & Janssen, 2011), Kirschner, Paas and Kirschner (2009) have emphasised an alternative technique of effectively dealing with individual working memory limitations by making use of the multiple working memories of individuals in group approach learning environments. From a cognitive load theory perspective, it is argued that dividing the processing of information in the working memory across individuals in a group approach environment is useful because this technique allows information to be divided across a larger reservoir of cognitive capacity, thus increasing the working memory capacity (Kirschner et al., 2011). According to Dhlamini (2012), in a group approach learning environment, which represents a huge working memory system, the limitations of individual working memories are not exposed because individual working memories are not subjected to processing each piece of problem-solving information. Therefore the risk of overloading each group member is lowered, and an individual's working memory capacity is freed up whilst the group's collective working memory capacity is expanded, and the cognitive load may be reduced (Kirschner, 2009).

According to Kirschner (2009), within a group setting information processing is characterised by active and conscious sharing (i.e. retrieving and explicating information), discussing (i.e. encoding and elaborating the information) and remembering (i.e. personalising and storing the information) valuable task-relevant information and knowledge held by each group member. For a group to perform a mathematics task, it is not necessary that all group members be highly knowledgeable in task-related information or be able to process all available information by themselves and at the same time (Johnson, Johnson & Stanne, 2001). As long as there is communication and coordination between group members, the information elements within the task and the associated cognitive load can be shared amongst group members (Kirschner, 2009).

DISCUSSION AND CONCLUSSION

Using research from other studies this paper has highlighted the important role of group work in teaching and learning environments, and the need to consider its inclusion and application in mathematics classrooms. It is true that recent curriculum recommendations include the use of group learning activities as a form of active learning to supplement or even replace conventional instructional approaches. Unfortunately, collaborative and group learning environments are not as heavily advocated in schools as one might think, and in some instances are discouraged in favour of conventional formats. Given the discussions in this paper there is a need to encourage mathematics teachers to embrace the philosophy of teaching some of the topics in mathematics using a group learning approach. In order to enhance learners' performance, this paper demonstrated that the cognitive load theory (CLT) could provide useful guidelines for instructional designs that are suitable to group learning environments.

The review in this paper focussed on studies that documented the positive influence of group learning approach on the performance of learners. While there has been this promising oucomes on the role of group learning environments on learners' performance, other researchers have contested that group learning is not necessarily a guarantee for positive learning outcomes (see, Boylan & Smith, 2012; Gregor & Cuskelly, 1994; Heath, 1998; Soller, 2001). For instance, Boylan and Smith (2012) reported that collaborative or group learning environments could create many challenges for learners. Using CLT principles, Kirschner, Paas, and Kirschner (2009b) have argued that the possible cause of studies showing mixed and even negative findings may be that the structures constituting cognitive architecture have not been systematically considered when designing and carrying out research on group learning (for other inputs, see also Dhlamini & Mogari, 2011; Kirschner, Sweller, & Clark, 2006).

In addition, this paper has reiterated the important role of a teacher in group learning environments, and that this critical role should not be discarded. Given some of the discussions in this paper it is clear that the teacher could play a critical role in establishing and modelling productive group norms and practices to promote meaningful group conversations. While helping learners to organize themselves in groups of five to seven members a teacher may also help learners to set out rules to regulate group dynamics, and further assist group members to assign roles to each group members. Learners engaged in such group learning environments cannot only strengthen their content knowledge but can also learn increasingly important twenty-first century skills, such as the ability to work in teams, solve complex problems and to apply knowledge gained in group setting to a variety of circumstances. Therefore cooperative group work is an ideal environment for learners to construct knowledge through social interactions. Cobb, Wood and Yackel (1990) note that social interactions constitute a crucial source of opportunities for learners to learn mathematics through constructing individual's mathematical knowledge.

The author believes that a group learning approach should be made a popular learning arrangement for teaching mathematics in schools. In mathematics classrooms, group learning approach seems to hold a great promise as a supplement to other modes of subject delivery by providing learners with opportunities to practice mathematics skills and concepts with peers, and using mathematical language to discuss and critique mathematical concepts. In conclusion, it is the author's view that mathematics learners should be placed in powerful learning environments, such as those generated by group learning approach, to engage them in effortful interactions that promote shared knowledge and meaningful understanding of mathematics.

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