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Metacognition and Cooperative Learning in the Mathematics Classroom

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ABSTRACT

Based on theoretical notions of metacognition in light of the reality of mathematics learning and teaching in Saudi Arabia, this study aimed to explore a teacher's and students' perceptions of the nature of the relationship between cooperative learning and an improvement in metacognition. Consequently, a case study design was favoured in order to suit the research agenda and meet its aims. The participants consisted of one case study class from a secondary school in Saudi Arabia. Semi-structured interviews and classroom observation were used for data collection. The findings of the data analysis asserts that metacognition can be assisted through the creation of a suitable socio-cultural context to encourage the social interaction represented in cooperative learning. This has a role in motivating the establishment of metacognition, as the absence of this social interaction would impede this type of learning. The importance of the student's role in learning through metacognition was asserted by this study.

KEYWORDS
Metacognition, Cooperative Learning and Mathematics Learning

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Introduction

The concept of metacognition was explained by Flavell, Brown and Kluwe. Flavell (1979, p. 1232) referred to metacognition as "one's knowledge concerning one's own cognitive processes and products or anything related to them", and as: 'The active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or date on which they bear, usually in the service of some concrete goal or objective. Brown (1987) referred to it as someone's knowledge and control of their own cognitive system. Similarly, Kluwe (1982, p. 202) emphasized that, 'There are general attributes which are

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common to these activities referred to as 'metacognitive': a) the thinking subject has some knowledge about his own thinking and that of others; b) the thinking subject may monitor and regulate the course of his own thinking.

On the basis of this premise, it can be said that the concept of metacognition contains two major elements; firstly, knowledge of cognition, secondly, monitoring and regulating ones' own cognition, which can be called executive processes, as described by Kluwe (1982). The first aspect of metacognition refers to one's own knowledge or beliefs about features of one's cognition, as the above authors agreed; knowledge about the information processing system, as Brown (1987) added: and knowledge about three categories, person, task and strategy variables, as Flavell (1979) illustrated. The second aspect of metacognition refers to the monitoring and regulation of cognitive enterprise. Flavell (1979) used the concept of metacognitive strategy to describe the executive process through monitoring one's cognition. Brown (1987), on the other hand, described both as metacognitive skills, which are assumed to both monitor and regulate one's systematic cognitive activity. Kluwe (1982) asserted that the executive process has two main functions aiming directly at gaining knowledge about one's cognitive processes: monitoring these processes and regulating one's cognitive activity. The executive process, according to Kluwe (1982), refers to four elements that are included in executive monitoring: Identification (what am I doing?), checking (did I succeed? did I make progress?), evaluation (is my plan good? are there better alternatives?) and prediction (what could I do? what will the result be?). According to Brown (1987), the second aspect of metacognition includes activities such as planning, monitoring and evaluation. Planning activities requires predicting the results, planning strategies, choosing alternative trails, etc. Monitoring activities requires testing, rescheduling and revising learning strategies. An evaluation outcome requires evaluating the use of effects in the light of the criteria of effectiveness and efficiency.

Taking all these arguments into account, a need for theoretical clarity is certainly present. This would include improved definitions and descriptions of the numerous components of the concept (Azevedo & Aleven, 2013). With regards to improved definitions, it can be concluded that metacognition from an educational standpoint refers to one's knowledge and the monitoring and control of one's own systematic cognitive activity which requires certain metacognitive skills such as planning and evaluation. Noteworthy in the context of discussing the concept of metacognition, the important issue remains determining the basic subject of the concept of metacognition. Particularly since Brown (1987) mentioned that the concept of self-monitoring and control method is essential in the growing field of metacognition and Kluwe's view (1982, p. 220) being that "the subject of metacognition is regulation of one's own information processing".

The presentation of a definition for metacognition does not mean that there is unanimous agreement about the borders of the concept. This is due to the fact that, over time, the scope of definition has grown in tandem with metacognition becoming a multifaceted concept (Buratti & Allwood, 2015).

Metacognition and sociocultural context

There is evidence, according to Brown (1987), that a great deal of learning happens through interactions between the learner and others. Thus, a teacher who is interested can improve a child's active metacognition by providing him/her with related experiences regarding regulation skills which are created within a social situation. According to Larkin (2010), a large body of research on metacognition has surrounded information processing models and cognitive psychology since the 1970s. Another significant area of study has been concerned with understanding the way in which metacognition assists in 'wise and thoughtful life decisions' as Flavell (1979, p. 910) put it. The concept of agency among social psychologists has also been of great importance, looking into how individuals act purposefully though monitoring and evaluating behaviour. The way in which we 'think about thinking' and develop metacognition of self, other, tasks and strategies is dependent on the sociocultural context (Larkin, 2010).

In this regard, Thomas (2012) highlighted two beliefs surrounding metacognition that should be questioned: that metacognition in all its forms is a positive influence, or that only one type of metacognition is beneficial. These premises do not take into account the influence of the context in which students operate. As metacognition should assist students to achieve goals in their wider life context, then it is crucial to adapt metacognition in its application to varying realities. Metacognition should be seen as a result of the surrounding environment in which students gain reasoning skills, instead of perceiving it as intuitive. The way in which cultures evaluate effective thought and consequently metacognition differs greatly across the globe. Hence some strategies for implementation may only be suited to certain contexts and models - proposing a broad and 'one size-fits-all' nature should be treated with scepticism due to the risks involved. Based on these premises, Larkin (2010) concluded that a theory of metacognition which boosts a process of reflection and self-criticism, encourages individuals to discuss education, considers the needs of specific groups in specific contexts, and allows for introspection on issues such as the student-teacher relationship, would be a theory that can be employed in order to build a more socially representative education establishment. In this regard, Larkin (2015) highlighted the sociocultural theory of metacognition in identifying the interrelated social, psychological and cultural aspects of education and the development of metacognition.

Metacognition and cooperative learning

Research has shown that metacognition can be developed through co-operative or collaborative learning (Bernard & Bachu, 2015; Hurme, Järvelä, Merenluoto, & Salonen, 2015; Kramarski & Mevarech, 2003). However a distinction needs to be made between these two terms as they refer to different types of learning although both are founded on constructivist learning theory (Bernard & Bachu, 2015). In order to understand them, the intended meaning behind these terms will be clarified, along with the context of their usage. Following this, it will be summarized into a provisional definition to be used in this study.

According to Chinn (2010), the two terms may be used interchangeably in everyday and even academic language. The rationale behind this is that student participation through small groups predominates in both situations (whereas passive lecture-based teaching, or the 'traditional method' as referred to in this study, favours the completion of particular tasks). Both strategies also fundamentally support a discovery-based method of learning (Chinn, 2010). It has been suggested that this misconception has emerged due to the overlap in both the concepts themselves and the use of the terms (Pannitz, 1996). According to Pannitz (1996), while collaboration is a belief system or even a philosophy held in terms of lifestyle, cooperation is a structure for interaction targeted at a defined goal related to the content. Hence it is more structured and guided than collaborative learning, with the teacher playing a role in control of the interaction. In cooperative learning, groups are focused on advancement towards a teacher-set goal, rendering the group more structured. In contrast, with collaborative learning groups differ depending on group members rather than a goal (Panitz, 1999).

Rockwood (1995) identifies the contrast also, yet he states that specific tasks exist in both methods and notes that comparisons among groups regarding method and conclusion are present in both contexts. However, he identified that the key difference was in the type of knowledge that the strategies dealt with. In this he concluded that cooperative dealt with traditional (canonical) knowledge whereas collaborative was more social-constructivist. Despite existing examples of collaborative learning being implemented in primary school such as CASE@KS1 (Adey, Robertson, & Venville, 2001), Panitz (1999) suggested that cooperative learning be applied mostly at the primary school level but this could extend to secondary. This was because this age group required structure in order to achieve targets and maintain focus. He claimed that collaborative learning was more suitable for tertiary education, where foundational knowledge was already well developed and non-foundational knowledge should be focused on, or where concepts may require conference and exchange of ideas without a set answer. The group can operate as a feedback mechanism in such a context, where unanimous agreement is not the end result. Rockwood (1995) concurred with this view by stating that cooperative learning was a useful means to reach mastery of fundamental knowledge, and only then would students become ready to converse, discuss and assess.

Based on these premises, it is difficult to determine which specific definition of group work to apply with all of its characteristics in mathematics learning through metacognition at the secondary stage. However, it can be said that group work in mathematics learning in secondary schools in the Saudi educational context takes some advantages from both methods. This is because this style of learning generally has some cooperative characteristics, as highlighted earlier; however, the teacher's role is not central and is supposed to remain supervisory. This is specifically seen when solving problems as a step in the context of dealing with mathematics problems. There should be innovation to generate solutions and methods to solve problems or to understand new mathematical concepts. Furthermore, the teacher should not, at this stage, be guiding this process but rather supervising it. If it is suggested for the student to be the centre of the learning process in each stage of solving the mathematics problem, than this is confirmed at the stage of finding a strategy to solve. Hence it is challenging to classify the systematic learning of mathematics for this age group in the characteristics of a single framework from among the types of group learning. This is because mathematics learning at secondary school holds characteristics of both types. As a result, clarifying the provisional definition for the nature of group work remains the most important aspect, whether it is named as cooperative or collaborative learning.

Artzt and Newman (1997) outlined necessary ingredients for a group working towards a common goal. Firstly, there must be a perception of teamwork and a common goal. Secondly, groups must realize that the problem is shared and the benefits of success or burdens of failure are equally shared among all members. Thirdly, to achieve this goal, members must interact with one another and discuss all problems. Lastly, it should be obvious that all individuals' work has a direct impact on the success or failure of a group. Adding to this, in the context of the current study, group work is focused on certain prepared activities which had a previously defined goal dependent on the steps of the IMPROVE programme. Finally, despite the benefits of group work, this is not to say that other methods are invalid, as the importance of teacher instruction and individual work remains, as Blatchford, Kutnick, Baines, and Galton (2003) asserted.

In terms of how researchers regard metacognition and cooperative learning, there is uncertainty towards cooperative learning's effectiveness in improving the effects of metacognitive training. Hinsz (2004) explored the improvement of one's understanding of cognitive processes through metacognition in a team setting. A comparative study was conducted by Desoete (2007) among students who had all undergone metacognitive training, yet were divided by those who had done so individually and those who had done so in small groups. The study indicated that the individually trained students improved more than the students trained in groups. This is because there are no external stimuli in the individual sessions to distract the students when they are analysing the task, building connections between the new and old knowledge and solving problems through strategies. A study conducted by Moga (2012) showed that both the individual and group training showed improved results. The study conducted on seventh grade students showed that students in the individual training programme showed better results of improvement in prediction skills compared to the group training session. He justified his study's result by claiming that the Romanian education system does not support cooperative learning and hence students are not familiar with learning in a group environment, so the results obtained were expected as per the conditions. The results of Kramarski and Mevarech (2003) are contradicted by these studies, as they endorsed the concept that cooperative learning combined with metacognitive training seemed to yield much better results than the individual ones. In the same vein, Goos and Galbraith (1996) concluded that interaction within groups could either harm or encourage metacognitive decision making during problem solving. The deciding factor in this was the students' capacity and willingness to share metacognitive training. Artz and Armour-Thomas (1992) expressed more definitively that problem solving in small groups may encourage metacognitive behaviours, thus assisting students to find sound solutions. Bernard and Bachu (2015) concurred with this view by explaining that collaborative learning has assisted students in problem solving by encouraging metacognition. Hurme et al. (2015) presented findings indicating that when pairs worked on computer assisted problem solving, metacognition was a mutual process and encouraged peer thinking. Yet participants of a group must all participate in the monitoring and control of collective problem solving to effectively build knowledge. According to Hartman (2015), while metacognition has previously been theorized as self-reflection on thought, pairs and groups can also collectively be involved in metacognitive activities. Coles (2013) called for further research into the idea of co-regulation in group settings to determine similarities and dissimilarities in cognitive processes, the influence of this on self-regulation, and the effectiveness in arriving at learning outcomes.

Hartman (2015) employed the term metacognitive group activities to describe groups of 3-4 students, whereas Hogan, Dwyer, Harney, Noone, and Conway (2015) employed the term metacognitive collaboration. This involves a process of group members pondering and reflecting on their collective information processing, and attitudes towards work. According to Hogan et al. (2015, p. 90) various features need to be present to bring about effective metacognitive collaboration. These are:

> effective facilitation, feedback and instruction for the collaborative process and goals; fostering improved team functioning in the collaborative context, including the encouragement of cooperative, investigative discourse; and the use of tools and methodologies which facilitate group coherence, and the management of complexity and group problem-solving. (p. 90)

Hurme et al. (2015) described the role of metacognition in collaborative learning contexts, where metacognition was perceived as a mutual social dynamic. This shared social metacognition is both the monitoring and regulation of cognitive processes on the interpersonal level. Overall, such research ascribes mutual, social metacognition as a significant feature of collaborative problem solving approaches. Yet an in-depth explanation of what gives metacognition a social and mutual aspect is still uncommon and further efforts are required to understand the social and shared features, along with their significance in the problem solving process. Regarding this dimension, the current study sought to explain the nature of the relationship between cooperative learning and an improvement in metacognition in the mathematics classroom.

IMPROVE programme

The IMPROVE programme was presented by Mevarech and Kramarski (1997). It encompasses three interrelated components (Mevarech & Kramarski, 1997, p. 369):

> (a) Facilitating both strategy acquisition and metacognitive processes; (b) Learning in cooperative team[s] so four students with different prior knowledge: one high, two middle, and one low-achieving student; and (c) Provision of feedback-corrective-enrichment that focuses on lower and higher cognitive processes. (p. 369)

IMPROVE is an acronym for the instruction steps that comprise the method: Introducing new concepts, Metacognitive questioning, Practising, Reviewing and reducing difficulties, Obtaining mastery, Verification, and Enrichment. This is designed for implementation in smaller groups which include four students of diverse capabilities, particularly after a concept has been introduced to a class. Students pose three forms of metacognitive questions, these being categorized as comprehension, strategic and connection questions.

There are some reasons that the IMPROVE programme was chosen to be implemented in this study. Firstly, the IMPROVE programme uses the metacognitive perspective and how it can be activated in mathematics teaching and learning. Secondly, the programme is centred on the belief that learning is not a rote process but rather one of interpretation, as many constructivists would argue. In doing this, students build meaningful relationships between new and previous knowledge, thus leading to the assertion that this is a process of construction rather than recording and memorization. This conforms to the current study which was engaged in the socio-cultural perspective. Thirdly, the programme includes cooperative learning which in turn helps in understanding metacognition and mathematics within the socio-cultural context as it was presented in relevant section of the current study. Fourthly, the IMPROVE method has proven to have a sizeable positive impact on mathematical performance in problem solving across several age groups. (Cetin et al., 2014; Grizzle-Martin, 2014; Kramarski and Mevarech 2003; Kramarski, Mevarech, and Arami, 2002; Kramarski and Michalsky, 2013; Mevarech and Amrany, 2008; Mevarech and Kramarski, 1997). Despite all these reasons, it is important to assert that the IMPROVE programme was carried out in order to enable the formulation of a clearer and more complete picture of the nature of the relationship between cooperative learning and an improvement in metacognition in the mathematics classroom in Saudi Arabia, rather than seeking to improve a specific strategy or to measure students' achievement.

Study aim and question

Based on theoretical notions of metacognition in light of the reality of mathematics learning and teaching in Saudi Arabia, this study aimed to explore A teacher's and students' perceptions of the nature of the relationship between cooperative learning and an improvement in metacognition. Consequently, this study sought to respond to one question; how do secondary students and their teacher perceive the nature of the relationship between cooperative learning and an improvement in metacognition in the mathematics classroom?

Methodology of the study

The qualitative research approach can fulfil research needs in terms of understanding how humans make sense of the world they experience and live in (Merriam, 1998). To help achieve this, Stake (1995) asserts that the researcher-as-interpreter should observe the situations under investigation in a subjective manner in order to recognise what is happening and, at the same time, examine, revise or verify the co-constructed meanings of the participants. In this study, given the research aim, objective and question, an explanatory approach was adopted although elements of the evaluative approach were also incorporated. In collecting the qualitative data for this research, the methods used are individual semi-structured interviews and participant observation. The study was carried out in order to enable the formulation of a clearer and more complete picture of the nature of the relationship between cooperative learning and an improvement in metacognition in the mathematics classroom.

Participants

Since this study does not seek to generalize its results but to understand 'what is happening' and 'the relations linking the events, purposive sampling was used as the method of selecting the sample (Merriam, 1998). The participants were chosen based on a purposive sampling technique. I chose a small city which might be a more suitable environment to fulfil the following requirement criteria: the number of students in the class should not exceed 30 students, and teachers found who were cooperative and enthusiastic to implement the idea of metacognitive teaching. In addition, there should be a pre-existing practice of cooperative mathematics learning among students and teachers. Considering these criteria to find a suitable environment might help me to focus on the main subject of the study, particularly the IMPROVE programme based on cooperative learning. There was one class at the secondary school; this class is considered a case study which contains 30 students and their teacher. Seven students and their teacher gave individual interviews. These students were chosen through co-ordination with the teacher in order to determine which students were best able to express themselves on their opinions and feelings, with these students being of various educational achievement levels. The teacher's interview lasted 45 minutes, with the students' interviews lasting approximately 30 minutes. As for the teaching staff involved in this research was called Mr Fallatah as a pseudonym. Subsequent to gaining his undergraduate degree in mathematics at King Abdulaziz University in 1998. The participating students in Mr Fallatah's class were Mohammed, Ziyad, Ragab, Omar, Mazen, Qusay and Fadul (all pseudonyms). All the participating students in Mr Fallatah's class were 17 years old. All participating students lived in the same area of city.

Main Study

Before I began the main study I met the teacher twice; each time the meetings lasted one hour. These meetings were scheduled in order to discuss the IMPROVE programme and how the teachers could implement it in the maths classroom context. I gave the teacher the freedom to choose appropriate situations in which to apply the IMPROVE programme, based on the content of the lesson and the preparedness of the students. Since IMPROVE assumes that cooperative-mastery learning based on peer interaction and the systematic provision of corrective feedback enhances mathematical thinking, students learnt in teams consisting of four students, as follows:

- Each session began with the teacher's short presentation (about 10 minutes) of the new materials to the whole class using the question-answering technique.

- Following the introduction, students started to work in small groups using the materials the teacher had designed. Students took turns in asking and answering three kinds of metacognitive questions: (a) Comprehension question: What's in the problem? (b) Connection question: What are the differences between the problem you are working on and the previous problems? (c) Strategic question: What is the strategy/tactic/principle appropriate for solving the problem? Whenever there was no consensus, the team discussed the issue until the disagreement was resolved (see **Error! Reference source not found.** as an example of an activity).

• Talking about the problem, explaining it to one another, comparing it to what was already known, approaching it from different perspectives, balancing the perspectives against one another, and proceeding according to what seems to be the best option at the time, students actually used the diversity in their own prior knowledge to self-regulate their learning. When all team members agreed on a solution, they wrote it down on their answer sheets. Students' answers included the final solution, mathematical explanations, and a sample of metacognitive responses (e.g., "This is a problem about ...," "The difference between this problem and the previous problem is ...," "The mathematical principle appropriate for solving the problem is . . . because . . . .").

• When none of the team members knew how to solve a problem, they asked for teacher assistance.

• At the end of the lesson, the teacher reviewed the main ideas of the lesson with the entire class.

• When common difficulties were observed, the teacher provided additional explanations to the whole class.

• When students worked in small groups, the teacher joined one team for 10 minutes and worked with them as an additional team member.

• When the teacher's turn arrived, he modelled the use of the metacognitive questioning in solving the problems. The teacher read the problem aloud, used the metacognitive questions, and explained each step of the solution. Teachers listened to how students coped with the problems and provided assistance when need. Teachers worked with each team at least once a week.

All of these applications were observed. At the conclusion of this period I conducted semi-structured interviews with the teacher and the previously mentioned seven students. Interview sought to respond to one question: how do secondary students and their teacher perceive the nature of the relationship between cooperative learning and an improvement in metacognition in the mathematics classroom?

Data analysis

Despite thematic data analysis has been discussed by Braun and Clarke (2006) who explain that data themes can be categorised as inductive ('bottom up'), or theoretical ('top down'), The method employed in this study involved just elements of theoretical thematic analysis. Overall, coding reflected information that had been expected to be found before the study.

The individual interviews, along with the observations were conducted in Arabic, and transcribed and analysed in that language to preserve the meanings. After acquainting myself with the data and having formulated some general ideas about the notable features within it, I then began to generate preliminary coding by assigning a 'code' to specific content using a software called MAXQDA. I had a long list of codes that were assigned to extracts. I then examined each coded extract and organised these codes into groupings that I called 'categories'. These categories were checked by a colleague (who holds a doctoral degree in Education) who agreed with the logical aspect of these groupings after extensive discussion. This phase involved sorting these different codes into potential categories, and collating all the relevant coded data extracts within these categories using the software. I then read through the 'code system' (as it is called in the software) and pondered how much each code agreed with the category. Then I created themes that were inferred based on the link between the different categories.

Findings

In terms of the relationship between cooperative learning and metacognition, Mr. Fallatah thought that a strong connection existed between metacognition and cooperative learning. When speaking of cooperative learning, he considered low academic achievers as being unable to participate with their classmates in the discussion. He said: 'Students with low academic achievement benefit less than other students because they cannot participate with their classmates in the discussion and working towards the solution of the problems and also because mathematics requires previously gained knowledge.' On the other hand, he said: "If students are outstanding students (in terms of grades), this could increase their enthusiasm for engaging in cooperative learning with other students of lesser ability". Based on these premises, he suggested that: 'The activities should involve indirect solutions, previous experience, hold new ideas, and should be challenging. This encourages students to interact more with the subject, the teacher, and among themselves.' Hence, the importance of monitoring the cooperation of each work group was raised in the interview. He said: "Looking at the worksheets to evaluate students' work reveals to the teachers many aspects of the groups' cooperation". (These worksheets had been designed according to the IMPROVE programme.) In addition he considers that 'Every student should try to present what would help the other group members with solving problems. As for this method in itself, the division of students into varying educational achievement groups proved to be valuable in aiding cooperation.'

Regarding the subject of communication between students and to what extent it can facilitate metacognition, it arose from interviews with students that – in general – there was a weakness in skills involving communication with others. For example, a group of study participants stated that they did not wish to speak with others, be it about methods of thinking or even in their wider learning. The student Fadul asserted, 'I don't like to discuss with others about my way of thinking, because I am rather weak in mathematics, so I don't want to speak about this weakness in front of others.' Another aspect is that some students just have a better thought method than me, so I am somewhat shy to talk to them. This was similarly expressed by the student Mazen, who said: "I don't discuss how I think with my class partner, which is because I think that is a personal matter, relating only to me".

Despite this, when the participants were asked whether or not they would accept their classmates' corrections in mathematics learning, their answers differed between those who did and didn't accept this, and yet every participant mentioned that such correction is a positive influence. For example, the student Mohammed stated, 'My classmates' correcting my mistakes is something more positive than negative. It's an advantage because I can correct my own errors, but is also negative as when the classmate correcting me is at a much higher mathematics level than me, his correction indicates that I have a big flaw in my thought method, which is something that embarrasses me.'

The student Fadul explained that, "The downside is that when my classmates correct my mistakes during mathematics learning, I doubt my self-confidence. The positive thing is that I can learn from my mistakes." Expressing a noteworthy view, Ziyad articulated that "the negative aspect is that the person correcting you is still presenting you with ready knowledge about a certain mistake, and doesn't teach you how you learn". During the interview the participants generally did not raise anything indicating the presence of skills in dialogue with others, which would hinder learning through metacognition.

Several participants in the interviews presented data pointing to a relationship between cooperative learning and metacognition. Mohammed highlighted that "metacognition really benefitted cooperative learning because it provoked thinking in an organized way, and gave a greater opportunity for all students to participate". He added: 'Following an organized thought method enables the student to monitor his thought and then amend it. Therefore I see that working in groups improves the students' ability to monitor their thinking.' The student also mentioned that: 'Through learning in a small group, I can know which students have ways of thinking parallel to mine and which differ from my method of thought; to do this I draw a link in my mind between the person and his type of thinking.' In this regard, Mohammed underlined the importance of "dividing the class into groups in a way suitable to benefit from metacognition". Mazen added to this by stating, 'Really, cooperative learning enhances metacognition. Metacognition is also beneficial in creating a cooperative atmosphere between group members in how they monitor each other, and how they evaluate their method of thinking in dealing with mathematics problems, and the teacher is more able to discover their methods of thinking. The student also described how learning through metacognition would require good communication between learners and not with the textbook. Speaking on this point, he said, "I think that learning through metacognition is one that exists between learners and cannot be between the student and the textbook". Ragab built on this by explaining how metacognition encouraged cooperative learning. He commented, "Metacognition helps you to arrange your ideas and helps group members cooperate better than before. The reason for that is because it is a technique for thinking and also dialogue." On the same topic, the student Ziyad thought that the lack of implementation of cooperative learning was a barrier to learning through metacognition. He stated, "One of the obstacles to learning with metacognition is that the school has not used cooperative learning in a practical or correct way".

Discussion

The basic components of the IMPROVE programme were centred on strategy acquisition, metacognitive processes and feedback-corrective enrichment for both lower and higher cognitive procedures (Mevarech & Kramarski, 1997). A further aspect was cooperative learning in groups of four – which consisted of one student with a strong body of prior knowledge, two with average knowledge and one at the lower end of the spectrum. This final aspect will be dealt with in this section of the discussion, in which the relationship between cooperative learning and metacognition will be discussed along with the need for cooperative learning in an environment suitable for learning through metacognition. This will be grounded in the findings of the study and in light of the theoretical framework for this subject.

Moga's (2012) study indicated that the link between metacognition and cooperative learning had not been given sufficient attention. Thus, the relationships between metacognition and cooperative learning need more research. In order to become acquainted with the nature of cooperative learning as practised by the mathematics teachers and their students who participated in this study, it is important to discuss the nature of the teacher-student and student-student relationship. Moreover, the extent of the connection between the concept of cooperative learning and metacognition will be discussed in this section.

The findings of the current study underlined the presence of the required skills among participating teachers for cooperative learning strategy. Such skills included commitment and discipline to timing, group distribution, activity management, presentation of concepts, mathematics problem solving and the correction of student errors. Adding to this, the teachers excelled at communicating with students about issues in class and were open to their suggestions. The findings revealed an openness to new and unorthodox methods, with teachers encouraging quality over quantity of solutions. Specifically, this meant a preference for multiple solutions of the same problem, rather than the solution of a greater number of problems. However, it cannot be said that the teacher-student relationship was entirely conducive to the implementation of IMPROVE. This is because the learning in the case study largely revolved around the direct delivery of mathematical concepts, according to the findings. This came in contrast to a more suitable participatory atmosphere targeting knowledge construction as well as the necessary adjustment of students' thought in dealing with such problems. This also involved the monitoring and highlighting of errors made by students in their solving, leading to tension in the relationship. This tension originated from several sources, one of which may have been the overbearing nature of such supervision, or the haste with which concepts were delivered and problems solved, which only served to confuse students. It would be unfair to hold teacher solely responsible for the existence of time constraints – they are required to complete all the units in the curriculum by the end of term – regardless of whether or not extra time is needed to employ metacognition. Hence, the teacher's position as conductor of the learning process and the conveyer of knowledge served as an obstacle in observing metacognitive characteristics in learning. This was consistent with Larkin's (2006) study, which identified a lack of sufficient opportunities for students to cooperate on a higher cognitive level as a key obstacle. This was due to the fact that it could hinder their ability to implement or even develop metacognitive strategies and be given feedback about their cognitive processing.

The findings demonstrated that communication skills were generally weak in participants hampering the interaction required for cooperative learning, let alone that which would be needed for productive learning through metacognition. This confirms the importance of communication for effective group work, as explained by Larkin (2006). She explained that communication skills such as listening, contribution and sharing were enhanced by collaborative work. Furthermore she stated that such working arrangements would impact their individual ways of thinking.

The findings demonstrated various reasons for a weak cooperative environment. Firstly, a reluctance on the part of several students to participate in group work, neither about individual ways of thinking specifically nor learning in general. This stems from a number of beliefs held by some students, one of which was the perceived difficulty of expressing themselves on their thought methods. Another was the perception that thought methods were a personal matter that did not require expression to begin with. A further reason was that students felt insecure about revealing their errors in front of others as it would demonstrate their weakness in the subject of mathematics, which they felt would have a negative impact on their self-confidence. There were some students who did not accept criticisms from others who were weaker academically. Furthermore, many did not see the benefit of criticisms as their solutions rather than methods were being scrutinized, which they were able to identify as a form of ready knowledge rather than a constructive comment.

The second important reason for the reluctance of students to discuss was a weakness in communication skills, which was clarified in this study as participants did not contribute in a way that demonstrated the presence of such skills. One of the manifestations of this weakness was a shyness to participate, which was raised by the findings of this study. This could be due to the lack of students' familiarity with presenting ideas and discussing solutions; this undoubtedly hindered the evaluation of their thought and perhaps the presentation of a full and clear picture of their thought process.

Another reason for weakness in this regard was the nature of the activities presented to the students. The findings showed that activities were overly simplified in their steps to solving and explicit as to the ideas behind them. Some problems did not even require any form of cooperation as they lacked features that might stimulate thought. Participants were often able to distinguish between problems that required group work and those that did not. According to them, this depended on the nature of the problem and its difficulty. Another reason for poor communication may have been weak academic achievement in mathematics. Students with low levels either felt embarrassed to participate or may have been discouraged from doing so by other students and instead preferred to leave the process to students with greater capabilities.

In the early stages of IMPROVE's implementation, it was naturally difficult to perceive a significant shift in the teacher-student relationship. Teachers continued to dominate much of the discussion, notably so in confronting obstacles faced by students. Further along in the programme's implementation, the relationship began to transform into a systematic and purposeful version of its former self. This is due to the fact that learning methods themselves took on these same characteristics. Teachers began to discuss problems in greater depth and detail, which encompassed the reduction of difficulties, checking solving methods and comparison of problems. This was targeted at the development of student awareness of thinking and building confidence in their abilities to learn through metacognition. Yet findings continued to demonstrate the significance of student commitment, discipline and listening skills in order to obtain the desired results of IMPROVE's implementation. The findings displayed an improvement in the participation of students in the learning process after the programme's implementation. Another finding of this study was that the reasons for this progress lie in the intended preparation of activities presented to students. A second reason was distributing the groups in a manner that encouraged cooperative learning. The findings showed that preparation of activities was essential in motivating students to work cooperatively and metacognitively, which is in line with the study of Larkin (2006). Her study highlighted that the task itself was crucial to the success of collaborative group work. The findings present some characteristics of such activities, such as employing indirect solutions and previous experience while containing new concepts and challenging students. Such activities push students to engage head-on with the subject, its teacher and each other. The worksheets presented were designed in line with the IMPROVE programme.

The findings displayed that metacognition and cooperative learning were closely intertwined. Cooperative learning is crucial in bringing about a suitable environment for learning through metacognition, as students are made capable of monitoring and evaluating each other's method of thinking at close quarters in the mathematics classroom. This is consistent with a number of studies, such as Desoete (2007); Kramarski and Mevarech (2003). These studies affirmed that cooperative learning seemed to be an effective way to further the impact of metacognitive instruction. In that context, students placed in cooperative groupings during training sessions showed greater development in their metacognitive skills than those being trained individually. In the present study, the findings also highlighted that success in cooperative learning can be attributed to the utilization of work maps, which are of significant assistance when problem solving and communicating with other students. Specifically, they helped to shift the group's centre of gravity from a dominant outstanding student to one which was more equally dispersed.

On the other hand, the findings showed that metacognition assisted cooperative learning, and hence the relationship between the two is one of mutual benefit as metacognition contributed a more organized thought method, relating back to the use of work maps. This helped in administrating group dialogues in an effective and useful manner. This characteristic was noted in Moga's (2012) research, in which the significance of metacognition in cooperative learning was described as lying in its capacity to harness the capabilities of stronger students in a constructive manner. More specifically the aforementioned study explained that students with better developed metacognitive abilities would hold greater awareness of learning requirements and hence could contribute more in cooperative groups.

As cooperative learning combined with metacognition bestows students with the central role in the learning process, they are tasked with knowledge construction, which enhances their ability to solve mathematical problems. This was consistent with Mokos and Kafoussi's (2013) study which claimed that students' performance in mathematical problem solving was boosted by working in small groups. This was due to the fact that such arrangements created a socially interactive atmosphere which was grounded in metacognitive questioning for a more systematic and structured process.

The fact that cooperative learning can serve as an aid to learning through metacognition was stressed by a participant who detailed specific methods which could be used to maximise the benefits of this combination. The first of these was the use of multiple solutions, with groups collectively evaluating the solutions of other groups, enhancing the thought process. Another method discussed was that of self-correction, after which students would present their errors and amendments in front of classmates, providing a window into their thought process and allowing other students to reflect on this. The strategy of comparing and contrasting solution was seen as critical, be it within a group or with other groups, the teacher and the textbook. This enhances introspection and allows the learner to discern his errors rather than being told them by way of ready knowledge. This is supported by Moga's (2012) research which suggested that students should note down their solutions, discuss with a classmate and subsequently present it to the class. The benefit of this stems from an obligation to discuss ways of thinking, reflecting on their position and expressing their opinion. Therefore, students can simultaneously evaluate themselves and gain knowledge from their classmates. It would also allow the teacher to evaluate students collectively, checking for true understanding by examining the confidence with which they communicated and presented. Teachers hoped for a period of time longer than the academic year so that students could be fully acclimatized to learning with metacognition. Not only did it allow for the teacher to evaluate all the students collectively, it also relieved the teachers of the need to explain all the material, and hence their roles became more supervisory and corrective than explanatory. This is consistent with Larkin's (2006) study, which mentioned that teachers would initially be the key motivators of group work. However, as time progressed teachers were able to withdraw more, and rather than driving group work would gently guide the group, thus allowing for greater awareness of thought among students.

The findings of this study demonstrated these conclusions in several ways. Participants themselves alluded to the significant shift in responsibilities that comes as a consequence of metacognitive practice. They explained that students shifting to the centre of the educational process stimulated a search for knowledge or an intellectual curiosity. It also developed students' thinking abilities and bestowed them with the necessary tools to evaluate themselves, particularly in a way pertaining to thought. These impacts were heightened among the more serious students. This does not mean to say that the teacher's role in learning through metacognition diminishes; rather, it is reformulated to transform from one which merely transfers knowledge to one which constructs it. It transforms to one targeted at assisting and enabling students to assess their way of thinking in order to improve it in their learning of mathematics. This confirms the importance of the teacher's role in the cooperative context and is in line with the study of Mokos and Kafoussi (2013).

Based on this, metacognition can be assisted through the creation of a suitable socio-cultural context to encourage the social interaction represented in cooperative learning. This study served to clarify this point, and came in agreement with the study of Sandi-Urena, Cooper, and Stevens (2012). This work stressed that examining the effects of social interaction on learning could benefit metacognition and problem solving. These researches used qualitative analysis to investigate the enhancement of metacognition in contexts that are already well-developed in terms of social skills such as reflective discussion, verbalization, thinking aloud, group planning, monitoring and evaluating.

These premises clarify the importance of creating an educational context that encourages social interaction in learning. This has a role in motivating the establishment of metacognition, as the absence of this social interaction would impede this type of learning. This was set out in the findings and was consistent with the conclusions of Larkin (2006). Her study underlined the fact that metacognition is susceptible to change though social persuasion, explaining that just as metacognition is adaptable it can also be the opposite. Larkin (2006, p. 25) went on to state the following: Unless students are given the opportunities to interact with others at a substantive cognitive level it may be difficult for them to practice or elaborate on metacognitive strategies or to gain feedback about their own cognitive processing.

Conclusion

The study's findings clarified the importance of creating an educational context that encourages social interaction in learning. It would also be challenging to create metacognitive learning if a student does not play an active role in the search for information and merely receives it in a ready form. This has a role in motivating the establishment of metacognition, as the absence of this social interaction would impede this type of learning.

Disclosure statement

No potential conflict of interest was reported by the author/s.

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