Partial Metacognitive Blindness in Collaborative Problem Solving

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This paper investigates the impact of group dynamics on metacognitive behaviours of students (aged 13-14) during group collaborative problem solving attempts involving a design-based real-world applications project. It was discovered that group dynamics mediated the impact of metacognitive judgments related red flag situations and metacognitive failures. The existence of partial metacognitive blindness was also discovered and two contrasting phenomena could result from this because of differing group dynamics.

There has always been sustained interest in investigating factors influencing problem solving success (e.g., Ang, 2009; Chan & Mansoor, 2007; Garofalo & Lester, 1985; Schoenfeld, 1985; Scott, 1994; Stillman, 2004). Researchers have also been looking into group collaborative processes which facilitate and impede problem solving success (e.g., Artzt & Armour-Thomas, 1990, 1992; Goos, 1997, 2002; Lioe, Ho, & Hedberg, 2005). This paper discusses the role of metacognition in group problem solving during a design-based mathematical applications project based on a larger study conducted with lower secondary students (aged 13-14) at three Singapore government schools. In particular, the impact of group dynamics on *metacognitive blindness*, a concept developed by Goos' (1997, 2002), which affects the quality of mathematical outcomes during collaborative problem solving will be examined. For a more in-depth understanding of partial metacognitive blindness, a brief review of pertinent literature is presented here.

This study adopts Flavell's (1976) definition of metacognition which highlights two inter-related components, metacognitive knowledge and metacognitive regulation:

> Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them…Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective. (p. 232)

Metacognitive knowledge is about *awareness* of how factors (i.e., person, task, and strategy) act and interact to influence the outcome of a thinking process (Flavell, 1981) such as decision making. Metacognitive regulation is concerned with the use of *control* processes (e.g., monitoring, selection, and management) for instance during a problem solving experience. In real-life, it is a challenge documenting the use of metacognitive knowledge and regulation processes, particularly in the midst of small group interactions influenced by group dynamics. Hence, this study has attempted to identify only *overt behaviours* which could be indicative of intra- or inter-personal metacognitive monitoring and regulation. Although metacognitive monitoring behaviours may at times lead to subsequent regulatory actions, it may often be the case that one is observed without the other.

However, as much as the presence of metacognitive behaviours is crucial for favourable problem solving outcomes (Schoenfeld, 1985), researchers have found that the quality of the nature of metacognitive interactions (Stillman & Galbraith, 1998) is just as important. Goos (1997, 2002) identified three *red flag* situations in her study of group collaborative problem solving process: (a) lack of progress, (b) error detection, and

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(c) anomalous or strange results. According to Goos, red flag situations are distinguished from routine monitoring behaviours (e.g., assessment of knowledge, approach, outcomes) which served to confirm that the problem solving process is on the right track. Metacognitive red flags can occur at critical junctures where the problem solvers are faced with important decision making pertaining to the success or failure of their attempts. Thus, purposeful, conscious, and at times drastic actions (e.g., pausing for reflection, backtracking, re-doing the problem in another way) may be warranted to change problem solving pathways.

Nonetheless, subsequent metacognitive regulatory behaviours (or the lack of them) in reaction to red flag situations also play a large role in savaging or sabotaging the problem solving situation. Goos (2002) identified three types of *metacognitive failures* displayed by problem solvers in reaction to red flags. These are described by the metaphors of "blindness", "vandalism", and "mirage". Metacognitive blindness occurs when a problem solver did not notice his or her likelihood of impending failure in solving the problem, opting for instance to continue with an inappropriate approach. Metacognitive vandalism comes into play when problem solvers decide to take destructive action to deal with a deadlock situation (e.g., changing the conditions of the problem so as to suit the fixed mindset of the problem solver). Metacognitive mirage takes place when problem solvers mistakenly change course of actions upon perception of difficulties which in fact do not exist.

Metacognitive judgements for appropriate regulatory behaviours as well as metacognitive failures in reaction to red flag situations are recognised by this researcher to be crucial to the success of group collaborative problem solving. These are often mediated by existing group dynamics. Given the focus on metacognition in the Singaporean mathematics curriculum framework (Curriculum Planning and Development Division, 2006), there are still limited studies to date within the Singaporean context investigating the impact of group dynamics on metacognitive failures, specifically, that of metacognitive blindness. This impact in turn will have a bearing on the quality of mathematical outcomes during collaborative problem solving. In one such study on primary school students (aged 12), Chan and Mansoor (2007) discovered that inter-personal regulation of thinking during collaborative problem solving raised the level of metacognitive thinking such that group members are more impervious to metacognitive failures. However, there was no analysis of the nature of red flag situations and likely metacognitive failures from their sample. Very little was mentioned about the nature of group dynamics and how this has affected the groups' metacognitive judgements, and hence the quality of their mathematical products from their problem solving attempts.

Research Questions

Findings to the following two research questions will be presented in this paper:

- How is metacognitive blindness manifested during collaborative problem solving in a design-based applications project?
- In what ways do group dynamics impact on metacognitive blindness during collaborative problem solving?

Research Design

Research Task

A design-based applications project primarily involving mathematics, science, and geography was implemented in 16 classes of students (n = 617) from grades 7 and 8 (aged 13-14) in two educational streams (high and average) across three Singapore government secondary schools. The project followed the theme of environmental conservation and was completed through 15 weekly meeting sessions. Students worked in groups of four to design an environmentally friendly building at a location of their choice within Singapore (Figure 1). Each group was given some project-related tasks (e.g., research on available land space) during the meeting sessions to help them work towards their building design. Supporting materials developed by the researcher according to the guidelines set by Singapore Ministry of Education were used for some of these sessions. In particular, two student-group case studies (Groups 1 and 2) based on their selected participation in two mathematical tasks with written components will be reported in this paper: (a) cost of furnishing and fitting out a selected area in the building (i.e., flooring, painting, appliances, and furniture) and (b) hand-drawn scale drawings of the actual building. Towards the end of the project, student-groups constructed physical scale models of their buildings from recycled materials based on their drawings.

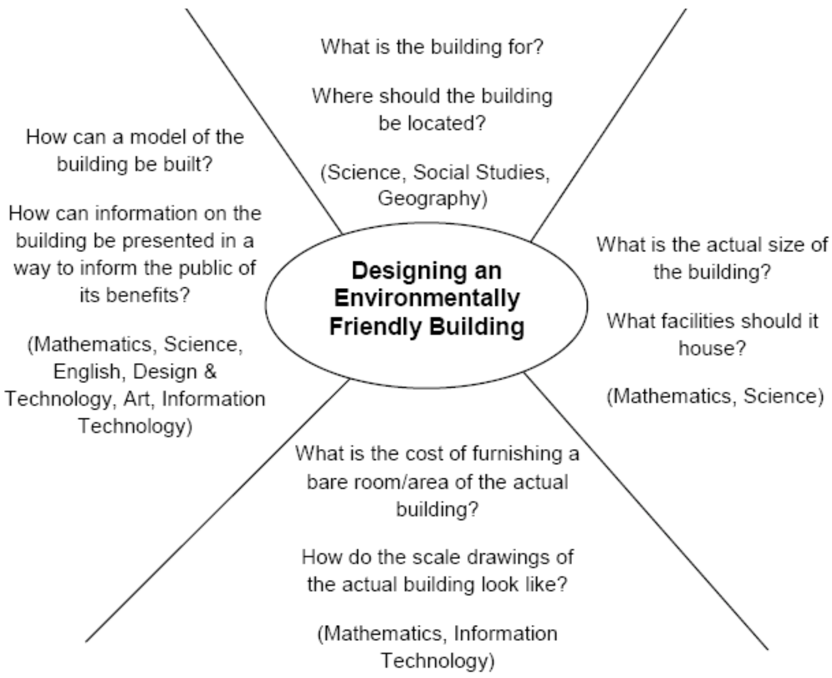

Figure 1. Framework of researcher-designed project.

Setting and Sample

Student participation during the study was facilitated using the project-based approach (Quek, Divaharan, Liu, Peer, Williams, & Wong, 2006). There were no special instructions for teaching intervention. Participating classes had at least one teacher with mathematics, science, geography, and design and technology specialisation facilitating each meeting session. The teachers used their usual facilitation methods and they could reorganise the sequence of the proposed materials and adapt the provided resources, except for the stated tasks (a) and (b) above.

The researcher tracked the progress of ten case-study groups (n = 38, two students excluded due to technical difficulties) throughout the project in their weekly discussion sessions during curriculum time. These included five groups in each stream with the maximum of one group from a class. Students formed their own groups and each group consisted of students with mixed-ability in mathematics.

Data Collection Methods

A multi-site multi-case-based approach (Yin, 2009) was adopted in data collection and analysis. Documentary (i.e., copies of students' work, field notes), audio-visual (i.e., video-generated data), and verbal evidence (i.e., interview-generated data) were collected.

Each of the ten groups was videotaped during their in-class discussions on (a) and (b) above. Individual group members also participated in video-stimulated recall interviews within one week of their discussions. In addition, written work from the groups (i.e., notes, research materials, resources, drafts, drawings, and task sheets), project files, and final products of the project were collected for analysis along with their teachers' comments and grades. The researcher took lesson observation notes focusing on given instructions and the nature of teacher scaffolding as well.

Analysis Procedures

Audio-visual evidence was the main source of data for analysis for the purposes of this paper. Documentary and verbal evidences were used to triangulate findings. Student-group interactions on the tasks (a) and (b) above were coded using a cognitive-metacognitive analysis framework adapted from Schoenfeld (1985), Goos (2002), and Artzt and Armour-Thomas (1992). However, only the results derived from coding of various red flag situations (i.e., lack of progress, error detection, strange results) and instances of metacognitive failures (i.e., blindness, vandalism, mirage) will be reported here.

Findings

In an extension of Goos' research (1997, 2002), it was discovered in this study that *partial metacognitive blindness* exists in group collaborative problem solving process. Partial metacognitive blindness occurs when a red flag situation was detected and possibly surfaced by at least one member of the group (i.e., red flag alert raised) while others were blind to it. This is compared with *total metacognitive blindness* where a red flag situation was completely missed by all group members.

Interestingly, both positive and negative problem solving outcomes could arise from the effects of partial metacognitive blindness. A desirable mathematical outcome may occur when appropriate and immediate regulatory actions were adopted by group members who detected a red flag situation even though others were blind to it. On the other hand, metacognitive vandalism, where inappropriate regulatory actions were manifested by any group member against the expectations of others within the group, could drastically alter the course of action towards problem solving failure or nonsensical solutions.

Partial Metacognitive Blindness, Productive Group Dynamics, and Improved Mathematical Outcomes

Table 1 details the occurrences of partial metacognitive blindness in Group 1. For this group, desirable mathematical outcomes resulted due to timely and appropriate regulatory actions by members of the group in reaction to partial metacognitive blindness of one member. {} brackets represent translated verbal interactions in Standard English. [] brackets record gestures or physical actions undertaken by group members.

Table 1
Excerpt from Group 1 Detailing Partial Metacognitive Blindness During Scale Drawing Task

Speaker	Line	Contents
Sani:	1	1 is to 1 your scale? 1 is to 1 is to 5?
	2 3	{So what do you mean? Is the scale you forgot 1 cm representing 1 metre or 1 cm representing 5 metres?}
Choon:	4 5 6	[Checking possibility of a guess, also beginning to ask a series of questions in an attempt to detect possible mistakes in logic.] Then square metre….how many square metre? {What is the area of the building in square metres then?}
Fanny:	7	[Guessing, cannot remember] 1 is to….err…
Choon:	8 9	You mean {the} model…{Do you mean the scale for the physical scale model for our building? But this doesn't make sense.}
Fanny:	10	[Guessing again.] 1 cubic metre… ***(Red Flag – Error in Mathematical Concept)***
Choon:	11	[Mistake detected.] You mean 1 cm^3 equals to 5 square metre?***(Red Flag Alert)***
Fanny:	12 13 14 15	[Referring to a guessed scale for the actual building that they have decided to make their drawings based on. Fanny was confused with the units of area and volume used.] Why not? Why 1 cm^3 cannot be {cannot represent} 5 square metres? ***(Metacognitive Blindness)***
Choon:	16	[Questioning Fanny about her mathematics understanding]
	17	5 square metres? 5 square metres? {Are you sure 1 cm^3 equals 5 m^2?} ***(Red Flag Alert)***
Fanny:	18	{Do you mean} 5 {m} by 5 {m} by 5 {m}?***(Metacognitive Blindness)***
Choon:	19	5 square metre{s} is not 5 {m} by 5 {m} by 5 {m}… ***(Regulatory Action – Correcting Misconception to Change Approach in Scale)***
Kit:	20	[Agreeing with Choon.] {5 square metres is} 5 {m} by 5 {m}!

Group 1 was in the middle of discussing the appropriateness of the scales chosen to make their scale drawings of the building. Choon, the dominant group member who was also the leader of the group, "interrogated" Fanny intensively (lines 11 and 17) and provided red flag alerts to help her realise her confusion between area and volume (lines 10, 14, and 18). The group members were trying to remember the scale they had decided upon earlier for the drawings representing their environmentally friendly shopping centre. Fanny, the recorder for the group, did not bring her notes from an earlier discussion. Sani and Choon were prompting her to remember what she had recorded. Instead, Fanny made guesses about the chosen scale revealing her metacognitive blindness and confusion about the mathematical concepts of area and volume.

Table 2

Excerpt from Group 2 during cost of furnishing task

Speaker	Line	Contents
Ken:	1 2	[In Mandarin.] The most we budget our toilet furnishings as one million dollars!
Alan:	3	Hey…{$} 5000…5000…
Ken:	4	No…not enough…
Alan:	5	{$}5000 enough already…
Ethan:	6	{$}10,000! {$}10,000! ***(Red Flag – Error in Logic)***
Alan:	7 8	[To Ethan, exclaiming in horror.] The bathroom $10,000! {$}5000, that's already too much for furnishing the bathroom! ***(Red Flag Alert)***
Ken:	9 10	Here put in one more zero can already [Adds in one more zero to the original budget of $1000 on the worksheet, making it $10,000.] ***(Metacognitive Blindness, Metacognitive Vandalism)***
Alan:	11 12	[To Ethan, in Mandarin.] This is only a bathtub, are you sure it cost{s} so much to furnish it?! We only use a little of it everyday! ***(Red Flag Alert)***
Ken:	13	[Shouting at Alan, irritated.] Shut up! [Decided on the cost of bathtub on behalf of the group.] ***(Metacognitive Blindness)***
Alan:	14 15	[To Ken.] I give opinion…you ask me to shut up… so I shut up loh! [Angry at Ken's outburst towards him, decides to keep quiet for the rest of the time]
Ethan:	16	[Pointing to Alan and Ken.] You two shut up!
Ken:	17	[To Ethan and Alan.] How long you want? {What are the dimensions of the toilet?}
Alan:	18	[Refused to answer Ken.]
Rean:	19	[Looks on, keeping quiet.] ***(Red Flag Situation Ignored Deliberately)***
Ken:	20	[Mumbling to himself, calculating the area of the toilet floor.] 30 time{s} 30 is 900 {m^2} ***(Metacognitive Blindness)***
Ethan & Alan:	21	[Look away, staring outside the classroom.]
Ken:	22	[Continues to mumble to himself.] One thousand…
Ken:	23 24 25	[To Ethan and Alan, commenting on the total cost of furnishing after calculations.] Wow! This is already over our budget! ***(Red Flag – Anomalous Result) (Red Flag Alert)***
Ethan & Alan:	26	[No comments.]
Ethan:	27 28	[In Mandarin.] Add in one more "zero" and make it $100,000 as the furnishing budget… ***(Metacognitive Blindness, Metacognitive Vandalism)***
Alan:	29 30	[In Mandarin.] Skip the bathtub! {Do not include the bathtub in the toilet!}…this is a toilet. ***(Red Flag Alert)***
Ken:	31	Okay…add in two "zeros"… {He changes the budget to $1,000,000.} ***(Metacognitive Blindness, Metacognitive Vandalism)***
Alan:	32 33 34	This is a toilet…your school toilet don't have bathtub! {I am reminding you that we are actually estimating the cost of furnishing a toilet at our school and so the budget for furnishing costs need not be so high.] ***(Red Flag Alert)***
Ken:	35 36	[Shouting, for the sake of winning the argument for having $1,000,000 as the budget.] Hey…toilet in the hotel lah! ***(Metacognitive Blindness)***
Alan:	37	[Disagrees with CB, shaking his head.] What hotel?!

It was apparent from the excerpt in Table 1 that Choon had large social influence with the group. Choon directed questions (lines 8, 11, and 17) towards Fanny in an authoritative tone and consequently tried to present her with the correct mathematical concept (line 19). Here, Choon's timely and appropriate monitoring and regulatory actions respected by others managed to redirect the subsequent flow of cognitive-metacognitive interactions towards a more accurate scale representation, thereby altering the work outcome positively.

Partial Metacognitive Blindness, Counter-Productive Group Dynamics and Negative Mathematical Outcomes

In contrast, Table 2 shows an excerpt from Group 2, outlining how metacognitive vandalism occurred after partial metacognitive blindness, negatively affecting the quality of mathematical outcome from the problem solving process.

The group was trying to come to a consensus about the budget they would set aside for furnishing a toilet in their environmentally friendly school. Alan and Ethan reviewed the feasibility of Ken's ideas and raised red flag alerts (lines 6, 7 to 8, 11 to 12) at appropriate junctures. However, Ken, a loud dominant member of the group, exhibited an inappropriate regulatory behaviour when he rudely terminated the exploration approach in order to halt his peers' critique of his ideas (line 13). This resulted in others being unwilling to contribute further to the discussion (lines 18 to 19, 21, 26). With no one in the group allowed to check his work, Ken continued to exhibit metacognitive blindness towards red flag situations of error in logic (line 20) until he himself raised a red flag pertaining to anomalous result (line 25). However, the existing group dynamics was so counter-productive that Ken still persisted in being metacognitively blind to his unrealistic estimations of the budget (lines 31 to 36), spurred on by the erroneous misconceptions of Ethan (lines 27 to 28).

In this group Ken controlled the flow of interactions through his choice of whether to give due recognition to the red flag alerts of others and corresponding regulatory actions. Ken's choice was affected by his attitude towards the other group members and his desired quality of work to be produced. Either way, there was a large impact brought upon the group's interactions, resulting in poor work quality.

Discussion and Conclusion

It was discovered that group dynamics mediated the impact of metacognitive judgments related red flag situations and metacognitive failures. In an extension of Goos' study (1997, 2002), this author recorded the existence of partial metacognitive blindness during group collaborative problem solving. Partial metacognitive blindness when mediated by productive group dynamics can lead to an improvement in mathematical outcomes of the problem solving process (see Table 1). On the other hand, partial metacognitive blindness when mediated by counter-productive group dynamics may well result in less-than-desirable mathematical outcomes and could be detrimental to the subsequent problem solving attempts by the same group (see Table 2).

In addition, it was also discovered that dominant members in the group played a large role in controlling group dynamics. When red flag alerts were raised, these dominant members very often served as "gate-keepers", making conscious choices to either allow for metacognitive blindness to continue or stepping in to divert the flow of interactions towards positive results. Hence, intervention programmes targeted at elevating the mathematical outcomes of group collaborative problem solving within the context of the Singaporean school system may well begin with cultivating good social behaviours during group work such that fruitful mathematical discussions can arise when group members are respected for their views.

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