Social Interaction and Ability Grouping: Their Effects on Students' Metacognitive Experiences in Stoichiometric Problem Solving

FITZGERALD L. FABELICO, Ph.D.
College of Teacher Education, Nueva Vizcaya State University, Bambang, Nueva Vizcaya, Philippines
fitzgeraldfabelico@yahoo.com

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Abstract *- This study investigates the effects of social interaction and ability grouping on students' metacognitive experiences in stoichiometric problem solving. The social and educational dimensions of social interactions are particularly investigated in this paper. The educational dimension of social interaction includes ability grouping while the social dimension comprises metacognitive functions and transactive structures. Metacognitive functions include the generation of New Idea and the Assessments of strategy, results, and understanding. Transactive structures involve self-disclosure, feedback request, and other monitoring responses. Students' metacognitive experiences include feelings of liking, difficulty, confidence, satisfaction, and estimates of time, effort, and solution correctness. This descriptive study employed both the quantitative and qualitative methods.*

The results showed that students' metacognitive functions and transactive structures vary across ability groups. Moreover, metacognitive functions and transactive structures showed a weak degree of association with ability grouping. Students' metacognitive experiences like feelings of liking, difficulty, confidence, satisfaction, and estimates of time, effort, and solution correctness vary across ability groups. Although metacognitive functions and transactive structures affect quantitatively students' metacognitive experiences in solving stoichiometry problems, the effect does not vary across ability groups. However, it is important to note that other monitoring transactive structure influences students' feeling of difficulty and estimate of effort in solving chemistry tasks across ability groups.

Keywords: *social interaction, ability grouping, metacognitive experiences, chemistry problem solving*

I. INTRODUCTION

Many educators and researchers claim that students encounter difficulties in chemistry problem solving. Of all the chemistry concepts cited in the literature, stoichiometry has long been a problem for both secondary and college students (Arasasingham, Taagepera, Potter & Lonjers, 2004; Fach, de Boer & Parchmann, 2007). Moreover, *stoichiometric problem solving* requires sound conceptual understanding of the particulate nature of matter, mole concept, chemical equations, types of chemical reactions, limiting reagents, algebraic skills, and proportional reasoning ability (BouJoude & Barakat, 2003; Sanger, 2005; Wood & Breyfogle, 2006).

Another factor that is related to chemistry problem solving is *metacognition*. It is defined as cognition of one's cognition (Flavel, 1979). These are higher order mental processes that are involved in learning that subsumes metacomprehension, self-monitoring, metacognitive monitoring, and self-directed learning (Coutinho, Hastings, Skowronski & Britt, 2005). Flavel (1979) identified the two functions of metacognition, namely the monitoring and the regulatory functions. The *monitoring function* refers to what one knows about cognition while the *regulatory function* involves the use of this knowledge for the control of cognition (Efklides, 2001). While the regulatory functions includes metacognitive knowledge and metacognitive experiences, the control functions have the metacognitive skills or the use of strategies as their manifestations (Efklides, 2006).

Metacognitive knowledge is a declarative knowledge regarding one's and other's knowledge, beliefs, and experiences (Efklides, 2001, 2006) that is retrieve from long-term memory (Flavel, 1979). *Metacognitive experience* also called as concurrent metacognition *(*Hertzog & Dixon, 1994), online metacognition (Efklides, Samara & Petropolou, 1999), subjective cognitive, or affective experiences (Efklides 2001, 2006) that are short-lived (Efklides & Tsiora, 2002) and present in short-term memory (Efklides, 2006). Metacognitive experiences include feelings of liking, difficulty, confidence, satisfaction, and estimates of time, effort, and solution correctness (Efklides, 2006).

Several studies underscored that *social interactions* are essential element in developing students' metacognitive strategies in problem solving activities (Goos & Galbraith, 1996; Goos, Galbraith, & Renshaw, 2002; Frith, 2012). The complex nature of social interaction includes the educational and social dimensions (Kreijns, Kirschner & Jochems, 2002). The *educational dimension* focuses on group learning, tasks contexts, or learning performance. The *social dimensions* deal with social processes, non-tasks contexts, or social performance (Kreijns, Kirschner, & Jochems, 2002).

Social interaction provides opportunities to students to become aware and conscious of their own and their colearners' metacognitive strategies and metacognitive decisions during problem solving. The manner by which students maintain social contact and maximum participation during group tasks is dependent on the stability of their social interaction with others. Consequently, during social interactions, the *grouping of students* also plays an important role in the learning process. Several studies stressed the effects of social interactions and grouping of students in solving chemistry tasks (Bilgin, 2006; Krystyniak & Heikkinen, 2007).

Because metacognitive experiences are relevant to coregulation of learning (Salonen, Vauras & Efklides, 2005) and are found to trigger socially shared metacognition (Iiskala, Vauras, Lehtinen & Salonen, 2011) during social interactions, this study aimed to shed more light to understand the nature of students' metacognitive experiences in solving stoichiometry problems as influenced by social interaction and ability grouping.

II. OBJECTIVES OF THE STUDY

The main objective of the study is to investigate the effects of social interaction and ability grouping on students' metacognitive experiences in stoichiometric problem solving. Specifically, the study aimed to determine the significant differences of metacognitive functions, transactive structures, and metacognitive experiences exhibited by the students and the correlation of these variables to ability grouping; to determine the effect of metacognitive function on students' metacognitive experiences across ability groups; and to determine the effect of transactive structures on students' metacognitive experiences across ability groups.

III. METHOD

Research Design

This study employed the descriptive design using both the quantitative and qualitative methods of research. In this research design, the different groups of students were allowed to solve their group stoichiometry tasks (GSTs) to elicit students' metacognitive function (acts) and transactive structures (transacts) during social interactions.

Participants

The participants were the freshmen BS-Nursing students of a private sectarian university at Bayombong, Nueva Vizcaya. The participants were grouped based on the results of their College Aptitude Admission Test as low, average, or high ability students. The 18 participants were grouped homogeneously into six groups comprising of three members per group. The six groups had gender-balanced members.

Instruments

The retrospective *Metacognitive Experience Questionnaires (MEQ)* was adopted from Efklides (2002) to document students' metacognitive experiences after solving their group stoichiometry tasks. The *Group Stoichiometry Tasks (GST)* includes the algorithmic and conceptual stoichiometry problems in chemistry. These GSTs were adopted from Chiu (2001), and from Wood and Breyfogle (2006). The topics for the GSTs include the mole ratio and limiting reagents. The *Group Thinking Journal (GTJ)* was also used to document group performance during social interaction and serves as reflection journal for the activity. The *Researcher's Observation Journal (ROJ)* included observations, field notes, and anecdotal records of the students during social interaction.

Procedure

Before the activity, the participants were trained on how to write their answers and responses in their GTJ. The researcher also gave a brief lecture to the participants before each activity. The lecture was mainly informational and no processing was done. The GSTs were given to the participants with one topic per session. The algorithmic and the conceptual GSTs were given during the sessions, respectively. The students were given a maximum of one hour to complete the tasks. All of the activities were audio and video recorded to document all verbal and non-verbal cues during the social interactions. After the students are done with their GSTs and GTJ, the students were requested to answer individually the retrospective MEQ.

Data Coding and Discourse Analyses

The transcription of students' utterances was adopted with modification from Goos, Galbraith and Renshaw (2002). The frequencies of the observed social dimensions of social interaction were recorded and analyzed using both quantitative and qualitative methods.

Metacognitive function refers to the metacognitive acts or the number of student utterances during group discussions. To facilitate the transcription and coding process, these categories of metacognitive functions were described based on the definition provided by Goos, Galbraith and Renshaw (2002). *New Idea* occurs when potentially useful information come to light or an alternative approach is suggested or uttered by one of the group members. The *Assessment* category included the following: *Assessment of strategy* involves the execution or appropriateness of strategy; *Assessment of result* refers to the accuracy or a sense of a result; and the *Assessment of understanding* which pertains to one's knowledge or understanding of the chemistry concepts or tasks.

Transactive structure refers to the transactive behaviors, statements, or utterances made by a student during social interaction. The categories of transactive structures were adopted from Goos, Galbraith and Renshaw (2002). This includes self-disclosure, feedback request, and other-monitoringt. *Self-disclosure* are self-oriented statements characterized by clarification, elaboration, evaluation, or justification of one's own thinking. *Feedback Requests* are self-oriented questions that invite group mates to critic one's own thinking. *Other monitoring* are other-oriented statements, questions and responses that represent an attempt to understand group mates' thinking.

All the utterances and dialogues of the participants were transcribed and had undergone a dual coding process. The transcripts of students' metacognitive function and transactive structures were categorized by the researcher and were validated by experts in the fields of psychology and education.

IV. RESULTS AND DISCUSSION

Metacognitive Functions and Ability Grouping

Table 1 shows the means and standard deviations of students' metacognitive functions across ability groups. The overall mean showed that the students across ability groups had manifested mostly assessment of strategies, followed by the assessment of understanding, assessment of results, and generation of new ideas, respectively.

Table 1. Means and standard deviations of students' metacognitive functions across ability groups

Grouping	**Metacognitive Functions**			
	New Idea	Assessment of Strategy	Assessment of Result	Assessment of Understanding
High Ability	**6.83**	**16.2**	**12.7**	**16.2**
	(4.36)	(10.5)	(6.5)	(9.68)
Average Ability	**4.67**	**22.3**	**18.0**	**23.3**
	(3.45)	(18.9)	(9.06)	(20.2)
Low Ability	**5.00**	**31.8**	**19.5**	**16.0**
	(4.56)	(16.6)	(9.27)	(5.73)
Overall	**5.50**	**23.4**	**16.7**	**18.5**
	(4.02)	(16.2)	(8.41)	(13.0)

Note: The means are written in bold numbers while the standard deviations are enclosed in parentheses.

Using Chi-square test for independent samples, the results indicate that across ability groups, the students had highly significant differences in their metacognitive functions as shown in Table 2.

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Table 2. Comparison of students' metacognitive functions across ability

Compared Group	χ^2	*df*	*p - value*
Across Ability Groups	33.154	6	.000*
High Ability vs. Average Ability	8.306	3	.040
High Ability vs. Low Ability	21.375	3	.000*
Average Ability vs. Low Ability	17.961	3	.000*

** Significant at α =.001*

The high ability groups had generated more new ideas than the average ability and low ability groups. The average ability groups had manifested more assessment of their understanding than the high ability and low ability groups. Conversely, the low ability groups had exhibited more assessment of their strategies and results than their high ability and average ability groups counterparts. This implies that the students in their respective ability groups are engaged in shared metacognitive regulation. They involved executive processes in their social action like planning, identifying the problem demands, revising problem-solving strategies, monitoring on-going activity, evaluating and criticizing the learning material, reality testing, predicting the consequences, and checking outcomes (Brown, 1987; Efklides, 2006).

Although there are significant differences in the metacognitive functions of the different ability groups, Cramér's *V* revealed that there is a weak degree of association between ability grouping and metacognitive functions (V = .120, p < .001) and there is only 7.6 % reduction in error in predicting the value of ability grouping based from the value of students' metacognitive functions (λ = 0.76, p < .01). This indicates that metacognitive function could not be used to identify the ability of a group. This also suggests that in social interaction, social regulation cannot be reduced to the group member's individual characteristics such as self-regulatory activities; rather inter-rational characteristics and functioning are needed in order to understand group dynamics as a complex situational interplay across different systemic levels (Volet, Vauras, & Salonen, 2009).

Transactive Structure and Ability Grouping

As reflected in the overall mean in Table 3, the results revealed that across ability groups, the participants had expressed more self-disclosed transactive responses followed by other monitoring and feedback requests transactive structures, respectively. The results also showed that all of the transactive structures are dispersed across ability groups as reflected by the standard deviations.

Table 3. Means and standard deviations of students' transactive structure across ability groups

Grouping	Transactive Structures		
	Self Disclosure	Feedback Request	Other Monitoring
High Ability	**33.5** (19.9)	**17.8** (15.9)	**24.3** (14.8)
Average Ability	**44.3** (32.4)	**23.2** (19.4)	**23.7** (11.7)
Low Ability	**32.7** (11.7)	**21.2** (8.13)	**39.5** (22.4)
Overall	**37.5** (22.2)	**20.7** (14.5)	**29.2** (17.6)

Note: The means are written in bold numbers while the standard deviations are enclosed in parentheses.

Table 4 shows that the students' transactive structures are highly significant across ability groups.

Table 4. Comparison of students' transactive structures across ability groups

Compared Group	χ^2	*df*	*p - value*
Across Ability Groups	37.238	4	.000*
High Ability vs. Average Ability	3.629	2	.163
High Ability vs. Low Ability	15.556	2	.000*
Average Ability vs. Low Ability	34.812	2	.000*

** Significant at α =.001*

Pairwise comparison of the different groups revealed that the high ability and average ability groups had the same transactive responses during their social interactions. Moreover, the high ability groups expressed more self-disclosed transactive responses than the low ability groups. Similarly, the average ability groups had uttered more self-disclosed responses and feedback requests than the low ability groups. This result implies that the participants expressed more self-disclosed transactive responses to verbalize their own thinking and conceptions of the tasks either by clarification, elaboration, or justification of their own thoughts. Givry and Roth (2006) stressed that conception are publicly displayed forms of meaning-making talk by a speaker rather than a mental content. Through social interaction, the participants are stimulated to elaborate and explain their own conceptual knowledge (Van Boxtel, Linden & Kanselaar, 2000) and that through self-disclosure, the participants were able to express their internal conceptions to the outside world. Previous researches showed that self-explanations (self-disclosure) are significant predictor of learning gains (Renkl, 1997) and are potentially powerful technique for acquiring knowledge (Wong, Lawson & Keeves, 2002) that lead to the modification of already available prior-knowledge for the construction of new knowledge (Ploetzner, Dillenbourg, Preier & Traum, 1999). Through self-disclosure, the high ability and average ability groups had more varied conceptual knowledge to share to their colearners as compared to low ability groups. In addition to this, the results also suggest that the high ability and average ability groups involved explicit metacognitive processes during their social interactions. Explicit metacognition, according to Frith (2012), enables the students to reflect on and justify their behavior to others, to share their experiences of action and sensation with others. Sharing experiences also enables the students to develop more accurate explicit models of the world even without objective feedback and as a result, the students can alter their understanding and experiences of how to make decisions (Frith, 2012).

The results also exposed that low ability groups had expressed more other monitoring transactive responses and feedback requests in their social interactions than the average ability and high ability groups, respectively. This implies that the regulation of colearners is easier than self-regulation and that the horizontal division of labor reduces the cognitive load imposed on the individual learner during problem solving (Dillenbourg, 1999). Likewise, the low ability groups were involved in implicit metacognitive processes and in mentalizing activities (Frith, 2012). Implicit metacognition enables the students to adopt a “we-mode”, through which they automatically take account of the knowledge and intentions of others. Additionally, *mentalizing* is the ability to take account of the mental states of others and use this information to predict behavior (Frith, 2012).

The results on the correlation of students’ transactive structures and ability showed that there is a weak degree of association that exists between ability grouping and students’ transactive structures ($V = .109$, $p < .001$) and that only 4.6 % is reduced when one predicts the values of transactive structures based from value of ability grouping ($\lambda = .046$, $p < .05$). This suggests that transactive structures could not be used to identify the ability of a certain group. This further suggests that social interaction entails a complex process of social regulation that involves self-disclosure, feedback requests, and other monitoring transactive events.

Metacognitive Experiences Across Ability Grouping

The means and standard deviations of students’ metacognitive experiences across ability groups are presented in Table 5. The overall mean showed that the students across ability groups experienced high feelings of liking, difficulty, confidence, satisfaction, and high estimates of effort, time, and solution correctness in solving their group stoichiometry tasks.

Table 5. Means and standard deviations of students’ metacognitive experiences across ability groups

Grouping	Metacognitive Experiences						
	Feeling of Liking	Feeling of Difficulty	Estimate of Effort	Estimate of Time	Estimate of Solution Correctness	Feeling of Confidence	Feeling of Satisfaction
High Ability	**3.08**	**2.67**	**2.91**	**2.64**	**2.68**	**2.81**	**2.85**
	(.342)	(.258)	(.476)	(.495)	(.438)	(.394)	(.430)
Average Ability	**2.79**	**2.71**	**3.18**	**3.18**	**2.77**	**2.79**	**3.08**
	(.102)	(.431)	(.772)	(.311)	(.311)	(.246)	(.393)
Low Ability	**3.12**	**2.87**	**3.39**	**3.23**	**2.83**	**2.77**	**2.89**
	(.328)	(.527)	(.375)	(.514)	(.204)	(.383)	(.332)
Overall	**3.00**	**2.75**	**3.16**	**3.02**	**2.76**	**2.79**	**2.94**
	(.303)	(.405)	(.570)	(.503)	(.318)	(.327)	(.378)

Note: Very Low (1.00 – 1.50), Low (1.51 – 2.50), High (2.51 – 3.50), Very High (3.51 – 4.00).
The means are written in bold numbers while the standard deviations are enclosed in parentheses.

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As shown in Table 6, Kruskal-Wallis test revealed that students' metacognitive experiences do not differ significantly across ability groups.

Table 6. Significant differences in the metacognitive experiences of students across ability

Metacognitive Experiences	χ^2	*df*	*p - value*
Feeling of Liking	4.284	2	.117
Feeling of Difficulty	1.005	2	.605
Estimate of Effort	3.326	2	.190
Estimate of Time	4.789	2	.091
Estimate of Solution Correctness	1.098	2	.578
Feeling of Confidence	.087	2	.957
Feeling of Satisfaction	1.346	2	.510

During social interactions, the participants across ability groups had experienced high feelings of liking, difficulty, confidence, satisfaction, and estimates of effort, time, and solution correctness in their group stoichiometry tasks. This indicates that although the participants across ability groups experienced high metacognitive feelings and metacognitive estimates in stoichiometric problem solving, they still had positive outlook for their chemistry tasks. Peer collaboration among the participants allows them to apply scaffolding techniques during problem solving. During the process of scaffolding, the students are aware of their colearners' metacognitive experiences. Efklides (2006) underscored that metacognitive experiences are products of monitoring of the person's cognition and have an effect on the control of both the person's and other's cognition. Furthermore, Salonen, Vauras and Efklides (2005) posited that awareness of colearners' cognition and metacognitive experiences affects scaffolding match and successful coregulation in learning. Consequently, the participants across ability groups were more sensitive and responsive to the metacognitive experiences of their colearners. Peers' cognitive and metacognitive support or scaffolding can alleviate students' feeling of difficulty during problem solving (Efklides, 2006). Furthermore, the results also imply that when the participants share their experiences with others, subjective experiences (metacognitive experience) are forming reliable beliefs about the world and that sharing of experiences depends on explicit metacognition (Frith, 2012). Because each member of the group were engaged in explicit metacognition, the participants across ability groups experienced high feelings of liking, confidence, satisfaction, and high estimates of solution correctness during stoichiometric problem solving.

Metacognitive Functions and Metacognitive Experiences

It is noteworthy that across ability groups, the metacognitive functions of the participants are correlated with their metacognitive experiences. New idea is moderately correlated with estimate of effort ($G = -.358$, $p < .01$) and estimate of time ($G = -.423$, $p < .01$). Assessment of strategy is moderately correlated with the feeling of difficulty ($G = .500$, $p < .01$). These denote that when the participants manifest more metacognitive acts on the construction of new ideas, the participants could have experienced lower estimates of effort and lower estimates of time in problem solving. This also implies that the students were engaged in socially mediated construction of new idea and conceptions. Moreover, when the participants exhibit more metacognitive acts on the assessment of strategy, the participants could have experienced lower feelings of difficulty in solving their group stoichiometric tasks. Thus, students' feeling of difficulty is reduced when students are mutually engaged in socially shared metacognition through the assessment of their strategies during problem solving activities.

Transactive Structure and Metacognitive Experiences

Finally, across ability groups, other monitoring transactive structures were found to be moderately correlated with the students' feeling of difficulty ($G = .308$, $p < .05$) and with estimate of effort ($G = -.309$, $p < .05$). These indicate that when the participants manifest other monitoring transactive responses or implicit metacognition during social interactions, then the participants experience lower feelings of difficulty and lower estimate of effort during stoichiometric problem solving.

V. CONCLUSIONS

The conclusions drawn from this study are as follows: students' metacognitive functions and transactive structures vary across ability groups. These metacognitive functions and transactive structures also showed a weak degree of association with ability grouping.

Similarly, students' metacognitive experiences such as feelings of liking, difficulty, confidence, satisfaction, and estimates of effort, time, and solution correctness also vary across ability groups. The metacognitive

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function on the generation of new idea influences students' estimate of effort and estimate of time while assessment of strategy influences students' feeling of difficulty in chemistry problem solving across ability groups.

Although both the metacognitive functions and transactive structures affect quantitatively students' metacognitive experiences in solving chemistry tasks, the effect does not vary across ability groups. However, across ability groups, other monitoring transactive structure influences students' feeling of difficulty and estimate of effort in solving group stoichiometry tasks.

VI. RECOMMENDATIONS

To achieve successful collaboration during small-group problem solving activities in chemistry, the teacher should play a crucial role in maintaining a "dynamic match" in providing scaffolding and assistance to meet students' specific needs during social interaction. The teacher should be flexible, sensitive, responsive, and cautious during the intervention to avoid misdirection, confusion, and even discourage the learners to take the challenge in resolving their difficulties during problem solving. The teacher should also consider the quantity, quality, and timing of assistance whether to intervene or not to intervene during students' social interaction.

The high ability and average ability students should be given non-directive teacher regulation and minimal scaffolding during their social interactions. In this way, the students will be given the opportunity to settle their own cognitive conflicts and create their own understanding of the tasks at hand. However, to avoid frustrations during social interactions, the low ability students should be given more directive teacher regulation and scaffolding interventions to encourage them to be persistent during problem solving. Microgenetic studies should be conducted in the future to probe into the details of changing dimensions and moment-by-moment effects of social interaction on students' metacognitive experiences during stoichiometric problem solving. The variables such as gender, type of chemistry tasks, affective behaviors, and inter-relational control processes should also included in the research design.

REFERENCES

Arasasingham, R., Taagepera, M., Potter, F., & Lonjers, S. (2004). Using knowledge space theory to assess student understanding of stoichiometry. *Journal of Chemical Education, 81* (10), 1517 –1523

Bilgin, I. (2006). The effects of pair problem solving technique incorporating Polya's problem solving strategy on undergraduate students' performance in chemistry. *Journal of Science Education, 7* (2), 101 – 106.

BouJaoude, S., & Barakat, H. (2003). Students' problem solving strategies in stoichiometry and their relationships to conceptual understanding and learning approaches. Electronic Journal of Science Education 7 (3). Retrieved July 25, 2006 from *http://unr.edu/homepage/crowther/eise/boujaoude.pdf*

Brown, A. (1987). Metacognition, executive control, self-regulation and other more mysterious mechanisms. In F. Weinert & R. Kluwe (Eds.), *Classroom manangement* (pp. 144 – 181). Hillsdale, NJ: Erlbaum.

Chiu, M.H. (2001). Algorithmic problem solving and conceptual understanding of chemistry by students at a local high school in Taiwan. *Proceedings of National Science Council, ROC (D), 11* (1), 20 -38.

Coutinho, S., Hastings, K., Skowronski, J., & Britt, M. (2005). Metacognition, need for cognition and use of explanations during ongoing learning and problem solving. *Learning and Individual Differences, 15*, 321 – 337.

Dillenbourg, P. (1999). Introduction: what do you mean by collaborative learning? In P. Dillenbourg (Ed.). *Collaborative learning: Cognitive and computational approaches.* (pp. 1 – 19) Amsterdam: Pergamon.

Efklides, A. (2001). Metacognitive experiences in problem solving: metacognition, motivation, and self-regulation. In A. Efklides, J. Kuhl, & R. Sorrentino (Eds.), *Trends and Prospects in Motivation Research* (pp. 297 – 323). The Netherlands. Kluwer Academic Publishers.

Efklides, A. (2002). Feelings of judgments as subjective evaluations of cognitive processing: how reliable are they? *Psychology, 9* (2), 163 -182.

Efklides, A. (2006). Metacognition and affect: What can metacognitive experiences tell us about the learning process? *Educational Research Review, 1*, 2 – 14.

Efklides, A., Samara, A., & Petropoulou, M. (1999). Feeling of difficulty: An aspect of monitoring that influences control. *European Journal of Psychology of Education, 14* (4), 461 – 476.

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Efklides, A., & Tsiora, A. (2002). Metacognitive experiences, self-concept, and self-regulation. *Psychologia, 45*, 222 -236.

Fach, M., de Boer, T., & Parchmann, I. (2007). Results of an interview study as basis for the development of stepped supporting tools for stoichiometric problems. *Chemistry Education Research and Practice*, *8* (1), 13 – 31.

Flavel, J. (1979). Metacognition and cognitive monitoring: A new era for cognitive- developmental inquiry. *American Psychologist, 34* (10), 906 – 911.

Frith, C. (2012). The role of metacognition in human social interactions. *Philosophical Transactions of the Royal Society B 367*, 2213-2223. doi:10.1098/rstb.2012.0123

Givry, D., & Roth, W. (2006). Towards a new conception of conceptions: interplay of talk, gestures, and structures in the setting. *Journal of Research in Science Teaching, 43* (10), 1086 – 1109.

Goos, M., & Galbraith, P. (1996). Do it this way! Metacognitive strategies in collaborative mathematical problem solving. *Educational Studies in Mathematics, 30*, 229 – 260.

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: creating collaborative zones of proximal development in small group problem solving. *Educational Studies in Mathematics*, *49*, 193 – 223.

Hertzog, C., & Dixon, R. (1994). Metacognitive development in adulthood and old age. In J. Metcalfe & A. Shimamura (Eds.), Metacognition: Knowing about knowing (pp. 227 – 251). Cambridge, MA: Bradford.

Iiskala, T., Vauras, M., Lehtinen, E. & Salonen, P. (2011). Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes. *Learning and Instruction, 21 (3)*, 379 – 393.

Kreijns, K., Kirschner, P., & Jochems, W. (2002). The sociability of computer-supported collaborative learning environments. *Educational Technology & Society*, *5* (1), 1 – 20.

Krystyniak, R., & Heikkinen, H. (2007). Analysis of verbal interactions during an extended, open-inquiry general chemistry laboratory investigations. *Journal of Research in Science Teaching, 44* (8), 1160 – 1186.

Ploetzner, R., Dillenbourg, P., Preier, M., & Traum, D. (1999). Learning by explaining to oneself and to others. In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches* (pp.103 – 121). Amsterdam: Pergamon.

Renkl, A. (1997). Learning form work-out examples: a study on individual Differences. *Cognitive Science*, *21*, 1 -129.

Salonen, P., Vauras, M., & Efklides, A. (2005). Social interaction – what can it tell us about metacognition and coregulation in learning? *European Psychologist*, *10* (3), 199 – 208.

Sanger, M. (2005). Evaluating students' conceptual understanding of balanced equations and stoichiometric ratios using a particulate drawing. *Journal of Chemical Education 82* (1), 131 – 134.

Van Boxtel, C., Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and Instruction*, *10*, 311 – 330.

Volet, S., Vauras, M., & Salonen, P. (2009). Psychological and social nature of self- and co-regulation in learning contexts: An integrative perspective. *Educational Psychologists*, *44*, 1-12.

Vygotsky, L. S. (1978). *Mind in Society. The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wood, C., & Breyfogle, B. (2006). Interactive demonstrations for mole ratios and limiting reagents. *Journal of Chemical Education*, *88* (5), 741 – 743.

Wong, R., Lawson, M., & Keeves, J. (2002). The effects of self-explanation training on students' problem solving in high school mathematics. *Learning and Instruction*, *12,* 233 – 262. 68 – 891.