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The Development of a Self-regulation in a Collaborative Context Scale

Victor Law[1] · Xun Ge[2] · Deniz Eseryel[3]

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Abstract Self-regulation has been shown as a critical factor in learning in a regular classroom environment (e.g. Wolters and Pintrich in Instr Sci 26(1):27–47, 1998. doi:10.1023/A:1003035929216). However, little research has been conducted to understand self-regulation in the context of collaboration (Dinsmore et al. in Educ Psychol Rev 20(4):391–409, 2008. doi:10.1007/s10648-008-9083-6). Recently, researchers have been exploring how learners regulate themselves in collaborative problem-solving environments using qualitative methods (e.g. Chan in Metacogn Learn 7(1):63–73, 2012. doi:10.1007/s11409-012-9086-z; Lajoie and Lu in Metacogn Learn, 2011. doi:10.1007/s11409-011-9077-5). However, there is a lack of instruments to measure self-regulation in a collaborative context (SRCC). Therefore, the current study was intended to propose a new instrument to measure SRCC. One hundred and thirty-one college students from a Mid-western university completed a survey for SRCC after participating in a collaborative problem-solving task. The exploratory factor analysis yielded four factors: clarification and resolution, elaboration, refuting, and summarization. Three of the four factors were moderately correlated. The results contribute to our understanding of self-regulation in a collaborative context, which allows researchers to study this phenomenon quantitatively.

✉ Victor Law
vlaw@unm.edu

Xun Ge
xge@unm.edu

Deniz Eseryel
deniz.eseryel@ncsu.edu

[1] Program of Organization, Information, and Learning Sciences, University of New Mexico, Zimmerman Library Rm 238, MSC05 3020, 1 University of New Mexico, Albuquerque, NM 87131-001, USA

[2] Department of Educational Psychology, Jeannine Rainbolt College of Education, University of Oklahoma, 820 Van Vleet Oval, Collings Hall 321, Norman, OK 87131-0001, USA

[3] College of Education, North Carolina State University, 1890 Main Campus Dr, Raleigh, NC 27606, USA

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1 Introduction

Research shows that self-regulation is an important component in ill-structured problem-solving processes (e.g. Ge and Land 2003; Shin et al. 2003). Numerous self-regulation studies have been conducted in various contexts, including regular classrooms, hypermedia environments, and web-based e-learning environments, which indicated relationships between self-regulation and learning outcomes (Azevedo et al. 2004; Dabbagh and Kitsantas 2005; Greene et al. 2012; Kramarski and Gutman 2006; Whipp and Chiarelli 2004; Wolters and Pintrich 1998). Alexander (1995) argued that self-regulation is context specific, and self-regulation in social contexts should be distinguished from self-regulation in solitude. As collaborative learning being more prominent in today's classroom settings, it is important to understand self-regulation in the new context of collaborative learning environments.

In the last decade, some researchers have been conducting studies to understand self-regulation in collaborative contexts (e.g. Efklides 2008; Järvelä and Järvenoja 2011; McCaslin 2009). The concepts of co-regulation and shared regulation have been explored qualitatively (e.g. Hadwin et al. 2010; McCaslin 2009; Lajoie and Lu 2011; Volet et al. 2009). Volet et al. (2009) developed a two-dimensional co-regulation framework including a cognitive and metacognitive dimension, and a social dimension. Lajoie and Lu (2011) employed Volet's framework to examine co-regulation in the context of medical decision making in emergencies. Their qualitative results suggested that students' co-regulation behaviors were related to their medical decision making.

Despite the active exploration on the concept of self-regulation in collaborative contexts, little quantitative research has been conducted to examine this construct. Therefore, the goal of the current study is to develop a plausible instrument to measure self-regulation in a collaborative context through exploratory factor analyses, which we hope will allow other researchers to examine this new phenomenon quantitatively.

2 Theoretical Framework

Three bodies of literature guide the development of the scale of self-regulation in a collaborative context: self-regulation, collaborative learning, and problem solving. *Self-regulation* has been viewed as an active process that learners plan, monitor, and reflect upon their cognition, motivation, and emotion (Boekaerts 1997; Pintrich 2000; Zimmerman 1990). Drawing from the information processing theory, Butler and Winne (1995) argued that feedback is a key process of self-regulation. Students interact with their environment by monitoring their environment, and then modifying their goals and learning strategies after they receive the feedback. A collaborative problem-solving environment involves multiple team members who interact constantly. Thus, students who regulate in a social environment not only passively monitor inputs from their peers (their social environment), but also actively provide feedback to their peers (act as the social environment of

others). In order to further examine self-regulation in a social environment, we also need to understand how people solve problems collaboratively.

People work together *collaboratively* to understand and solve problems. They share information, search for meanings and solutions, and maintain a share understanding of the problem (e.g. Iiskala et al. 2011; Teasley and Roschelle 1993). Many qualitative studies have been conducted to examine collaborative interactions in problem solving and knowledge construction scenarios. For example, Fawcett and Garton (2005) found that students in a collaborative learning environment justified one's positions and consider others' positions. Goos et al. (2002) found high school students clarified, elaborated, and justified their ideas. In addition, they also sought feedback, invited others for critique; at the same time they also offered critiques to others during collaborative problem-solving activities. Those collaborative behaviors are the cornerstones of the proposed scales.

While engaging in collaborative processes, students also engage in *problem-solving* processes. Drawing from information processing theory, Gick (1986) modeled problem solving as a recursive process, where problem solvers keep on revising their understanding of the problem if their solutions fail. Similar to Gick's framework of problem solving, Voss and Post (1988) identified two key components of ill-structured problem solving: problem representation and solution generation. Therefore, problem solvers not only need to regulate themselves in searching for a solution, but also regulating themselves in representing the problem.

2.1 Self-regulation in a Collaborative Context

Although many researchers have called for the attention to explore self-regulation in a social context (e.g. Alexander 1995), most of the studies on self-regulation still focus on self-regulation at the individual level when an individual student interacts with his/her regular classroom environment (Dinsmore et al. 2008). Recently, the phenomenon of social aspects of self-regulation has gained some attention. Researchers have developed different constructs to describe the self-regulation process in social contexts, such as co-regulation, shared regulation, other-regulation, socially shared metacognition, and social metacognition (Chiu and Kuo 2009; Hurme et al. 2009; Iiskala et al. 2011; Järvelä and Järvenoja 2011; McCaslin 2009; Volet et al. 2009). Taking Vygotsky's approach, Hadwin et al. (2010) examined co-regulation as a transitional process when self-regulation is gradually appropriated by individual learners, and shared regulation as a social process that multiple people regulate a collective activity. Volet and Mansfield (2006) viewed other-regulation as a way a person control another person's behaviors. In the current study, we view self-regulation as an individual process within a collaborative process, in which individuals can influence others as well as be influenced by others (e.g. Järvelä et al. 2010).

Despite the increasing attention to social aspects of self-regulation, the existing research has mostly concentrated on the motivational and emotional aspects of self-regulation in a social environment (Järvelä et al. 2008; McCaslin 2009; Volet and Mansfield 2006; Volet et al. 2009). Very few studies used a cognitive lens to understand self-regulation in a social environment, even though cognitive dimension is a key dimension in self-regulation (e.g. Butler and Winne 1995; Pintrich 2000).

To examine self-regulation in a collaborative context quantitatively, we need a valid and reliable instrument. However, few instruments have explored the construct of self-regulation in a collaborative context. Metacognitive Strategies for Learning Questionnaire (MSLQ) is a widely used instrument that measures self-regulation (Pintrich et al. 1991). Nevertheless, only two social dimensions, help seeking and peer learning, are included in

the instrument. Furthermore, the items in MSLQ situate self-regulated learning in a regular classroom environment. Consequently, MSLQ cannot fully capture self-regulation activities in collaborative learning environments. Another study tapped into the human dimensions in understanding self-regulation, and developed instruments of self-regulation that included human interaction dimensions (Cho and Jonassen 2009). Two different scales were developed in Cho and Jonassen's study: the affect/motivation scale and the interaction strategy scale. The affect/motivation scale revealed four factors: enjoyment of human interaction, self-efficacy for interaction with instructors, concern for interactions with students, and self-efficacy for contributing to the online community. The interaction strategy scale revealed three factors: writing strategies, responding strategies, and reflection strategies. Their study expanded the understanding of self-regulation in a social context to include affective and motivational aspects. Their study also suggested that human interaction is an important external factor that should be considered in learning environments (Cho and Jonassen 2009). Although this scale provided the research community with instruments to understand self-regulation with some understanding of human interactions, this instrument still lacks the power to understand how students self-regulate in a collaborative problem-solving environment, when students have to interact and co-construct knowledge.

Another closely related framework to measure self-regulation in collaborative contexts is found in the collaborative problem-solving literature. The Organization for Economic Co-operation and Development (OCED) drafted a framework to assess collaborative problem solving, which included some self-regulation dimensions in the framework (OECD 2013; Webb and Gibson 2015). Ge and Land (2004) also suggested regulation of cognition such as planning, monitoring, and reflection are required in problem solving. Indeed, the PISA framework include those self-regulation processes as the key problem-solving competencies. However, the PISA framework focuses the interpersonal perspectives in collaborative problem solving. The current study argue that a good self-regulation scale should also be balanced with the intrapersonal perspectives as well.

2.2 Purpose of the Study

The purpose of this study is to identify the potential underlying dimensions of the construct, self-regulation in a collaborative context. Exploratory factor analyses were conducted to identify the factor structure. In addition, correlations among the factors were calculated to examine the relationships among various factors.

Drawing from the three key pieces of literature described above, self-regulation in a collaborative context is defined as an *individual process* whereby a problem solver (1) sets goals, (2) monitors, and (3) reflects on his/her cognition through interpersonal interactions. These interactions include self-regulation based on the input from others, as well as inviting others to make comments or provide suggestions to facilitate self-regulation in an ill- structured problem-solving process. In order to self-regulate in a social environment, students engage in various activities such as clarification, elaboration, justification, summarization, and critiquing. Since problem solvers need to form their problem representations and also develop plausible solutions, the initial items of the scale include self-regulation behaviors in both the problem representation phase and the solution generation phase. The structure of self-regulation of a collaborative context above guides the development of the items in the current study.

3 Methods

3.1 Participants

One hundred and thirty-one undergraduate students enrolled in an educational psychology course at a Midwestern university participated in the current study. Students received extra credits by participating in the research. Ninety-two percent of the participants were female, and eight percent were male. Most of the participants reported that they had some prior knowledge on the topic of the problem that they engaged in this experiment. Only a small percentage of the participants indicated that they knew a lot or knew very little on the topic.

3.2 Procedures

Groups of 3–4 students (randomly assigned) participated in a collaborative problem-solving task (for 20–30 min), which required them to discuss an ill-structured problem with their team members and then came up with a solution. A jigsaw problem-solving activity was given to the participants to ensure collaboration among the peers during the task. Each of the participants was provided with only one piece of the information regarding the problem. As a result, participants had to share information with one another and work together to solve the problem together. At the end of the activity, the participants completed a survey which asked them to recall their self-regulation behaviors during the collaborative problem-solving activity.

3.3 Instrument

The instrument was developed based on three theoretical frameworks: self-regulation (Pintrich 2000; Zimmerman 2001), collaborative learning (Goos et al. 2002; Iiskala et al. 2011; Teasley and Roschelle 1993), and ill-structured problem solving (Jonassen 1997; Sinnott 1989; Voss and Post 1988). Items were adopted from existing self-regulation and problem-solving scales, including Motivated Strategies for Learning Questionnaire (Pintrich et al. 1991) and a self-report questionnaire of ill-structured problem-solving skills by Ge (2001). Seven-point Likert scale items ranging from 1 (strongly disagree) to 7 (strongly agree) measured how well students set goals, monitor their cognition, and reflect on their problem-solving processes. Example items are shown in Table 1. Two doctoral and one Master's students who majored in Educational Psychology participated in a pilot study to provide feedback on the items to improve the wordings. In addition, items were modified based on the results of another pilot study.

4 Data Analysis and Results

4.1 Exploratory Factory Analysis

Exploratory factor analyses were employed to determine the structure of the self-regulation in a collaborative context scale. To determine the number of factors, principle axis factoring extraction was used to estimate the number of factors because this type of factoring

Table 1 Four factor solutions for self-regulation in a collaborative context scale

	Factor loadings						
	Factor 1	Factor 2	Factor 3	Factor 4	M	SD	α
When I did not understand my peers' understanding of the problem I asked them to clarify it	**0.923**	0.034	−0.144	−0.089	4.78	1.756	0.843
When I did not understand my peers' perspectives I asked them to clarify their perspectives	**0.897**	−0.084	0.031	0.000	4.68	1.824	0.844
When I saw a misunderstanding of the problem among the team members I tried to resolve the issues	**0.573**	0.55	0.197	0.109	1.94	1.764	0.861
When solving the problem as a group I explained the possible solution alternative(s) to my peers	**0.489**	0.010	−0.060	0.118	5.55	1.359	0.886
When I did not understand my peers' solution alternatives I asked them to clarify it	**0.846**	−0.069	0.025	0.022	4.65	1.793	0.847
When there was a misunderstanding to the solution alternatives among the team members I tried to resolve the issue	**0.619**	0.127	0.074	−0.019	4.82	1.684	0.860
When I solved the problem I described the relationships between stakeholders and the problem to my peers	0.171	**0.555**	−0.046	0.063	4.98	1.501	0.804
When my peers explained their understanding of the problem I elaborated on their understanding	−0.064	**0.908**	−0.063	−0.059	5.53	1.320	0.796
When my peers stated possible problem constraints I elaborated on their understanding	−0.042	**0.624**	0.172	0.000	5.47	1.152	0.803
When my peers suggested a solution I elaborated on their understanding	−0.042	**0.876**	0.006	−0.063	5.74	1.131	0.774
After my peers explained their solution alternatives I shared my understanding with them	0.129	**0.483**	−0.067	0.198	5.61	1.309	0.814
I refuted my peers' understanding(s) of the problem	0.028	0.029	**0.664**	−0.063	2.96	1.780	n.a.
I refuted some of my peers' solution alternative(s)	−0.015	−0.024	**0.892**	0.043	3.11	1.859	n.a.
I summarized the group's understanding of the problem to understand the problem better	0.034	−0.055	−0.073	**0.855**	5.57	1.440	n.a.
I summarized the input of our team to come up with a solution	−0.064	0.046	0.064	**0.686**	6.02	1.186	n.a.

Unique factor loading >0.450 are in bold. α = Cronbach's alpha coefficient if item deleted. Since two of the factors only had 2 items, no Cronbach's alphas if deleted for factor 3 and factor 4

is free of distribution assumptions. Bartlett's test of sphericity indicated that there was sufficient correlation among the variables ($p < 0.01$), which is one of the assumptions of exploratory factor analysis.

The eigenvalue rule and scree plot were used to guide the choice of number of factors in the analysis. Originally, six factors were found with eigenvalue smaller than 1. The scree plot suggested that there were three to six factors. Therefore, we started to explore the six possible factors. One item with initial communality <0.4 were deleted because it had relatively little commonality with the other variables. Promax rotation was employed because the key sub-constructs of self-regulation (i.e., planning, monitoring, and reflecting) were closely related. Items were deleted if they failed one or more of the following three criteria: (1) the absolute value of loadings was >0.45, meaning the item had a high correlation with other items associated with the same factor; (2) no cross-loaded items, where absolute values of their loadings were >0.4 on more than one factor; it meant the same item could explain two more factors and (3) a factor had to have more than one item (Hair et al. 2006; Tabachnick and Fidell 2007).

After deleting the problematic items, the exploratory factor analysis revealed a four factor structure, explaining 67.97 % of the variance, with eigenvalues >1. The scree plot also suggested a four factor structure. The final four factors were named (1) clarification and resolution, (2) elaboration, (3) refuting, and (4) summarization. Table 1 summarized the items, factor loadings, mean, standard deviation, and Cronbach's alpha coefficient if item deleted.

The first factor, consisting of six items, accounted for 35.99 % of variance. This factor was named *clarification and resolution*, and it had an alpha of 0.879. A high Cronbach's alpha ($\alpha > 0.7$) indicated a high internal consistency of the scale (Hair et al. 2006). Cronbach's alpha coefficients if item deleted for all six items were consistently above 0.75. The second factor, consisting of five-items, accounted for 13.24 % of variance. The factor was named *elaboration*. The alpha for this factor was 0.832, and the Cronbach alpha coefficients if item deleted for all five items, were above 0.75. The last two factors, which had only two items per factor, accounted for 10.88 and 7.88 % of variance respectively. We named the factors as *refuting* and *summarization*. The factors had Cronbach alphas of 0.74 and 0.73 respectively.

4.2 Correlations

Correlations among the four factors and Cronbach Alphas are shown in Table 2. The three factors out of four from the results were moderately intercorrelated (r range from 0.306 to 0.519). The factors were significantly correlated suggesting that the four dimensions of self-regulation in a collaborative context not only share common variance, but also contain unique variance.

Table 2 Correlations of four sub-scales

	Alpha	Clarification and resolution	Elaboration	Refuting	Summarization
Clarification and resolution	0.879	1.00			
Elaboration	0.832	0.519**	1.00		
Refuting	0.740	0.397**	0.306**	1.00	
Summarization	0.730	0.353**	0.443**	−0.004	1.00

n = 119; * $p < 0.05$; ** $p < 0.01$

5 Discussions and Implications

Most of the research on self-regulation in collaborative contexts has been conducted qualitatively (e.g. Chan 2012; Lajoie and Lu 2011; Volet et al. 2009). The current research took a first step to develop a plausible instrument to measure self-regulation in a collaborative context. This study contributes to our understanding of self-regulation in a collaborative context and allows the field to examine the construct quantitatively.

The results of the current study revealed a four-factor model of self-regulation in a collaborative context, which included *clarification and resolution*, *elaboration*, *refuting*, and *summarization*. This result is consistent with Goos et al. (2002) research that examined social metacognition in a small group problem-solving context. They suggested that students self-discoursed (e.g., clarifying and elaborating their own thoughts), requested feedback (e.g., inviting a partner to critique their own thinking), and monitored others' input during collaborative problem solving. Our results suggested students clarified and elaborated their *own thoughts* as well as clarified and elaborated their understanding of *other members' thoughts* as those behaviors are shown in the items. Thus, self-regulation in a collaborative context is not a uni-directional process, but a bi-directional process. Moreover, in Goos's study, they did not include reflecting constructs in understanding self-regulation in social contexts. Our study suggested that students co-regulate in a problem-solving environment by refuting others and summarizing others' inputs, which indicated that problem solvers engaged in reflection and evaluation during the problem-solving processes.

In addition, the four-factor model may support a two-dimension model of self-regulation that highlights *monitoring* and *reflecting*, where clarification and resolution, and elaboration explain *monitoring*, and refuting and summarization explain *reflecting*. Contrary to the other three-dimension models of self-regulation that included planning, monitoring, and reflecting (e.g. Boekaerts 1997; Zimmerman 1990), the planning related constructs were not found in the final structure. It is possible that the planning items were also loaded fairly equally to both the monitoring and reflecting factors. As a result, the planning component of self-regulation was aggregated in the clarification and resolution factor.

Furthermore, the two-dimensional model is somewhat consistent with the PISA collaborative problem-solving framework including the dimensions such as monitoring and repairing the shared understanding, evaluating success in solving the problem, building a shared representation and negotiating meaning of the problem (OECD 2013; Webb and Gibson 2015). The four-factor model found in the current study provided some details of the self-regulation processes during collaborative problem solving such as clarifying, elaborating, refuting, and summarizing. However, some of the dimensions in the PISA collaborative problem-solving framework, such as discovering perspectives and abilities of team members, and describing the roles and organizations, are not included in the four-factor model. It is possible that those dimensions are more related to problem solving instead of self-regulation. Additional conceptualization of the SRCC construct is needed to refine the items in the future.

In conclusion, the current study provides a plausible instrument to examine self-regulation in a collaborative context. These preliminary results of the current study suggest that self-regulation in a collaborative context involves clarification and resolution, elaboration, refuting, and summarization. Replicated studies are needed to confirm the proposed four-factor structure using confirmatory factory analysis. With a confirmed instrument, we may

be able to examine how students' self-regulation in a collaborative context relates to some other interesting variables, such as students' characteristics and learning outcomes. Many researchers agree that self-regulation is an important process in learning, and tools have been developed to scaffold self-regulation (e.g. Manlove et al. 2006; Zhang et al. 2004). With a framework of self-regulation in a collaborative problem solving context that is suggested by the current study, the instructional design community may be able to develop tools to scaffold problem solvers' self-regulation in collaborative problem solving contexts.

A limitation of the current study is that it was conducted in a lab environment where students were assigned to ad hoc teams. Subsequent studies are required to examine self-regulation in a collaborative context in a naturalistic environment where groups solve authentic problems. Moreover, the data of the current study were collected in a College of Education where majority of the participants were female. Additional studies should be conducted with a more diverse sample. In addition, the current instrument is based on self-report items. The self-report instrument is good to capture the covert elements of self-regulation. For example, a member of the problem-solving team may covertly summarize the understanding which cannot be observed. A self-report survey will be able to capture this key of self-regulation behaviors. However, self-report instrument may not be able to represent participants' real intention and experiences (Winne 2010). Additional research should be conducted to triangulate self-report items with other data such as trace data or observational data to better capture self-regulation in a collaborative context.

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