Article

The Effect of Individual and Social Metacognitive Support on Students' Metacognitive Performances in an Online Discussion

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Abstract

Our research examined the effect of the Meta-CIC model on students' metacognitive performances in an online discussion. This model embeds individual and social metacognitive support within an inquiry computer-supported collaborative learning (CSCL) environment. The research population consisted of 150 high-achieving 7th- and 8th-grade students who were divided into four research groups, according to the instructional method to which they were exposed. An online discussion forum accompanied the students' inquiry process. The results indicate that the individual metacognitive support significantly affected students' online metacognitive performances, while the social metacognitive support increased the students' involvement in their peers' learning processes, and enabled them to collaborate in the CSCL. We therefore recommend embedding the Meta-CIC model in a CSCL environment as a means to develop students' online metacognitive performances.

Keywords

metacognition, computer-supported collaborative learning, online discussion, inquiry

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Introduction

Computer-Supported Collaborative Learning

Within the last decade, computer-supported learning environments have become more common (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003; Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005; de Jong, Kollöffel, van der Meijden, Staarman, & Janssen, 2005; Pihlainen-Bednarik & Keinonen, 2011). Some of these learning environments offer opportunities for collaborative learning, and they are referred to as computer-supported collaborative learning (CSCL) (Hurme, Palonen, & Järvelä, 2006; Janssen, Erkens, Kirschner, & Kanselaar, 2012; Stahl, Koschman, & Suthers, 2006). Online discussions are specific forms of CSCL, where groups of learners work over the Internet without constraints of time or space (e.g., Salovaara, 2005). Online discussions provide a powerful medium to promote a reflection and an exchange of ideas due to their unlimited and immediate accessibility, global reach, and delayed response time. These features help facilitate reflection on information presented previously and enable individuals to "think before talking" (Cohen & Scardamalia, 1998; Veerman, Andriessen, & Kanselaar, 2000; Zion, Michalsky, & Mevarech, 2005). Because students have more time to think in an asynchronic conversation, online discussions also enable a more precise expression than face-to-face communication. The explicit nature of online discussions makes it easier to detect contradictions or conflicts in students' opinions (Zion, 2008).

In spite of the potential of CSCL, it is clear that simply providing computers for teachers and students to use is insufficient in and of itself to bring about improved science learning (Makitalo-Siegel, Kohnle, & Fischer, 2011). Online discussions lack many characteristics of social interaction, such as nonverbal signals (e.g., eye contact, facial expressions, and gestures), auditory cues (e.g., voice inflection, and volume), and interpersonal signals (e.g., age, sex, and physical appearance) (Adrianson, 2001). The lack of social context cues may impede the establishment and maintenance of a secure and collaborative atmosphere and hinder the collaborative learning process (de Jong et al., 2005). Furthermore, the lack of these cues transforms the maintenance of *common ground* (i.e., shared background understanding) into a significant attention and effort consuming task, instead of a background task which occurs in face-to-face interactions (Carroll et al., 2003). A recent study by Janssen et al. (2012) demonstrated both the advantages and disadvantages of CSCL. On the one hand, the authors noted that when groups devoted more energy to regulating the collaboration, they performed better, indicating that a minimum amount of social activities is a prerequisite for successful group performance. On the other hand, social interactions may also distract the students from achieving the goal of promoting collaboration and the completion of a given task. Such distraction indicates a potential negative effect of social activities on group performance.

Research studies have implied that individuals who can effectively plan, monitor, and control their learning are best positioned to take advantage of computer-supported environments (Azevedo, 2005a; de Jong et al., 2005; Winters, Greene, & Costich, 2008). These skills are part of the concept of "metacognition," which includes skills that enable learners to understand and monitor their cognitive processes (Brown, 1987; Flavell, 1976; Schraw, Crippen, & Hartley, 2006). Accounts of metacognition have identified two major components: *knowledge about cognition*, which includes three subprocesses that facilitate the reflective aspect of metacognition; and *regulation of cognition*, which includes several subprocesses that facilitate the control aspect of learning. These subprocesses include planning, process management strategies, monitoring, debugging, and evaluation (Schraw & Dennison, 1994; Schraw & Moshman, 1995). Metacognition is one of the main components of self-regulated learning (SRL), which is the self-directive process by which learners transform their mental abilities into academic skills (Zimmerman, 2002). Consequently, a growing number of researchers regard SRL and metacognition as potential mediators between the potential of computer-supported learning environments (e.g., Azevedo, 2005a,b; Thomas, 2001; White & Frederiksen, 2005), or specifically of CSCL (e.g., Chan, 2012; Järvelä & Hadwin, 2013) and academic performance.

Scaffolding Metacognition in CSCL

Scaffolding metacognition in a CSCL environment is one of the major challenges facing researchers today. One way to foster student self-regulation and metacognition is through the use of various types of scaffolding. These types may include access to a human tutor who provides adaptive scaffolding to foster students' SRL (Azevedo, 2005a). Other research focuses on the use of computerized intelligent tutoring systems or sophisticated computer software which provide automated feedback to users, thus promoting and improving students' SRL (e.g., Aleven, Roll, McLaren, & Koedinger, 2010; Graesser & McNamara, 2010; Graesser, McNamara, & VanLehn, 2005; Hadwin, Wozney, & Pontin, 2005; Quintana, Meilan, & Krajcik, 2005; Roll, Aleven, McLaren, & Koedinger, 2007; Sánchez-Alonso & Vovides, 2007).

The Metacognitive-guided Inquiry Within Networked Technology is an example of a learning environment which was designed to support students' metacognition within online discussions (Zion et al., 2005). In this environment, students receive metacognitive support in the form of explicit metacognitive guidance, during their involvement in an inquiry process. This explicit metacognitive guidance includes questions which prompt the students to reflect upon their learning process. Each student answered the metacognitive questions autonomously several times throughout the inquiry process (Zion et al., 2005).

Although metacognition and self-regulation are considered as individual processes, they both include a social aspect (Jost, Kruglanski, & Nelson, 1998;

Salonen, Vauras, & Efklides, 2005). A key mechanism in developing and improving metacognition or self-regulation is the ability to observe and listen to other peoples' perspectives (Lajoie & Lu, 2012) through both social interaction and joint activities (de Jong et al., 2005). According to social constructivist learning theories, coregulation refers to the process by which our social environment serves to support or scaffold individual participation and learning (McCaslin, 2004). Through social interactions, learners can develop more self-regulation skills and gradually assume more responsibility for the performance of a given task (de Jong et al., 2005). A review of the literature reveals that the social component of regulatory processes is an emerging theme in the field of CSCL (e.g., Akyol & Garrison, 2011; Hadwin, Oshige, Gress, & Winne, 2010; Iiskala, Vauras Lehtinen, & Salonen, 2011; Janssen et al., 2012). Indeed, results of a study by Hurme et al. (2006) show that students demonstrate their metacognitive thinking, especially in reciprocal interaction with peers, in a CSCL.

According to Dillenbourg (1999), there is no guarantee that unstructured or unguided collaborations will evoke the interpersonal interactions which would trigger learning mechanisms. One way to enhance the effectiveness of peer collaboration is to structure the interactions by engaging the students in well-defined "collaborative scripts," which include a set of instructions regarding how the group members should interact, collaborate, and solve the problem (Dillenbourg, 2002). Accordingly, the collaborative scripts do not necessarily provide guidance on a conceptual level (e.g., by providing content-specific prompts), but rather on a (collaboration) process level, and scaffold activities that students could not yet engage in on their own (reviewed by Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegel, & Fischer, 2009). Caution should be taken not to "over-script" the collaborative process, which could result in disturbing the natural interactions or the natural problem solving process, increasing the cognitive load, "didactising" collaborative interactions, and producing interactions which lack goals (Dillenbourg, 2002). Such interference in the social dynamics of the group might impede the learning process. The apparent potential of scripting collaborations has resulted in its high popularity in the research field over recent years (e.g., Hämäläinen, Manninen, Järvelä, & Häkkinen, 2006; Strijbos & Weinberger, 2010; Weinberger, Stegmann, & Fischer, 2010).

Recently, Järvelä and Hadwin (2013) argued that optimally functioning groups bring together three forms of regulatory competence and engagement: team members regulate their own task engagement (SRL); the members transitionally support each other to successfully regulate their learning (coregulated learning); and the group collectively regulates the learning process in a synchronized and productive manner (shared regulation). Therefore, successful collaboration in a CSCL context requires targeted support for promoting or guiding (a) individual self-regulatory skills and strategies, (b) peer support and the facilitation of self-regulatory competence within the group, and (c) shared or collective regulation of learning (Järvelä & Hadwin, 2013).

The Meta-CIC Model

In the current research, we developed the Meta-CIC model, which was designed to increase students' engagement in metacognition within a CSCL environment. Students' engagement in metacognition is expressed by their online metacognitive performances. For this purpose, we embedded metacognitive support, which addresses both the individual and the social aspects of metacognition within an inquiry-based CSCL environment (Figure 1).

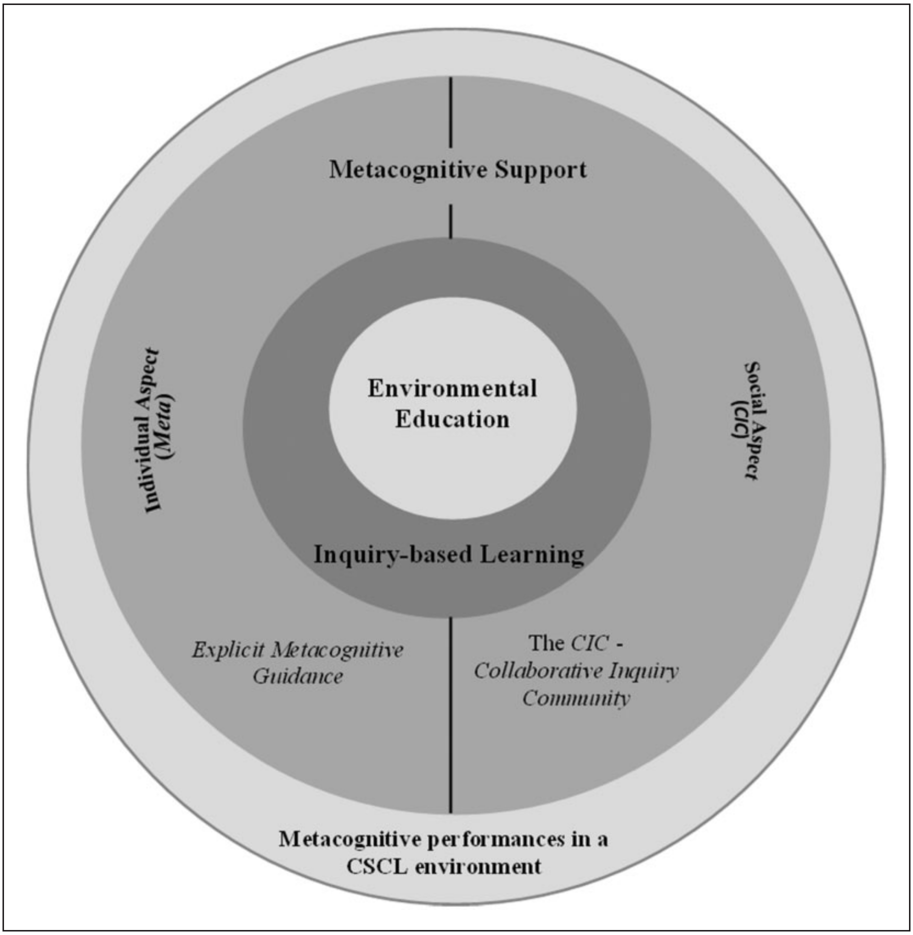

Figure 1. The Meta-CIC model for scaffolding students' metacognitive performances in a computer-supported collaborative learning environment.

The core of this model is the challenging open inquiry. Open inquiry is the highest level of inquiry-based learning (Schwab, 1962) and enables students to be active decision-making participants in all stages of the inquiry process (NRC, 2000). In open inquiry, the students engage in scientific questions, design and conduct investigations, formulate explanations from evidence, evaluate their explanations, and communicate and justify their explanations to others (NRC, 1996, 2000). The teachers serve as facilitators and guide the students throughout the inquiry process (e.g., Michalsky, Mevarech, & Haibi, 2009).

The individual aspect of metacognition is addressed through cognitive processes and reflection. For this purpose, we employed an explicit research-based metacognitive guidance, represented by the word *Meta* in the model. This model includes references to knowledge about cognition and regulation of cognition. The social aspect of metacognition is addressed through an innovative collaborative scheme which includes two levels of collaboration: the Collaborating Inquiry (CI) and the Collaborating Inquiry Community (CIC). The CI refers to the collaborative relationships between a pair of students, who work on the same inquiry project together. The CIC refers to the collaborative relationships among several pairs of students, each pair working on different inquiry projects. The CIC interactions expand learning beyond the limitations of one group, by building collaborative learning communities within the class, and providing opportunities for groups to exchange ideas and strategies, and to learn from each other's strengths and weaknesses (De Simone, Lou, & Schmid, 2001; Lou, 2004; Lou & MacGregor, 2004). The context and progress of other working groups provide each group with both motivational support and new insights (Lou, 2004; Lou & MacGregor, 2004). The groups are positioned to verbalize their thoughts, externalize their ideas, and provide feedback. Consequently, the CIC members further develop their critical thinking, self-regulation, and metacognitive skills. The combination of the CI and the CIC learning environments provides opportunities for all participants to engage in various cognitive and metacognitive activities.

Face-to-face interactions occur within the CIC learning environment. These interactions are important because they support the development of social relationships which play a major role in children's meaningful experiences (e.g., James & Bixler, 2008). Face-to-face interactions are appropriate for activities such as brainstorming, visual demonstration, and situations where enthusiasm can contribute to the success of the discussion (Meyer, 2003). Furthermore, face-to-face interactions promote visual and verbal communications, thus encouraging students who exhibit a wide range of learning abilities to participate (Michalsky, Zion, & Mevarech, 2007). These interactions provide both nonverbal and verbal feedback that can further encourage and facilitate the participation of group members in discussions.

The inquiry process is accompanied by an online discussion forum. In this CSCL environment, both the teacher and the students are active participants.

The forum is important to the inquiry process because this arena helps ensure the continuity of the inquiry process between face-to-face meetings of the teacher and the students (Zion, 2008). In addition, the online activity in the forum serves as a platform for students to express and practice metacognition, which is expressed by their online metacognitive performances.

Research Questions and Hypothesis

Our research examines the effect of the Meta-CIC model on students' online metacognitive performances in a CSCL environment. For this study, we asked the following questions:

1. What is the contribution of the Meta component, which supports the individual aspect of metacognition, to students' online metacognitive performances?
2. What is the contribution of the CIC component, which supports the social aspect of metacognition, to students' online metacognitive performances?
3. What is the contribution of the Meta-CIC model, which supports both the individual and social aspects of metacognition, to students' online metacognitive performances?

We hypothesize that the metacognitive support, in the form of the Meta or the CIC component, will improve students' SRL: the Meta component will encourage students' engagement in covert autonomous reflection; while the CIC learning environment will create a supportive social environment for students' engagement in the process of overt reflection. Consequently, these students will demonstrate higher online metacognitive performances relative to their counterparts. We further assume that the combination of both the Meta and the CIC components will have a synergistic effect on students' online metacognitive performances.

Method

The following section is divided into two parts. The first part describes curriculum design; it details the component of the educational intervention, which was developed according to the Meta-CIC model and implemented in this study. The second part describes the research design and the measurements which were used to examine the effect of the intervention on students' online metacognitive performances.

Curriculum Design

Research context. The students who participated in this study were engaged in a year-long inquiry-based environmental program, which was part of the students' mandatory science-education curriculum. The program was composed of two components: the first component included monthly visits to the Council for a Beautiful Israel, which is a public organization aimed at promoting quality of life in Israel through environmental education. During these visits, the students were introduced to environment-related issues. The program's second component included open inquiry-based projects, which were conducted by the students in their own school, under the supervision of their teachers.

Students' inquiry projects. In their schools, pairs of students were engaged in a full school year of environmental inquiry-based projects, in which they identified and examined real life environmental issues related to their nearby surroundings. The teacher closely supervised and facilitated students' entire process both at and after school. During school hours, the teachers conducted both collective class sessions and individual meetings with each pair of students. These face-to-face meetings included theoretical and practical explanations, examples, and feedback. After school hours, the students received further assistance and feedback from their teacher through an online asynchronous forum (see the detailed description later).

The instructional program was especially designed for this research. In this program, the inquiry process was divided into seven stages in accordance with scientific research methodology. The students' progression along these stages required the teacher's approval. Such an approach enabled the teachers to closely monitor the students' progress within the inquiry process. The seven stages were grouped into three chronological phases, which provide a holistic perspective on the rationale of the inquiry process: (a) *Framing the inquiry*, which included choosing a social-environmental inquiry issue as an inquiry topic and formulating the inquiry question; and generating the hypotheses; (b) *Conducting the inquiry*, which included developing the research tools, such as questionnaires, interviews, and observations; composing the literature review; conducting the experiment, and collecting data; and (c) *Concluding the inquiry*, which included data analysis and integration and organizing a discussion. Throughout the process, the students documented their inquiry in a structured report which resembled a scientific article.

An accompanying asynchronous online forum, a CSCL environment. Each class was accompanied by an asynchronous online forum, which served as a means of communication between the teacher and the students after school hours. In the forum, students posed questions, requested help and guidance, shared their ideas and monitored and compared their progress to others. The teachers provided theoretical, practical, and motivational support to the students and guided them throughout their inquiry process (see also Zion, 2008). All components of students' inquiry projects were uploaded to the forum for the teacher's examination throughout the entire inquiry process; the teacher closely monitored and evaluated each inquiry project and provided individual attention, support, and feedback for each of the student pairs. In addition to these personal interactions, the teacher regularly provided the students with an in-class overview on the inquiry progress.

Supporting the individual aspect of the metacognition through explicit metacognitive guidance. The explicit metacognitive guidance referred to the two main components of metacognition: knowledge about cognition and regulation of cognition.

Knowledge about cognition. Students' knowledge about cognition was developed using a Strategy Evaluation Matrix (SEM) as described by Schraw (1998). The SEM is designed according to the components of metacognitive knowledge and promotes explicit declarative, procedural, and conditional knowledge about learning strategies (Schraw, 1998). This tool includes information about how to use several strategies, the conditions under which these strategies are most useful, and a brief rationale for their use (Schraw, 1998). In the current research, we assigned specific learning strategies to each stage of the inquiry process (see examples in Table 1). The SEM was taught by the teachers during the face-to-face meetings with the students. Thereafter, the students received a brief

Table 1. Explicit Metacognitive Guidance—Examples of Learning Strategies That Were Taught During the Inquiry Process Using Schraw's (1998) Strategy Evaluation Matrix.

Strategy	How to use	Why	When to use
Brainstorming	Make a list of spontaneous ideas which are associated with a specific subject. Focus on quantity, withhold criticism, welcome unusual and wild ideas and combine and improve ideas (Osborn, 1963)	Facilitates creative problem solving and generation of ideas	In a search for new, creative, and unusual ideas, for example: in search of an inquiry topic
Flowchart	Present the process as a diagram —the steps are presented in boxes of various kinds connected by arrows which represent their order (Gilbreth & Gilbreth, 1921)	Visualizes the process as a means of understanding and improving it	(1) Composing the literature review, to follow the logical sequence of the review (2) To understand and follow procedural aspects of the inquiry process

summary of the strategies through the online forum. They were required to implement the strategies in the various stages of the inquiry process. Through the online forum, the teachers examined the students' use of the strategies and provided critical and constructive feedback.

Regulation of cognition. The metacognitive support for students' regulation of cognition was based on a combination of the Regulatory Checklist (RC) suggested by Schraw (1998), and Reflective Metacognitive Questions (RMQ) suggested by Mevarech and Kramarski (1997) and Zion et al. (2005). Mevarech and Kramarski (1997) demonstrated the advantage of such metacognitive guidance, which is an important component of the IMPROVE instruction method for teaching mathematics. The RC and RMQ used in this study are based on the IMPROVE method of promoting metacognition, with various adaptations in order to implement it into inquiry-based projects (e.g., Zion et al., 2004).

Regulatory checklist. The purpose of the RC is to provide an overarching heuristic that facilitates the regulation of cognition (Schraw, 1998). According to Schraw (1998), the RC enables learners to implement a systematic regulatory sequence to help them control their performance through a set of explicit prompts. In this study, the RC was administered to the students at each stage of the inquiry process and referred to the regulation of cognition subprocesses. Table 2 provides examples of the RC prompts. The teachers discussed the RC with the students during the face-to-face meetings at the beginning of each stage of the inquiry process.

Reflective metacognitive questions. After completing the tasks required at each stage of the inquiry, the RMQ was administered to the students. The RMQ

Table 2. Explicit Metacognitive Guidance—Examples of Prompts That Were Included in the Regulatory Checklist.

Planning
1. What is the goal of the task?
2. How much time do I need in order to accomplish my goal?
Process management
1. Which strategies are needed in order to accomplish my goal?
Monitoring
1. Am I reaching my goal?
2. Do the strategies I use improve the process?
3. Do I need to make changes in my plans?
Debugging
1. Am I encountering difficulties?
2. How can I overcome my difficulties?

served as a means of self-evaluation and contained metacognitive questions which required students to reflect upon their learning process (Mevarech & Kramarski, 1997; Zion et al., 2005). Similar to the RC, the RMQ addressed the five components of regulation of cognition. The RMQ included Likert questions in which students were required to indicate the level of agreement with a specific statement and open questions in which they were asked to detail their experiences. Table 3 provides examples of the reflective questions that were included in the RMQ.

The RMQ was first introduced to the students after they selected an inquiry topic and generated an inquiry question. The students were told that completing the RMQ would evoke a better reflection upon their inquiry process and help them accomplish their tasks. The teacher demonstrated how to complete the RMQ by verbalizing her own thoughts and reflections on the process. Thereafter, the students completed the RMQ individually after each stage of the inquiry (six times during the whole process). The teachers provided further assistance to students who encountered difficulties in completing the RMQ.

Supporting the social aspect of the metacognition through peer collaborations in the CIC. The social aspect of metacognition was addressed through peer collaborations in the CIC learning environment. In this environment, three pairs of students who worked on different projects joined together for a CIC meeting at each stage of the inquiry process. During these face-to-face meetings, students followed a macro script (see Dillenbourg & Hong, 2008) aimed at structuring collaborative learning and increasing the probability that various regulation processes would occur (Iiskala, Vauras, & Lehtinen, 2004). The collaborative script assigned a specific scenario in which students were required to follow throughout their CIC meeting. The scenario included (a) teachers' instruction,

Table 3. Explicit Metacognitive Guidance—Examples of Reflective Metacognitive Questions.

Evaluation

1. To what extent have you reached your goals?

Very large extent	Large extent	To a lesser extent	Not at all

Explain:____

2. To what extent have the learning strategies improved the process?

Very large extent	Large extent	To a lesser extent	Not at all

Which learning strategy was the most effective? Why? ______________________________

Did you use an original learning strategy of your own? Explain. __________________________

(b) peer feedback, (c) and peer modeling. Groups were encouraged to conduct lively discussions, verbalize their thoughts, and externalize their ideas.

The teacher opened the CIC meeting by introducing and explaining the current stage of the inquiry process. Thereafter, the evaluation occurred as each pair of students in the CIC described the progress of their inquiry project, while the other group members provided feedback, evaluation, and encouragement. The group repeated this procedure for each of its members' projects. Through this repeated scenario, each group member engaged and practiced various cognitive and metacognitive activities both as an evaluator and as a participant. Finally, in the modeling stage, all the students addressed one inquiry project at a time and modeled together the next inquiry procedure according to the teachers' explanations. Both the evaluation and modeling stages provided opportunities for the participants to exchange ideas, thoughts, strategies, and insights.

Research Design

Participants. The research population consisted of 150 high-achieving 7th- and 8th-grade Israeli junior high students. The students came from three schools of similar average socioeconomic status (as defined by the Israel Ministry of Education). The students were distributed across four high-achieving homologous classes, in which students were selected according to their academic achievements.

Three experienced science teachers participated in this study. Each teacher taught one class, while one of the teachers taught two classes in two subsequent years. All teachers hold a bachelor's degree and a teaching certificate and had previous experience teaching inquiry-based courses. The teachers participated in a 4-hour in-service training program, before the implementation of the inquiry program in the classes, and weekly 1-hour sessions during the inquiry process. The researchers closely assisted the teachers throughout the inquiry process and maintained ongoing contact with them.

Research groups

All the students in this research conducted social–environmental inquiry projects in the course of their school year. The students worked in pairs ($N = 75$); hence, the CI variable was present in all groups. All the pairs received guidance and support with their inquiry projects from the teacher during school hours. Additional help was provided to the students through the online asynchronous forums, one forum for each of the four research groups. The combination of face-to-face interactions during school hours and online support after school was a new experience for all the participating students.

The students worked on their inquiry projects after school hours. They were required to complete each step of the inquiry process within approximately one month, except for the development of research tools which was completed in approximately two months. The students managed the inquiry process according to their own schedule, provided they submitted their assignments at each stage of the inquiry process according to the prescribed submission schedule.

Each class was randomly assigned to a research group. The research groups differed in the instructional method to which the students were exposed (experimental conditions): the Meta component, which was either provided or not, and the CIC component, which was either present or not. The following four research groups participated in the study:

- *Individual and social metacognitive support—The Meta-CIC research group.* At the beginning of the year, the students formed pairs according to their own selection. Then, three pairs were assigned to a CIC group by the teacher. During school hours, at each stage of the inquiry process (approximately once each month), the students formed the CIC groups. After school hours, the students met their partners to complete their assignments. The Meta component was embedded within the teachers' instructions to the students.
- *Social metacognitive support only—The CIC research group.* Students were grouped into pairs and CIC groups as described above for the Meta-CIC group. In this group, the Meta component was not introduced to the students.
- *Individual metacognitive support only—The Meta-CI research group.* At the beginning of the projects, the students formed pairs according to their own selection. The Meta component was embedded within the teachers' instructions to the students.
- *Neither individual nor social metacognitive support—The CI research group.* Students were grouped into pairs as described for the Meta-CI group. The Meta component was not introduced to these students.

Assessing students' online metacognitive performances. We examined four online asynchronous forums of four classes from the four groups. Because we were interested in discussions among the students, we omitted teachers' messages from the data analysis. We examined students' messages using both content analysis and statistical methods.

Developing the metacognition inventory for online-discussions. Two components have been identified within the concept of metacognition: knowledge about cognition and regulation of cognition (Brown, 1987; Flavell, 1976; Schraw & Dennison, 1994). These two components served as the major categories for the MIND and were theoretically defined according to the work of Schraw and Dennison (1994). The regulation of cognition was further categorized according to the five subprocesses of regulation of cognition detailed by Schraw and Dennison (1994): planning, process management strategies, monitoring, debugging, and evaluation. The operational definitions ascribed to each category in the MIND are based on the statements of the Metacognitive Awareness Inventory questionnaire, described by Schraw and Dennison (1994). Necessary adjustments were made to these operational definitions so that MIND would capture metacognitive processes in the online forums. Following the initial development of the MIND, two researchers read a sample of 700 online messages out of a total of 1,952 messages, coded the messages accordingly, and assigned indicators to each of the categories. Discussions on the initial coding process led the researchers to formulate final defined indices and indicators (see Table 4).

Coding students' online messages using the MIND. The coding of all students' messages proceeded according to the MIND. A single message served as the unit of analysis. Using the MIND, the researchers assigned one, several, or no metacognitive performance criterion to each students' message (coding examples are presented in Table 5). In addition, each message was coded for background data which included the date and hour the message was written and identification of the students and their research groups. Because we wanted to follow the students' learning process regarding their online metacognitive performances, we ascribed each message to one of three chronological phases of the inquiry process: Phase 1 included messages concerning the framing of the inquiry; Phase 2 included messages concerning the operation of the inquiry; Phase 3 included messages concluding the inquiry. A detailed description of the four online forums is presented in Table 6. Following the coding process, a personal report was developed for each pair of students, detailing whether a metacognitive category was present in each of the students' messages. Thereafter, we calculated the sum of the times that each metacognitive category appeared in each student's messages, for each of the three phases in the inquiry process.

Data analysis. We conducted the data analysis on the total number of messages posted, knowledge about cognition, and the five subprocesses of the regulation of cognition. Scores in each variable reflect the number of times each metacognitive subprocess was mentioned in the total number of students' messages for each of the three phases of the inquiry process. Intercorrelations between the five subprocesses of regulation of cognition range between $r = .32$ and $r = .60$ ($p < .001$) and a factor analysis of the five dimensions revealed that they compose one factor (eigen value = 2.87, 57.47% of the variance). Acceptable internal consistencies were found ($\alpha = .72$–$.75$). Thus, the analyses were conducted with the total score for regulation of cognition. The differences among groups were examined with analyses of variance, while each pair of students served as the unit of analysis.

Table 4. The MIND—A Metacognitive Inventory for Online Discussions.

Component of metacognition	Theoretical definition (Schraw & Dennison, 1994)	Operational definition in the online forum
Knowledge about cognition	Knowledge about cognition includes three subprocesses that facilitate the reflective aspect of metacognition: declarative knowledge, about self and about strategies; procedural knowledge, about the use of strategies; conditional knowledge, about when and why to use strategies.	Students mention or describe the use of various learning strategies. The students may detail or ask for clarifications concerning how, when, or why to use learning strategies.
Regulation of cognition	Regulation of cognition includes several of the subprocesses that facilitate the control aspect of learning. Five component skills have been discussed intensively. These skills include: planning, process management strategies, monitoring, debugging strategies, and evaluation.	Planning: Students refer to, describe, or consult their goals, plans, and schedules. Students may express their satisfaction at meeting deadlines or their concern about failing to meet their schedules.
		Process management: Students refer to the technical aspect of the inquiry process. For example, students describe their progress, they provide details about the way they divide the task among them, they report about changes they made in their project performance, they comment about successful or unsuccessful applications of learning strategies, or they explain changes in the use of learning strategies.
		Monitoring: Students refer and examine the content of their project while working on the task. For example, they provide self-feedback and self-criticism; they detail doubts about their project; they ask for feedback, explanations, or

(continued)

Table 4. Continued

Component of metacognition	Theoretical definition (Schraw & Dennison, 1994)	Operational definition in the online forum
		clarifications; and they ask questions to deepen or confirm their understanding. Debugging: Students refer to difficulties or ask for help and support. On the technical level, students describe difficulties concerning the inquiry process itself: problems among the partners, locating interviewees and setting interviews, and locating respondents for the survey. On the content level, the students refer to difficulties concerning their inquiry project. For example, selecting a topic, generating a hypothesis, and developing research tools. Evaluation: Students refer to and examine the content of their project after completing the task. For example, they evaluate or criticize their project; they detail doubts about their project; and they ask for feedback or an evaluation of their completed assignment.

Characterizing students' perceptions of their online metacognitive performances. We conducted semistructured interviews with students who were randomly chosen from all research groups. These interviews were designed to examine students' perceptions of their online metacognitive performances: Meta-CIC ($N=7$), Meta-CI ($N=7$), CIC ($N=8$), and CI ($N=5$). In the audio-taped, transcribed interviews, the students described various aspects of the online discussions, such as their involvement in the discussions, their gains from the online activity, and the advantages and disadvantages of the online discussions. Additional data was collected from students' written reflections following their engagement in the inquiry process. In these reflections, the students addressed their conflicts, difficulties, and detailed their project management activities throughout the inquiry process.

Table 5. Coding Examples of Students' Messages using MIND.

Metacognitive component	Examples
Knowledge about cognition	☐ *I have posted my **research-tools table**,[5] is it OK? (Meta-CI, 517, strategies)[6]* ☐ *Never mind, I will post it again . . . soon to come my **concept-map** ☺ . . . (Meta-CI, 520, strategies)* ☐ *Please do not check the part **highlighted** in orange. We have a question for you **highlighted** in yellow. (Meta-CI, 523, strategies)* ☐ *Attached is my **flowchart** for the literature review!!! (Meta-CI, 529, strategies)* ☐ *Hi! This **flowchart** was baked with care, in a special oven design for today's methods. We present here our special **flowchart** for your review. We hope it matches your requirements. Look after it, we know it's tasty but please don't eat it since it has poisonous substances in it. . . ☺ (Meta-CI, 562, strategies)*
Regulation of cognition	☐ *Hi there! You did not post the file we worked on together on Thursday . . . Can you please post it soon so we **can finish working on it by Tuesday**? (Meta-CI, 543, planning)* ☐ ***Tomorrow I am meeting** with Rotem and we will be in touch with you. I will ask the teacher to dismiss us from class. (CI, 311, planning)* ☐ *We sent you our hypotheses yesterday and you still haven't answered . . . **we will not be able to complete it on time** . . . please **check it ASAP** and tell us if they are OK so we can continue. (CI, 375, planning, evaluation)* ☐ *We are sorry for **the delay** in correcting it. I had some problems with my computer . . . (CI, 207, planning)* ☐ *We **didn't understand** our fourth hypotheses . . . **how will we establish or disprove it in the future**?(CI, 116, debugging, monitoring)* ☐ *We have 26 questions in the interview **and its way toooo much**!! We would be very happy **if you could help us reduce them**!! Thanks!! (Meta-CI, 507, debugging, monitoring)* ☐ *Listen, most of the answers to our questions are "yes" or "no", but you said we needed 4 possibilities, **what should we do**? We **can't add more answers because they will not fit the questions.** (CI, 690, debugging, monitoring)* ☐ *..We couldn't think of more than two hypotheses . . . **it is very difficult** because we don't know too much about it☹ (CI, 67, debugging)*

(continued)

Table 5. Continued

Metacognitive component	Examples
	☐ *Because* ***we could not reach an agreement****, each of us posted his own research-tools table.* ***Please choose the one you think is the best.*** *(Meta-CI, 545, debugging, evaluation)* ☐ *... These are our hypotheses.* ***Please check*** *whether there are any mistakes or if we should add something. Thanks in advance* ☺ *(CI, 112, evaluation)*

Table 6. Details of the Four Online Forums.

Group	Number of pairs	Total number of students' messages	Total number of students' messages at first period	Total number of students' messages at second period	Total number of students' messages at third period
Meta-CIC	$n = 19$	490	54	265	171
CIC	$n = 22$	478	113	237	128
Meta-CI	$n = 13$	397	42	230	125
CI	$n = 21$	587	196	292	99

Note. CIC = collaborating inquiry community; CI = collaborating Inquiry.

Results

Assessing Students' Online Metacognitive Performances

Table 7 shows the total number of messages posted, and the total number of messages posted regarding knowledge about cognition and regulation of cognition, by research group and inquiry phase.

Data in the table show that up to 265 messages were posted per phase and group. Up to 55 messages were posted per phase and group concerning knowledge about cognition, and up to 250 messages were posted per phase and group concerning regulation of cognition (total score). Significant differences were found at phase 1 for the total number of messages posted ($\chi^2(3) = 94.78$, $p < .001$), for knowledge about cognition ($\chi^2(3) = 23.42$, $p < .001$), and for regulation of cognition ($\chi^2(3) = 41.11$, $p < .001$).

Mean total number of messages posted, beyond group and time was 8.68 ($SD = 7.84$), with a skewness value of 1.64 ($SE = 0.16$). The grand mean for knowledge about cognition was 0.79 ($SD = 1.66$), with a skewness value of 2.67 ($SE = 0.16$). The grand mean for regulation of cognition was 6.67

Table 7. Total Number of Messages Posted, and Total Number of Messages Regarding Knowledge About Cognition and the Total Score for Regulation of Cognition, by Research Group and Phase.

Students	Meta-CIC ($n = 19$)			Meta-CI ($n = 13$)			CIC ($n = 22$)			CI ($n = 21$)		
Inquiry phase	1	2	3	1	2	3	1	2	3	1	2	3
Total number of messages	54	265	171	42	230	125	113	237	128	196	292	99
Knowledge about cognition	2	43	4	2	44	4	15	55	4	0	4	0
Regulation of cognition—total score	24	240	143	16	182	93	62	219	95	85	250	91

($SD = 7.81$), with a skewness value of 1.83 ($SE = 0.16$). These values reflect a departure from normal distribution, yet its magnitude is reasonable. Therefore, due to the need to control the initial differences among the research groups in the first phase of the inquiry process, and because the interest in this study was the development of students' performances, the change in students' online metacognitive performances was examined at the student's level with analyses of variance. However, due to the departure from normal distribution, analyses were cross-examined with the nonparametric chi square.

Change in students' metacognitive performances. Table 8 presents the means and standard deviations for students' metacognitive performances and the total number of messages by research group and time. The means presented are at the individual (pair) level. The table shows that up to 52 messages ($M = 8.68$, $SD = 7.84$) were posted per student pair, with up to 44 messages ($M = 6.67$, $SD = 7.81$) relating to the regulation of cognition and up to eight messages ($M = 0.79$, $SD = 1.66$) relating to the knowledge about cognition.

Table 9 presents the means and standard deviations for the residual gains in students' metacognitive performances and the total number of messages by research group. The residual gains were calculated due to the initial differences between the groups in Phase 1. These gains represent the change scores, while using a regression analysis to statistically control the differences among the groups' initial scores. To examine the differences in the changes between the research groups, we conducted three Multivariate analysis of variances (MANOVAs) which compared the changes in the scores by research group, in relation to the three inquiry phases. The first MANOVA related to changes between Phases 1 and 2, the second MANOVA related to changes between Phases 2 and 3, and the third MANOVA related to changes between Phases 1 and 3. Table 10 presents the results of these analyses.

Table 8. Means (*M*) and Standard Deviations (*SD*) for Students' Metacognitive Performances and the Total Number of Messages by Research Group and Time ($N = 75$).

	Meta-CIC *M* (*SD*) ($n = 19$)			Meta-CI *M* (*SD*) ($n = 13$)			CIC *M* (*SD*) ($n = 22$)			CI *M* (*SD*) ($n = 21$)		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
Total number of messages	2.84 (2.75) (0–9)	13.95 (8.26) (2–30)	9.00 (8.41) (0–31)	3.23 (2.62) (0–10)	17.69 (12.22) (4–52)	9.62 (7.83) (0–21)	5.14 (4.16) (1–17)	10.77 (7.81) (0–29)	5.82 (5.68) (0–22)	9.33 (4.71) (0–16)	13.90 (8.35) (2–43)	4.71 (3.72) (0–13)
Knowledge about cognition	0.11 (0.32) (0–1)	2.26 (2.49) (0–7)	0.21 (0.42) (0–1)	0.15 (0.38) (0–1)	3.38 (2.22) (1–8)	0.31 (0.63) (0–2)	0.68 (0.99) (0–3)	2.50 (2.63) (0–8)	0.18 (0.50) (0–2)	0.00 (0.00) (0–0)	0.19 (0.51) (0–2)	0.00 (0.00) (0–0)
Regulation of cognition—total score	1.26 (1.63) (0–5)	12.63 (8.74) (1–29)	7.53 (7.37) (0–29)	1.23 (1.30) (0–4)	14.00 (11.93) (0–44)	7.15 (5.71) (0–20)	2.82 (4.06) (0–16)	9.95 (9.43) (0–33)	4.32 (4.18) (0–16)	4.05 (3.92) (0–15)	11.90 (9.94) (0–42)	4.33 (4.67) (0–17)

Table 9. Means (*M*) and Standard Deviations (*SD*) for Residual Gains in Students' Metacognitive Performances and Total Number of Messages Scored by Research Group ($N = 75$).

	Meta-CIC *M* (*SD*) ($n = 19$)			Meta-CI *M* (*SD*) ($n = 13$)			CIC *M* (*SD*) ($n = 22$)			CI *M* (*SD*) ($n = 21$)		
	Phases 1 and 2	Phases 2 and 3	Phases 1 to 3	Phases 1 and 2	Phases 2 and 3	Phases 1 to 3	Phases 1 and 2	Phases 2 and 3	Phase 1 to 3	Phases 1 and 2	Phase 2 to 3	Phase 1 to 3
Total number of messages	0.23 (0.91)	0.32 (1.37)	0.35 (1.26)	0.64 (1.29)	0.22 (1.05)	0.43 (1.15)	−0.31 (0.75)	−0.03 (0.76)	−0.17 (0.82)	−0.28 (0.89)	−0.39 (0.62)	−0.41 (0.53)
Knowledge about cognition	0.21 (1.00)	0.09 (0.87)	0.11 (0.95)	0.68 (0.94)	0.22 (1.53)	0.34 (1.44)	0.03 (1.15)	0.00 (1.19)	0.05 (1.14)	−0.64 (0.22)	−0.22 (0.04)	−0.37 (0.00)
Regulation of cognition—total score	0.26 (0.93)	0.34 (1.43)	0.40 (1.31)	0.42 (1.18)	0.19 (0.83)	0.34 (0.99)	−0.26 (0.93)	−0.16 (0.79)	−0.25 (0.74)	−0.22 (0.90)	−0.26 (0.72)	−0.31 (0.73)

Table 10. *F* Values for Group Differences in the Residual Gains of Metacognitive Performances and Total Number of Messages by Research Group ($N = 75$).

	Phases 1 and 2			Phases 2 and 3			Phase 1 to 3		
	F_{Meta} (1, 71) (η^2)	F_{CIC} (1, 71) (η^2)	$F_{Meta \times CIC}$ (1, 71) (η^2)	F_{Meta} (1, 71) (η^2)	F_{CIC} (1, 71) (η^2)	$F_{Meta \times CIC}$ (1, 71) (η^2)	F_{Meta} (1, 71) (η^2)	F_{CIC} (1, 71) (η^2)	$F_{Meta \times CIC}$ (1, 71) (η^2)
Total number of messages	10.86** (.133)	0.99 (.014)	0.69 (.010)	8.22** (.108)	0.78 (.011)	0.01 (.001)	11.66*** (.143)	0.01 (.001)	0.24 (.003)
Knowledge about cognition	12.44*** (.149)	0.24 (.003)	7.18** (.092)	3.48 (.049)	0.02 (.001)	0.07 (.001)	5.71* (.075)	0.01 (.001)	1.20 (.017)
Regulation of cognition—total score	6.56* (.085)	0.19 (.003)	0.07 (.001)	6.92* (.092)	0.31 (.005)	0.40 (.006)	9.24** (.117)	0.02 (.001)	0.02 (.001)

*$p < .05$.
**$p < .01$.
***$p < .001$.

The analysis of change between the first and second phases of the inquiry process was found significant for the Meta component: $F(3, 69) = 5.02$, $p = .003$, $\eta^2 = .179$; nonsignificant for CIC component: $F(3, 69) = 0.92$, $p = .434$, $\eta^2 = .039$ and significant for the interaction between the Meta and the CIC components: $F(3, 69) = 2.81$, $p = .046$, $\eta^2 = .109$. The significant effects for the total number of messages, knowledge about cognition, and the total score of regulation of cognition revealed the following: the changes in the scores for groups with the Meta component were positive and higher than corresponding changes in the scores for groups without the Meta component. For these groups, the changes were negative (total number of messages: $M = 0.40$, $SD = 1.08$ vs. $M = -0.30$, $SD = 0.81$; knowledge about cognition: $M = 0.40$, $SD = 0.99$ vs. $M = -0.30$, $SD = 0.90$; and regulation of cognition—total score: $M = 0.33$, $SD = 1.03$ vs. $M = -0.24$, $SD = 0.91$.) Our analysis of the interaction for knowledge about cognition revealed that the changes in the scores for all three experimental groups were higher than the changes in the scores in the CI research group ($p < .001$). We did not find any differences between the three experimental groups, all of which showed positive changes in the scores, while the score in the CI research group was negative.

The analysis of change between the second and third phases of the inquiry process was found significant for the Meta component: $F(3, 69) = 3.25$, $p = .027$, $\eta^2 = .129$; nonsignificant for the CIC component: $F(3, 69) = 0.30$, $p = .829$, $\eta^2 = .013$; and nonsignificant for the interaction between the Meta and the CIC components: $F(3, 69) = 0.37$, $p = .773$, $\eta^2 = .017$. Univariate analyses showed significant effects by the Meta component for the total number of messages, and for the total score of regulation of cognition. The changes in the scores for groups with the Meta component were positive and higher than comparable changes in scores for groups without the Meta component, which were negative (total number of messages: $M = 0.28$, $SD = 1.23$ vs. $M = -0.21$, $SD = 0.71$; and regulation of cognition—total score: $M = 0.28$, $SD = 1.21$ vs. $M = -0.21$, $SD = 0.75$). No other differences were found.

The analysis of change between the first and third phases of the inquiry process was found significant for the Meta component: $F(3, 69) = 4.67$, $p = .005$, $\eta^2 = .171$; nonsignificant for CIC component: $F(3, 69) = 0.01$, $p = .999$, $\eta^2 = .001$; and nonsignificant for the interaction between the Meta and the CIC component: $F(3, 69) = 0.96$, $p = .415$, $\eta^2 = .041$. Univariate analyses showed the following significant effects by the Meta component for the total number of messages, knowledge about cognition, and for the total score of regulation of cognition: Changes in the scores for groups with the Meta component were positive, and higher than changes in the scores for groups without the Meta component were negative (total number of messages: $M = 0.38$, $SD = 1.20$ vs. $M = -0.29$, $SD = 0.70$; knowledge about cognition: $M = 0.20$, $SD = 1.16$ vs. $M = -0.15$, $SD = 0.83$; and the total score of regulation of cognition: $M = 0.38$, $SD = 1.18$

vs. $M = -0.28$, $SD = 0.73$). No other differences were found. Similar results were detected with chi square analyses.

In sum, controlling for the scores of the first phase of the inquiry process, research groups which received the Meta component showed an increase in the total number of messages posted, compared with research groups that did not receive the Meta component. Likewise, groups which received the Meta component showed an increase in their metacognitive performances, regarding knowledge about cognition and regulation of cognition, compared with research groups that did not receive the Meta component. No meaningful difference was noted regarding the comparison between groups with and without the CIC component.

Students' Perceptions of Their Online Metacognitive Performances

In their interviews and written reflections, students from all research groups referred to their metacognitive performances in the online forum. The students referred to the various aspects of metacognition, as demonstrated by the following quotation:

> Working in such a manner, **in which we received feedback during the inquiry process**[1] was new to us. **When facing problems during the process**, we turned to the teacher through the online forum. **We asked questions and received an immediate response, helping us to move forward with great encouragement.** (*Hila & Ron, written reflection, Meta-CI*)[2]

These students addressed two regulative aspects of metacognition: monitoring and debugging, and highlighted the importance of the online forum as means of self-monitoring and assistance during the inquiry process. Another student further commented on the importance of self-monitoring during the inquiry process, as opposed to evaluation which occurs only upon completion of the project:

> Without an online-forum, you complete the project, and then you have a feeling that you received a lower grade then you could have received. When working with an online forum, **you can compare your work to that of others, and if something is wrong, than you correct it immediately!** (Shoval, *Interview, Meta-CIC*)

Throughout the inquiry process, a major part of the communication between the teacher and the students occurred in the forum. Because all parts of students' inquiry projects were uploaded to the forum for the teacher's examination and feedback, students could look at each other's projects and monitor and evaluate their own work accordingly:

> I think that if we had participated more and been more active in the online forum, **we would have had more ideas.** (*Inbal, written reflection, Meta-CI*)

> I think that the forum is a really good group. Personally, after I uploaded a file to the forum ... **I would look at others' files and see other good ideas** ... (*Tal, interview, Meta-CIC*)

Through the evaluation and monitoring of other groups' inquiry projects, students solved their own problems and overcame their own difficulties:

> The forum is excellent. **When I got stuck, I would always look at Tal and Eden's project, and see what they uploaded and what it should to look like**. Each time you {the instructor} would tell us to look at a file I would look ... and read it. (*Dan & Daniel, interview, Meta-CIC*)
>
> The forum helped us because **we could, for example, look at other groups' literature review and see how they wrote it** ... **It is in some way a class project and not just mine and Yuval's.** (*Neta, interview, CIC*)

Not all students realized the forums' metacognitive potential contribution to their inquiry projects. Some students came to this recognition only at the end of the inquiry process:

> There is no doubt that the online forum has an important role in the process of inquiry, **through the sharing of files/ difficulties / possible solutions / assistance.** Everything could have been easier if I had collaborated more. (*Ofir, written reflection, Meta-CIC*)

Through the forum, students could also monitor their peers' pace and schedules and plan their own process accordingly. Therefore, many students regarded the forum as a "planning" agent, as the following excerpts demonstrate:

> I think that the forum was a great tool ... **it helps you maintain a good pace.** For example, when you see that the majority {of the class} completed their literature review and began the discussion, it gives you motivation to continue the literature review and start the "discussion" chapter also. (*Aviah & Yamit, written reflection, Meta-CIC*)
>
> When you see that everybody uploads files and you don't, **it triggers you to work faster**. (*Dvir, Interview, Meta-CIC*)

Contribution of the CIC Component to Students' Online Metacognitive Performances

Although the theoretical background of the research indicates that the CIC intervention would contribute to students' metacognitive performances in the online forum, the statistical analysis did not indicate such a contribution. These results led us to reexamine students' messages in the online forum. We found that although students from all research groups were instructed to collaborate with their peers in the online forum, explicit collaboration among peers was not observed in the online forums of the Meta-CI or the CI research groups. Student collaborations were only observed in the online forum of the Meta-CIC and the CIC research group. Due to these few instances, these collaborations will be addressed using qualitative tools only.

Students' collaborations in the CIC online forum. Several themes emerged from instances of between-pair collaborations among students in the online forum. First, students monitored and compared their own progress to that of their peers; this was explicitly expressed in their online messages, for example:

> It is not fair that **everyone receives a golden cup**[3] {an icon in the online forum which indicates that the group performed a good job and can continue with their inquiry} **and we don't!** We are deeply offended!! (*CIC, 813, Gal & Maya*)[4]
> Can you please check our hypothesis as quickly as possible, **because we opened a gap and want to close it.** (*CIC, 301, Guy & Levan*)

Although the online forum holds great potential for collaborations among the students, we noted that students usually consulted or asked for help and feedback directly from their teacher. The teachers' central role in assisting throughout the inquiry process was preserved, and the students expected the teachers to respond and provide them with quick feedback and support. These expectations were preserved despite the CIC environment and the online forum, in which students' collaborations are the core feature in this setting. In addition, we identified several instances in which the students discussed their teacher's online conduct:

> We posted our hypothesis about three weeks ago to the forum and you {the teacher} still haven't examined them. **When will you check them**? (*CIC, 351, Yuni & Liel*)
> **She didn't answer us either** (*CIC, 350, Lihi & Yuli*)
> You haven't checked **anyone's** tool table; can you check **everybody's** table soon? (*CIC, 430, Bar*)

A unique phenomenon which was observed in this forum were the numerous spontaneous thank-you messages that were posted by the students at the end of the inquiry process and were addressed to the teacher. These messages further emphasize the central role of the teacher in the process.

> We want to **thank you** for your help during the whole year; **we couldn't have done it without you!** (*CIC, 1499, Shira & Rotem*)

> **Thank you** for all the help. **Thank you** for all the ideas. **Thank you** for the words of encouragement, and we're sorry for nagging you. **Thanks to you we have reached the end** (*CIC, 1543, Natalie & Or-el*)

Finally, although we observed a few cases in which students helped each other through the online forum, this assistance only concerned the procedural aspect of the inquiry process:

> You should first postulate your hypothesis, wait for the teachers' approval, and only then precede to the inquiry tools (*CIC, 406, Lihi & Yuli*)
> How will we reach the police, and the department of environment, and the department of transportation, and the municipality, and what should we say? (*CIC, 659, Ori & Aren*)
> ... Yoav and I already conducted an interview; we looked up in the internet and asked our parents to help us. So do the same and ask your parents to help you and contact the police and municipality ... good night- Mor. (*CIC, 658, Mor*)

Students' collaborations in the Meta-CIC online forum. Similar to the findings from the CIC forum, we found instances in which students from the Meta-CIC group explicitly expressed the comparison they made between their own inquiry process and that of their peers. For example:

> I have a problem, **I am really behind everybody with my inquiry project**, and I have problems with my survey. (*Meta-CIC, 1318, Rom*)
> I don't see any "discussion sections" here ... **could I be the first** one to upload this part? (*Meta-CIC, 1219, Max & Adam*)
> Hello dear Max! We uploaded our "discussion" section before you!! (*Meta-CIC, 1218, Tal & Shoval*)
> You {the teacher} have **checked everybody's** research tools, and skipped ours; we cannot continue. (*Meta-CIC, 836, Diana & Michal*)

In addition to the comparisons students made regarding procedural aspects of the inquiry process, as was observed in the CIC forum, we observed instances in which students referred to the content of other groups' inquiry projects. For example:

> I actually **looked at the literature reviews of other groups and I didn't see much difference between theirs' and mine** ... nevertheless, I will try and correct it. (*Meta-CIC, 1187, Max & Adam*)

We found that most of the students' questions in the Meta-CIC forum were addressed to the teacher. However, we noted several cases in which students explicitly requested help from their peers. Such requests may indicate that these students acknowledged that other pairs may contribute to their own inquiry process. In some cases, the students requested technical assistance, as in the following examples:

> **Does anyone know** how to accept the changes in the document? If somebody knows, please answer me (*Meta-CIC, 185, Dvir & Eylon*)
> **If anyone wants to** enter the forum from a smartphone/ i-pad/ i-pod, then all you have to do is ... {the student provides the instruction how to enter the forum}. (*Meta-CIC, 1126, anonymous*)

In other cases, the students provided a brief background about their own inquiry projects, which was followed by a request for help:

> Our inquiry question concerns the environment in the municipal stadium, and we are going there on Saturday to conduct a survey. Daniel cannot come, and I am looking for somebody who can join and help me. **Whoever can come, please call me**. (*Meta-CIC, 1227, Ronen & Daniel*)
> A survey concerning recycling of batteries—we ask you to give this survey to your parents to answer!!!! Please!!!! **Please answer and return it to the forum**!!! Thank you very much!!! Omri and Nadav!!! . (*Meta-CIC, 1321, Omri & Nadav*)
> **All help is welcome!!** First of all- have a happy holiday! We are Yuval and Ofir, and we are at the beginning of our literature review. We need information because if we look up in Google "benefits that are given to workers from a work place," more than 99% of the results are not useful for us. So, if you have information regarding benefits that are provided from the work place to parents, brothers, and sisters, uncles or aunts, grandmothers, or grandfathers, and even your neighbors, send the information to us through the forum, facebook, or phones ... **Please send us the information ASAP!!** Because we have to keep up with the schedule!! Thanks in advance!! *(Meta-CIC, 1303, Yuval and Ofir*)
> **If somebody comes across** a newspaper article, internet, video or anything else concerning green technology in schools, it will help us very much!! **Please upload it to the forum, or pass it onto us!!** If anyone needs help, we are here! *(Meta-CIC, 656, Or, Shir & Gil*)

As in the CIC online forum, we observed instances in the Meta-CIC online forum in which students provided help to each other. The students' assistance was primarily related to the procedural aspects of the inquiry process:

> **To all the groups** that need to print their inquiry papers on Saturday—Office Depot in Ashdod prints on Saturdays! If somebody needs printing you can go there ... (*Meta-CIC, 2200, Itai)*

In addition, unique to this forum, there were few instances in which the students' assistance was related to the content of the inquiry projects. In the following examples, although the original questions were addressed to the teacher, the students answered the questions proactively and independently. They evaluated and provided feedback about the students' project:

> In the survey's results, **you worked much harder than you were supposed to**: you prepared a graph for the percent of responses as well as for the numbers of responses, while all you had to do is a graph for the number of responses and not for the percentage of responses, and gather the percentage and number of responses in a table that appears above the graph ... Good luck! (*Meta-CIC, 2088, anonymous*)
>
> **To Tatiana**, in your hypothesis, you wrote "we hypothesize" but since you are working on your own you had better change to "I hypothesize." (*Meta-CIC, 2060, anonymous*)

Another unique phenomenon which was noted in the Meta-CIC forum was that several students uploaded information to the forum, which was intended to support their peers' inquiry process. This information was provided following peer requests or out of the students' own motivation.

Discussion

CSCL environments and specifically online asynchronous forums have a high potential in inquiry-based learning, as they provide a platform for fruitful discussions, collaboration, and reflection (e.g., Hurme et al., 2006; Veerman et al., 2000; Zion et al., 2005). However, research has shown that the online discussions do not consistently fulfill their full potential, and students' metacognitive performances remain low (Rourke & Kanuka, 2009). Research has also demonstrated that students who regulate their learning are likely to benefit more from online learning environments than their peers (Azevedo, 2005b; de Jong et al., 2005; Winters et al., 2008). Consequently, we designed the Meta-CIC model and implemented a systematic intervention to examine the contribution of individual metacognitive support (Meta component) and social metacognitive support (CIC component) on students' metacognitive performances in an online forum. We hypothesized that both the Meta and the CIC components, which support students' SRL, will contribute to students' online metacognitive performances. We also hypothesized that both the Meta and the CIC components will have a synergistic effect on students' online metacognitive performances and therefore expected the students of the Meta-CIC research group to demonstrate higher levels of online metacognitive performance compared with their peers.

The statistical analyses revealed that the Meta component significantly affected students' online metacognitive performances, in the major segment of the inquiry process. The contribution was noted on both components of metacognition, i.e., knowledge about cognition and regulation of cognition. These results are consistent with the results of previous studies, which have demonstrated the effect of metacognitive support on students metacognitive performances in various fields (e.g., Cross & Paris, 1988; Kaberman & Dori, 2009; King, 1991; Kramarski & Mevarech, 2003; Whitebread & Cárdenas, 2012; Zion, 2008) and extend this understanding into an inquiry-based CSCL environment. In addition, the statistical analysis revealed that between the first and second phases of the inquiry process, regardless of the metacognitive support received (Meta, CIC, or both), students from the three experimental research groups outperformed their peers from the CI research group. This occurred in the groups' metacognitive performances regarding the component of knowledge about cognition. These results highlight the importance of providing students with explicit or implicit strategic scaffolding, to improve their online strategic performances.

We did not find any significant difference among the research groups, in students' performances regarding the component of knowledge about cognition, between the second and third phase of the inquiry process The aspect of knowledge about cognition was possibly less prominent in this segment of the inquiry, as students were more engaged in the regulatory aspect of the process, such as planning their experiments, evaluating their results, and monitoring their analysis and conclusions. Therefore, the students who received the Meta component did not demonstrate an advantage over their peers in their online expressions of knowledge about cognition.

In spite of the promising theoretical background, the statistical analysis did not point to a significant advantage of the CIC component with reference to students' online metacognitive performances. One possible explanation is that the Meta component, which is designed to support the individual aspect of metacognition and scaffold autonomous monitoring of one's thinking, is a prerequisite for students' efficient engagement in the CIC environment. In this environment, students' reflective processes occur in a social environment. Consequently, the students did not exhaust the full potential of the CIC learning environment; this was reflected by the lack of a statistical significant effect of the CIC component on students' online metacognitive performances. Therefore, we suggest that future curriculums coordinate efforts to develop the individual aspect of students' metacognition, prior to their engagement in the CIC learning environment.

To further understand the learning process and the possible metacognitive gains of the CIC component, we examined the qualitative data which was derived from self-reporting research tools (i.e., interviews and reflections) and students' online messages. The analysis of the data from the self-reporting tools revealed that students from all the research groups explicitly referred to their online metacognitive performances. Students emphasized regulative aspects of metacognition, such as monitoring their work through the work of others, receiving help from other groups, comparing their pace to their peers, or providing help to each other. Despite the students' reported collaborations, we did not find supporting online data for collaborations in the forums of the CI or the Meta-CI research groups. The instances of students' online collaborations were only found in the Meta-CIC and CIC research group. Accordingly, we suggest that the CIC learning environment increases the students' engagement in their peers' learning processes and promotes peer collaboration in the CSCL.

Further qualitative analysis points to differences between students' collaborations in the CIC and the Meta-CIC forums. Whereas in the CIC forum, students' online monitoring referred only to procedural aspects of the inquiry process, online monitoring of students from the Meta-CIC group referred to both procedural aspects of the inquiry process and to the contents of the inquiry projects. Similarly, while in the CIC forum, students' online assistance referred only to procedural aspects of the inquiry process, online assistance from students in the Meta-CIC research group referred to both procedural aspects and to the content of their peers' inquiries. In a few cases, we noted that students from the Meta-CIC group provided help to their peers willingly, without an explicit request. Furthermore, we observed several cases in which students from this research group explicitly asked their peers for assistance. This finding contrasts the teacher's central role in leading the inquiry process, as was evident in the forum of the CIC research group. The comparison of the two forums illuminates the interface of the Meta and the CIC components in a CSCL environment. While the CIC component contributed to students' engagement in their peers' learning process, the Meta component deepened their understanding of its essence. Therefore, the combination of both components enabled the students to collaborate with their peers and address both procedural and content aspects of the inquiry process.

Why are these instances of online collaborations between students rare? According to the script theory of guidance (Fischer, Kollar, Stegmann, & Wecker, 2013), students' CSCL practices are shaped by dynamically reconfigured internal collaboration scripts. These scripts are a configuration of knowledge components about a collaborative practice that guide students' understanding of the collaboration process and their actions. One method to compensate for the lack of or nonfunctional internal collaboration scripts is to provide collaborators with external collaboration scripts that guide individuals in a collaborative situation. These external collaboration scripts enable students to engage in a case of a CSCL practice at a level beyond what they would be able to achieve without an external collaboration script. Following this theory, we posit that because the CIC component was designed as a face-to-face engagement and did not include an online manifestation this component did not significantly affect students' internal collaboration scripts of CSCL practices. Therefore, students' online metacognitive collaborations were not as common as we would expect following the social metacognitive support. We hypothesize that an online manifestation of the CIC component could better reconfigure students' internal collaboration scripts and result in more instances of online collaborations among the students. Future studies could examine this hypothesis.

In sum, the results of this research demonstrate the contribution of individual and social metacognitive support to students' metacognitive performances in a CSCL environment. We therefore recommend embedding the Meta-CIC model in an inquiry-based CSCL environment in order to engage students in comprehensive online discussions.

Limitations and Future Research

A limitation of this study concerns the participant population of the high-achieving students. Previous studies have demonstrated that metacognitive guidance is of particular relevance to low-achieving students (e.g., Cardelle-Elawar, 1992; Kramarski, Mevarech, & Arami, 2002; Pressley & Gaskins, 2006). Future studies could examine the effect of the Meta-CIC model on average or even low-achieving students, who may be less skilled in both regulating their learning, and in conducting their online metacognitive performances.

The students in this research were involved in both online and face-to-face interactions. The face-to-face interaction occurred both in the CI and CIC settings. The educational intervention likely had an effect on students' metacognitive performances during both the online and the face-to-face interactions; however, the current research examined students' performances only in the online environment. Furthermore, in a research by Bluemink and Järvelä (2004), the authors found that students were engaged in a rich variety of interactions during the face-to-face encounters, while students' activity in the web-based environment remained consistently on the same level throughout the course. These findings provide evidence for the different interactions that occur in a web-based versus face-to-face learning environment. Consequently, we recognize the need to examine the effect of the Meta-CIC model on students' metacognitive performances during the face-to-face interactions and compare them to the students' online metacognitive performances. By understanding the unique contribution of each learning environment and the relationship between them, researchers will be able to design more appropriate support mechanisms for teachers and students throughout the inquiry process.

Finally, an important question is whether embedding metacognitive support in a technological environment improves achievements. Choi, Land and Turgeon (2005) provided students with peer-questioning scaffolding aimed to facilitate metacognition during online group discussions. Although the scaffolds proved effective in increasing the frequency of student questioning during the online discussions, the scaffolds did not improve the quality of the students' questions or their learning outcomes. Saab, van Joolingen and van Hout-Wolters (2012) found that support of the collaborative inquiry learning enhances the use of regulative team activities, which leads to an improvement in learning outcomes. Similarly, we propose that future research examine whether the Meta-CIC model improves learning outcomes, such as students' inquiry reports, in addition to students' online metacognitive performances.

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Notes

1. The words in bold emphasize the aspects of metacognition.
2. Code index: students' pseudonyms, research group, source.
3. The words in bold highlight the main theme.
4. Code index: research group, message number, students' pseudonyms.
5. The words in bold served as coding markers.
6. Code index: Meta-CIC/Meta-CI/CIC/CI = research group, message number, metacognitive component.

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